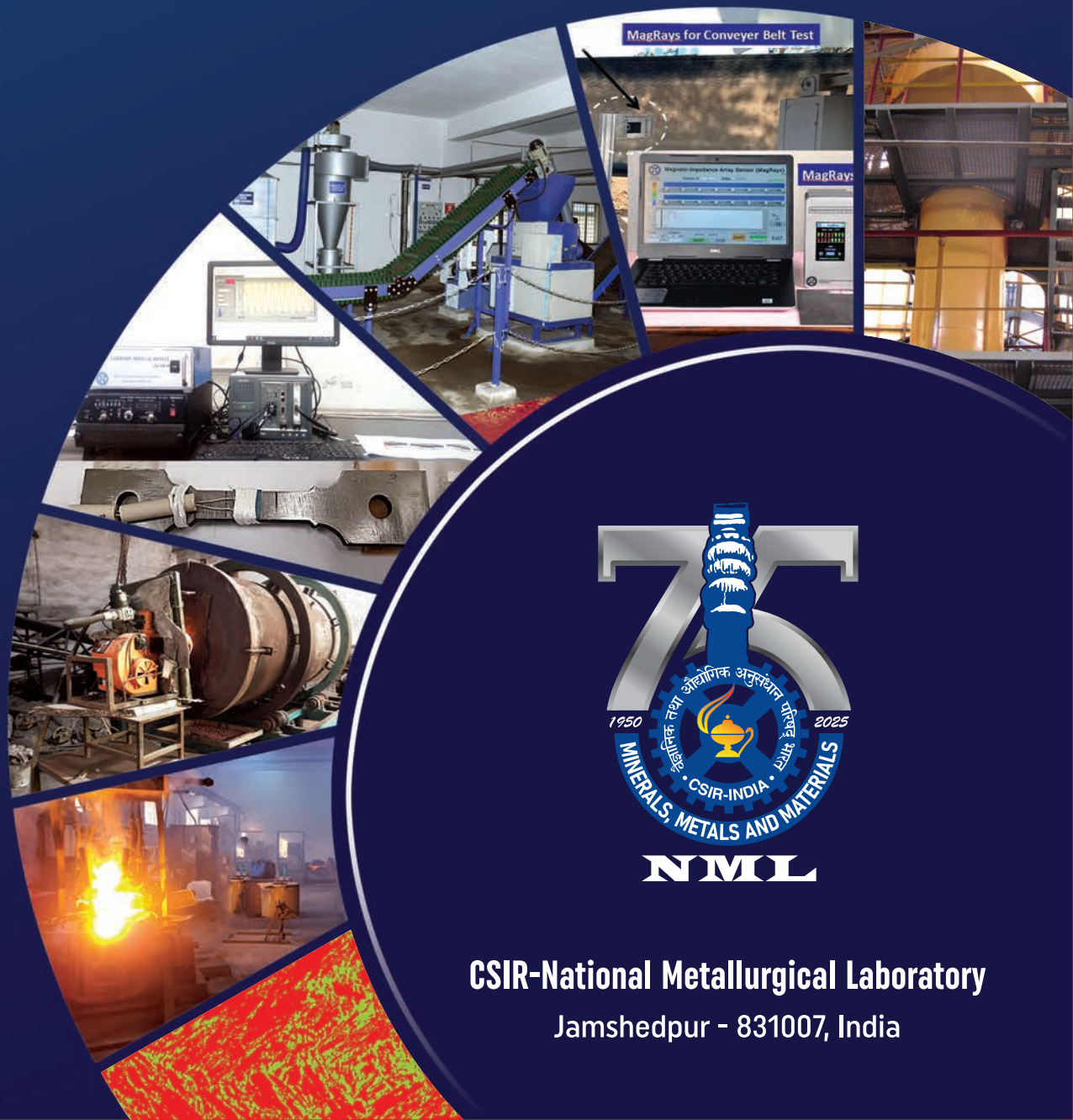
CSIR-NML Platinum Jubilee Annual Report 2024-25

सीएसआईआर
CSIR
भारत का नवाचार इंजन
The Innovation Engine of India

वार्षिक प्रतिवेदन
Annual Report 2024-25

CSIR-NML Platinum Jubilee 1950-2024

Celebrating 75 Glorious Years of Existence and Endeavours



NML

CSIR-National Metallurgical Laboratory

Jamshedpur - 831007, India

1946-2025

Reminiscence

CSIR-NML is celebrating the 75 glorious years of its existence and service to the nation in metals, materials, minerals, and mining. In the platinum jubilee year of CSIR-NML, this book treasures a few moments from the remarkable history of this institution. The CSIR-National Metallurgical Laboratory expresses gratitude to all who have contributed with their excellent leadership and dedicated services for the noticeable achievements of the laboratory.

Glimpses from the book

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CSIR-NML in News

the pioneer

NML celebrates 83rd CSIR Foundation Day with focus on future of mobility

न्यू इस्पात मेल

एनएमएल के वैज्ञानिक डा. गौरव रांगा इंजीनियर्स अवार्ड से सम्मानित

अन्तर्राष्ट्रीय विज्ञान महोत्सव का कर्टेन रेजर एनएमएल जमशेदपुर में आयोजित

शहर के स्कूल-कॉलेजों के विद्यार्थियों ने की शिरकत

दैनिक जागरण

भारत के समग्र विकास में महत्वपूर्ण भूमिका निभा रहा एनएमएल

प्रभात खबर

साइंस एंड टेक्नोलॉजी व इनोवेशन में उत्कृष्ट उपलब्धि के लिए मिला सम्मान

एनएमएल के वैज्ञानिक को राष्ट्रपति ने दिया राष्ट्रीय विज्ञान पुरस्कार

THE AVENUE MAIL

NML: Training to enhance skills in mineral characterization

प्रभात खबर

सीएसआइआर-राष्ट्रीय धातुकर्म प्रयोगशाला. प्लेटिनम जुबिली एक्सपो विजिट का किया आयोजन

स्कूली विद्यार्थियों ने एनएमएल का गौरवशाली इतिहास

लाइफ @ सिटी

संस्थान की तकनीक हुई भारतीय के लिए हो रही उपयोगी

सीएसआइआर-एनएमएल

शोध से तरक्की की राह पर भारत

न्यू इस्पात मेल

खेल जीवन जीने का एक तरीका: प्रेमलता

THE AVENUE MAIL

CSIR-NML transfers PCB recycling tech

प्रभात खबर

14 सरकारी स्कूलों के 420 बच्चों ने निजी कंपनियों व संस्थाओं के कार्यों को देखा

शैक्षणिक भ्रमण से विद्यार्थियों को करियर का चयन करने में मिलेगी मदद : उपायुक्त

1946

The Organization

Replica of Ashoka Pillar - a symbol of the science & industry of India in the past and an inspiration for future

Foundation laying ceremony performed by the Hon'ble Mr. C. Rajagopalachari, Education Minister, Government of India

ORGANISATION STRUCTURE

President
Council of Scientific and Industrial Research (CSIR)

Shri. Narendra Modi
Hon'ble Prime Minister of India

Vice President
Council of Scientific and Industrial Research (CSIR)

Shri. Jitendra Singh
Hon'ble S&T Minister

Secretary, Department of Scientific and Industrial Research (DSIR)
Director General, Council of Scientific and Industrial Research (CSIR)

Dr. N. Kalaiselvi

Director
CSIR-National Metallurgical Laboratory

Dr. Sandip Ghosh Chowdhury

MANAGEMENT COUNCIL

RESEARCH COUNCIL

R&D Divisions/Centre

Dr. S. Sivaprasad
Chief Scientist & Head
Materials Engineering (MTE)

Dr. Sanjay Kumar
Chief Scientist & Head
Metal Extraction & Recycling (MER)

Dr. Devbrata Mishra
Sr.Principal Scientist & Head
Mineral Processing (MNP)

Dr. Raghuvir Singh
Chief Scientist & Head
Advanced Materials & Corrosion (AMC)

Dr.(Mrs.) S Chakravarty
Chief Scientist & Head
Applied And Analytical Chemistry (AAC)

Dr.T.V.Vijaya Kumar
Chief Scientist & Head
CSIR-NML Madras Centre (NML-MC)

R&D Support Divisions

Dr. Sital Kumar Pal
Chief Scientist & Head
Research Planning & Business Development (RPBD)

Dr. Sarmishtha Palit Sagar
Chief Scientist & Head
Information Management & Dissemination Centre (IMDC)

Shri. Byomkesh Das
Cheif Scientist & Head
Information & Communication Technology Unit (ICTU)

Dr.Uday Bhaskara Rao Modavalasa
Principal Scientist & Head
Engineering Unit

Functionaries

Dr. S. Sivaprasad
Chief Scientist & Advisor
Human Resource Group (HRG)

Shri. Jay Shanker Sharan
Controller of Administration (CoA)
Administration

Shri. Pankaj Kumar
Finance and Accounts Officer (FAO)
Finance and Accounts (F&A)

Shri. Dayakant Kumar
Finance and Accounts Officer (FAO)
Finance and Accounts (F&A)

Shri Bhola Azad
Stores and Purchase Officer (SPO)
Stores and Purchase (S&P)

Shri. Naveen Kumar Sharma
Finance and Accounts Officer (FAO)
Stores and Purchase (S&P)

Overview of Council of Scientific & Industrial Research (CSIR)

CSIR's Vision

"Enhance quality of life of the citizens of India through innovative Science and Technology, globally competitive R&D, by developing sustainable solutions and capacity building to fulfil dream of Atmanirbhar Bharat".

This vision of CSIR is aligned to the Government of India's vision for the next 25 years 'Amrit Kal' when independent India becomes 100 years old.

The Council of Scientific and Industrial Research, under the Ministry of Science and Technology, Government of India, is a dynamic R and D organization consisting of 37 national laboratories, 39 outreach centres, one Innovation Complex, and three units with a pan-India presence.

CSIR has a strength of more than 3400 active Scientists supported by about 4000 technical and support personnel. CSIR is involved in research and development in several areas of science and technology. CSIR's "Thematic approach" to enable multidisciplinary research development for solving specific challenges in identified sectors: Aerospace, Electronics, and Instrumentation & Strategic Sectors; Civil Infrastructure & Engineering; Ecology, Environment, Earth & Ocean Sciences and Water; Mining, Minerals, Metals and Materials; Chemicals (including leather) and Petrochemicals; Energy (conventional and non-conventional) and Energy devices; Agri, Nutrition & Biotech; and Healthcare. The technological interventions of CSIR in the areas such as environment, energy, food, housing, agriculture, water etc., have been very significant in improving the quality of life. CSIR is also, the nation's custodian for Measurement Standards of Mass, Distance, Time, Temperature and Current.

CSIR also has a very strong Intellectual Property portfolio, cutting-edge technologies and more than 5800 papers in SCI Journals with an average impact factor per paper of 4.9. The latest addition to CSIR is its Innovation Centre at Mumbai, a state-of-the-art set-up spread over nine floors, equipped with 24 "ready-to-move" incubation labs in addition to furnished offices and networking spaces for innovative Startups, MSMEs, industry, and CSIR labs. The Innovation Centre is further enriching the country's start-up eco-system, and the Centre, with its facilities and expertise of CSIR, will further take this forward. It also serves as a connecting point between CSIR Scientists, MSMEs, start-ups, and Industry stakeholders. CSIR has created and is the custodian of the Traditional Knowledge Digital Library (TKDL), which is a tool to address unethical commercial exploitation of Indian Traditional Knowledge. CSIR also maintains the Microbial Type Culture Collection (MTCC) and Gene Bank.

CSIR, through its constituent laboratories, also plays an important role in the development of human resources in S&T and provides fellowships to students to take up research. The Academy of Scientific and Innovative Research (AcSIR) offers an opportunity for students to take up postgraduate studies and doctoral research from its constituent laboratories. CSIR has also played a pivotal role in taking science to the youth with its programs such as CSIR-JIGYASA and Skill Development program, ensuring the development of a scientific temper among the students. The programs aim to skill train, upskill, and reskill youth to improve employability.

The Council of Scientific and Industrial Research (CSIR) proudly celebrated its 83rd Foundation Day in 2024. While addressing the event, the Vice President of India, Shri Jagdeep Dhankhar termed CSIR as "Catalyst for Scientifically Imaginative Rashtra".

This replica of Asoka Pillar cast for the workers of National Metallurgical Laboratory of India was installed on the 26th November, 1950, on the opening of the Laboratory by Jawaharlal Nehru, Prime Minister of India, as a symbol of the science and industry of India in the past, a token of the present and as an inspiration for future.

CSIR-National Metallurgical Laboratory

CSIR-National Metallurgical Laboratory (CSIR-NML) is a premier Indian research organisation dedicated to various facets of Minerals, Metals and Materials with an emphasis on scientific research, technology development, industrial services and human resource development in these domains. The laboratory was founded by Hon'ble Sri C. Rajagopalachari on 21st November, 1946 and formally inaugurated on 26th November, 1950 by Pandit Jawaharlal Nehru "in a spirit of hope and in a spirit of faith in the future". The laboratory is one of the first few laboratories of CSIR that were established for the Scientific & Technological Development of the country. CSIR-NML played a significant role in the industrial revolution of India starting from 1950, especially in the areas of mineral processing, iron and steel making, ferroalloys and extraction of non-ferrous metals, notably magnesium. Asia's largest creep testing facility was also set up at CSIR-NML in the early 1970s and even today it ranks as one of the largest creep testing lab in Asia. Since inception, CSIR- NML has diversified its research in areas such as extraction of critical metals from primary and secondary resources, alloy development for import substitution, corrosion studies, mathematical and physical modeling of metallurgical processes, mineral research, value extraction and valorization of industrial and urban resource, advanced materials, integrity evaluation of critical industrial components and surface engineering.

The resources of metals are always scarce and the beneficiation of ores is inevitable. Particularly, in iron and steel industries, the increase in production of metal iron consumes large amount of iron ore. As a result, there is a depletion of high-grade iron ores and the thrust is on beneficiation of low-grade ores. The laboratory has developed a process that is capable of producing a concentrate of 2.77% Al2O3 with 83.8% yield and tailings with 43.2% Fe at 1kg/ton collector dosage at batch scale of beneficiation of iron ore. With depletion of high cement grade limestone, presently white cement industry is facing an acute shortage of cement making raw material. High-grade limestone containing less than 0.068% Fe2O3 and less than 0.015% MnO is generally used for such purpose. Development of dry beneficiation process technology for low-grade iron ore for iron and steel making is another current focus of the laboratory. Under this activity, two lab scale dry separators and a flowsheet for dry beneficiation of iron ore in lab scale for the size range -20mm to +0.1mm are developed. Further processing by reducing the iron ore feed size below -1mm in air table, magnetic separator has increased the yield percent with Fe content greater than or equal to 62%. Abandoned quantities of lean grade iron ore (<55% Fe) and non-coking coal (< 40% F.C) are locally available in Jharkhand. Due to low Fe and high gangue contents in the ferruginous material, beneficiation of these raw materials or converting them in to a value added product is a challenging task for iron and steel industry. Similarly, due to low fixed carbon and absence of caking properties, utilization of the lean grade non coking coal is difficult and remains dumpted in the mines head. The technological possibilities for the utilization of such lean grade raw materials deserve special attention of R&D scientists to convert them in to a value added product. Hence a process for production of DRI utilizing regionally available lean grade iron ore and non-coking coal has been developed by the laboratory.

The laboratory also carries out R&D work and quality assessment of both coking and non-coking coals, band by band analysis and seam overall analysis through chemical characterization using its state-of-the-art coal characterization laboratory. In the preceeding 10 years, CSIR-NML has undertaken many projects on coal and the notable one is on “Reducing ash content from washery grade coking coal and high ash non coking coal through oil agglomeration” sponsored by CMPDI, Ranchi. Through this project, a pilot scale process plant which can reduce the ash content of various coal from 22% ash to 8% ash has been developed. Coal from seven different origins such as Magad, Kedla, Topa, Rajrappa (Jharkhand origin) etc. were used for the purpose. The laboratory is also involved in the work of sampling, preparation, and analysis of washed coking coal from various loading points such as Rajrappa, Kedla, Kathara, Swang area (Jharkhand area) of CCL for supply to SAIL & RINL Steel Plant.

Extractive metallurgy has been one of the first activities of CSIR-National Metallurgical Laboratory. Some of the pioneering work carried out in this area were production of sponge iron in rotary kiln, Pidgeon process for magnesium metal extraction, extraction of Ni and Co from sea nodules, and so on. Aligning with the need of the country, these activities have been emerged into many major programs namely, Critical metal extraction from primary and secondary resources, Urban ore mining, Green steelmaking and Waste Valorization. Critical metal including rare earth element is the need of the country as product development for sectors like defence, space, mobility, renewable energy depends on them. Currently India is importing more than 90% critical metals. In 2023, Ministry of Mines released the list of 30 minerals which are critical for India. Out of these 30 minerals, CSIR-NML has carried out research on 16 minerals/ metals and considered one of the research institute who can deliver technology in this area. CSIR-NML has developed first indigenous sodium metal technology which was piloted. The program on critical metal focusses on tungsten, magnesium, sodium, vanadium, scandium, rare earth elements, lithium, cobalt, nickel and many more. Many of these developments are supported by the industries. CSIR-NML is participating in CSIR mission mode project on ‘Mapping & Tapping of Critical Metals”. In addition, a pilot plant for producing magnesium at the scale of 100 kg/day will be set up using modified Pidgeon process integrated with distillation facility.

Urban ores are the fastest growing secondary resources worldwide. Some of the important urban ores are E-waste, battery, CFL bulb, whitegoods, etc. India is the 5th largest producer of E-waste. At present, no indigenous technology exists in the country for extraction of individual precious metals and safe recycling of E-waste. Currently, E-waste recycling is handled by unorganised sector of dismantlers in environmentally unsafe manner. This institute has set up the first Urban Ore Recycling Centre of the country and developed many processes for the precious extraction of and critical metals from E-waste. A large number of technologies in this admair have been transferred to various industries. The global demand for lithium is going to increase drastically in near future due to increasing usage of rechargeable lithium–ion batteries in electric vehicles, smartphones and other portable electronics. India has very scarce resource of lithium in primary form and depends solely on import. As India is emerging as one of the largest market for smartphones and electric vehicles, the demand for lithium is going to increase. Thus there is serious need to develop indigenous technology to extract lithium from secondary resources. CSIR-NML has developed and transferred many technologies in this area. A feasibility has been established on recycling of car batteries for recovery of metals by hybrid hydrometallurgical route on bench scale where the electrode material was primarily Mn-based. Recently a pilot plant with 1 ton/ day input capacity for recycling of lithium batteries has been set up, which was inaugurated by Dr. V. K. Saraswat, Member, Niti Aayog. Another activity which is being pursued is recycling of solar panels.

Rare earth is very important strategic material, but India does not have primary resources and depend totally on imports. Nitiayog has formed a committee to look at the possibilities to extract rare earth from secondary resources such as fly ash and red mud. We have been assigned the responsibility to develop a comprehensive technology at pilot scale to extract maximum value from red mud including rare earth and use the residue. In this program three research institutes and three industries are participating. The establishment of a pilot-plant facility for producing magnesium using the Pigeon process, derived from calcined dolomite, aims to provide a more sustainable and efficient production method. This process offers an environment friendly alternative to traditional magnesium production techniques, reducing energy consumption and minimizing carbon emissions, while enhancing resource utilization. Dr. N. Kalaiselvi, DG, CSIR has recently laid the foundation stone of the plant on the occasion of the platinum jubilee foundation day of the laboratory.

Recently we started the activities on green steel and studying the hydrogen based DRI. Currently reaction kinetics studies are under progress. Another activity that we have started in this area is carbon sequestration and capture using MOF and a project is initiated under CSIR CCU mission. The suitability of MOF has been tested at pilot scale at RKDF University, Bhopal which has given a good absorption of carbon.

Another area where CSIR-NML is recognised internationally is bulk volume utilization of Industrial waste. We are working on hot stage modification of slag to extract metallic values and use the non-metallic residue as cementitious binder. In this area, we are also planning to work on deconstruction of LD slag, where each component of slag will be extracted as metal values. Development of construction and building material from industrial waste using geopolymerisation technology. By geopolymerisation process, alumina-silicate waste can be converted to cementitious material but the process emits 80% less CO2 than the conventional Portland cement and considered green. The three technologies which have been given to the industry are geopolymer cement from fly ash, paving blocks from various industrial wastes and quick road repairing material from fly ash and slag mixture. Currently the team is working on self-healing geopolymer under CSIR-First program.

Alloy development and materials engineering is another thrust area of CSIR-NML. Novel alloy development for a variety of applications ranging from defence to biomaterial applications is the major focus under this area. The laboratory has designed and developed a precipitation hardened compositionally complex alloy (CCAs) as replacement of existing super alloys, high entropy alloys for hydrogen storage applications, high ballistic strength armour steel, Zr based biocompatible alloys for biomedical applications are a few to name. The laboratory also provides yeoman service to industries in remaining life assessment, structural integrity assessment and health monitoring, and failure analysis of engineering components. Many industrial sectors spanning oil, power, space, navy, defense and nuclear are the partners to many of the programmes in this domain.

The contributions of the laboratory for the socio-economic development of the country are notable. CSIR-NML has initiated several programs to reach out to the society. The laboratory has been constantly putting efforts for the prosperity and benefits of the artisans of the country through upgrading traditional technology and implementing appropriate innovation relevant to artisans dealing with metallic materials. CSIR-NML has developed energy-efficient and eco-friendly coke-based brass and bell metal melting furnace which has several advantages over traditional furnaces. The laboratory has also developed an anti-tarnishing lacquer for use on copper, brass and bronze surfaces which is available under the commercial name BRASS CARE through on line marketing stores like AMAZON.

The laboratory has also contributed to the Govt. of India mission of "Skill India" and provides training to the various genres of participants like school & college students, entrepreneurs and industry collaborators. CSIR-Integrated Skill Development Program is one such program that caters to diverse cross section of people at various levels beginning with school dropouts to farmers to ITI diploma holders and graduates. The focus is to develop skills in the area of metals, metallurgy, manufacturing, waste utilization, soft skills and entrepreneurship development.

The laboratory has undertaken an initiative to create an E-Waste Cluster. This program aims to address the growing challenge of electronic waste (e-waste) by focusing on capacity building and technological advancements. The key objectives include informal sector capacity building and upgradation, formation of recycling clusters under the MSME Scheme; Developing and implementing advanced technologies for the recovery of valuable materials from e-waste, such as metals, plastics, and rare earth elements, thereby promoting resource efficiency and supporting a circular economy.

The institution has also built-up collaborations with academic institutions world-wide for undertaking collaborative futuristic R&D and academic purposes. A number of collaborative MoUs have been signed by the institution for enabling long-term academic exchange, joint research and access to each other's facilities to provide the better facilities in expansion of metallurgical, earth science and industrial development IIT-Kanpur, IIT-Patna, OP Jindal University, IIT Madras, IIT Rookree, IIT Kharagpur, IIT Bombay, University of Calcutta, Shiv Nadar University, Sathyabama University, and international academic exchange with University of Stavanger- Norway, University of Miskolc, Korea Maritime University (KMU) , University of Sentiago-De-Compostel (Desirous to undertake a Co-operative program of research and development of resources utilization and recycling technology), QUB, Belfast; University of Stuttgart are a few such academic institutions with whom agreements have been signed. CSIR-NML has continued to collaborate with prominent government organizations such as: Indian Armed Forces, Indian Navy, DAE, BARC, IGCAR, NFDC, DST, DMRL, BHEL, NTPC, ONGC, IOCL, BPCL, SAIL, HAL, ISRO, Indian Railways, RDSO, various Ordinance Factories, MECON, ARDB, NRB, and more. In addition, CSIR-NML partners with leading private sector companies, including: Tata Steel, JSW, Kalyani Steel, Vizag Steel, Essar Steel, JSPL, NALCO, Tata Motors, Vedanta, Hindalco, Aditya Birla Group, Tata BlueScope, IFB Ltd., Quaker Chemicals, L&T, GE India, Bharat Forge, Ramakrishna Forging, Ashok Leyland, Shree Cement, GACL, Pfizer, Reliance Industries, and various refineries, among others.

Our Vision Statement

"To become a global leader and an internationally benchmarked laboratory in mineral and metallurgical research and development. To become a self-sustained technology centre in minerals, metals and materials."

Research Council (RC)

Chairman

Shri Amarendu Prakash
Chairman, Steel Authority of India,
New Delhi

Members

Dr. Balamuralikrishnan
Director, DMRL
Hyderabad

Dr. Karabi Das
Professor & Dean (Outreach)
Member, Board of Governors
Indian Institute of Technology Kharagpur

Shri Chaitanya Bhanu
VP, Steel Manufacturing,
Tata Steel Limited

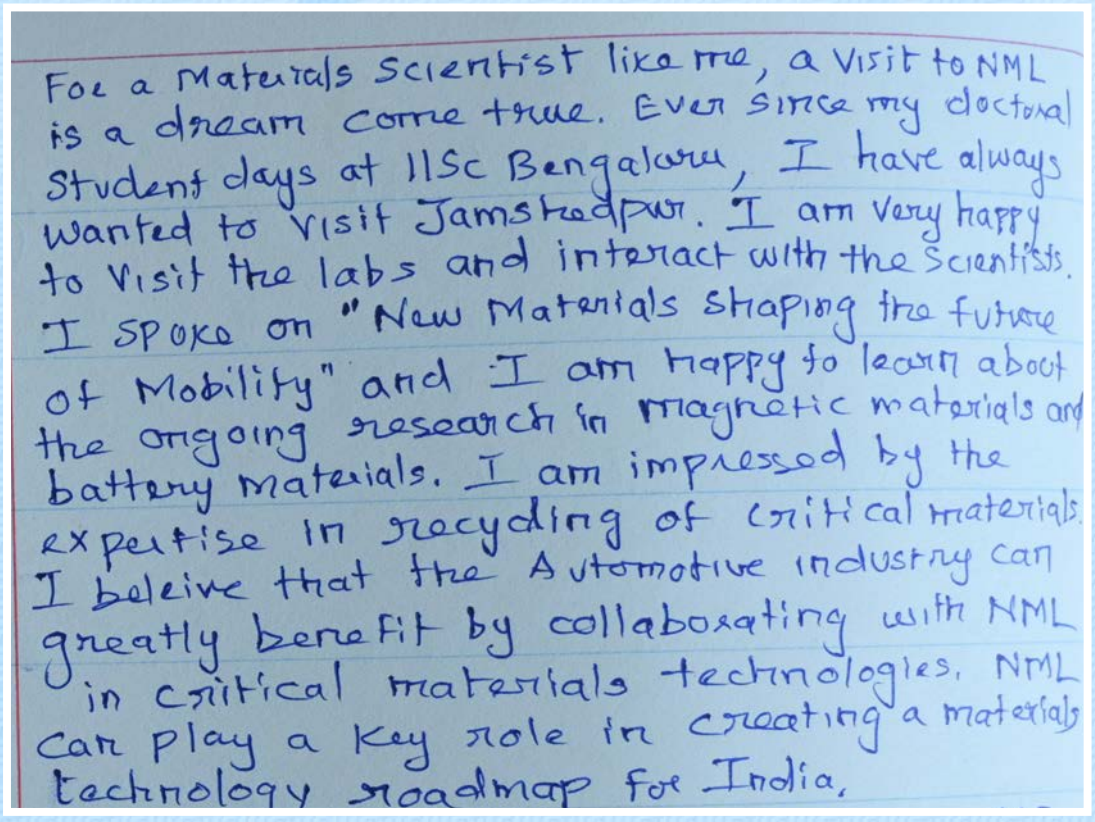
Dr. Prakash Kumar
Director
CSIR-National Geophysical Research Institute,
Hyderabad

Dr. S. K. Jha
Former C&MD
Mishra Dhatu Nigam Ltd
Hyderabad

Ms. Sukla Mistry
Former Director (Refineries)
Indian Oil Corporation Limited
New Delhi

Dr. R.M. Mohanty
Senior Principal Scientist,
Technology Management Directorate, CSIR,
New Delhi

Dr. Sandip Ghosh Chowdhury
Director, CSIR-National Metallurgical Laboratory
Jamshedpur



For a Materials Scientist like me, a visit to NML is a dream come true. Ever since my doctoral student days at IISc Bengaluru, I have always wanted to visit Jamshedpur. I am very happy to visit the labs and interact with the Scientists. I spoke on "New Materials Shaping the future of Mobility" and I am happy to learn about the ongoing research in magnetic materials and battery materials. I am impressed by the expertise in recycling of critical materials. I beleive that the Automotive industry can greatly benefit by collaborating with NML in critical materials technologies. NML can play a key role in creating a materials technology roadmap for India.

"For a materials scientist like me, a visit to NML is a dream come true. Even since my doctoral student days at IISc Bangalore, I have always wanted to visit Jamshedpur. I am very happy to visit the labs and interact with the scientists. I spoke on 'New Materials shaping the future of Mobility' and I am happy to learn about the ongoing research in magnetic materials and battery materials. I am impressed by the expertise in recycling of critical materials. I believe that the automotive industry can greatly benefit by collaborating with NML in critical materials technologies. NML can play a key role in creating a materials technology roadmap for India."

Dr. Shankar Venugopal

Vice President, Mahindra &Mahindra

26th September 2024

1947-55

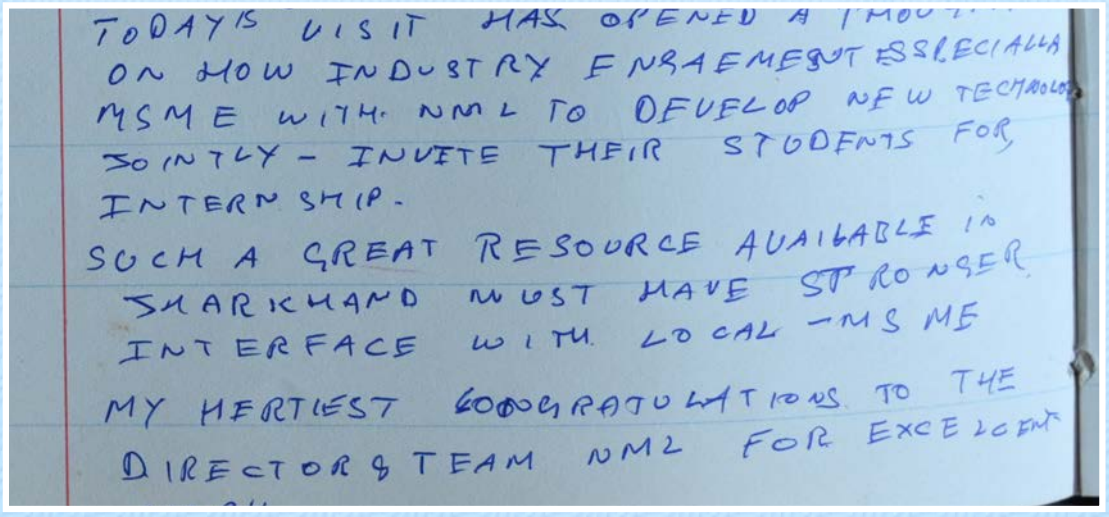
The Performance

The Hon'ble Shri. Jawaharlal Nehru opens the Laboratory

Inauguration of NML The Hon'ble Shri. Jawaharlal Nehru addressing the gathering

Construction work of NML building started

A dream realised


TODAYS VISIT HAS OPENED A THOU
ON HOW INDUSTRY ENGAEMENT ESPECIALLY
MSME WITH NML TO DEVELOP NEW TECHNOLO
JOINTLY - INVITE THEIR STUDENTS FOR
INTERNSHIP.
SUCH A GREAT RESOURCE AVAILABLE IN
JHARKHAND MUST HAVE STRONGER
INTERFACE WITH LOCAL - MSME
MY HERTIEST CONGRATULATIONS TO THE
DIRECTOR & TEAM NML FOR EXCELLENT

"Today's visit has opened a thought on how industry engagement especially MSME with NML to develop new technology. Jointly-invite their students for internship. Such a great resource available in Jharkhand must have stronger interface with local MSME. My heartiest congratulations to the Directors & team NML for excellent work."

Mr. Ranjot Singh,

Managing Director,

EMDET-Jamshedpur & Chairman-CII, Jharkhand

11th November 2024

Director's Foreword

In the past fiscal, the incessant efforts of our dedicated manpower brought us further closer towards achieving the CSIR-NML's vision of becoming a nationally relevant, globally benchmarked, and self-sustained technology and innovation center in minerals, metals, and materials engineering.

This year is special as we are celebrating the Platinum Jubilee year of our foundation in 1950. The year-long Platinum Jubilee celebrations have commenced from our foundation day on 26th of November 2024. The curtain raiser of the Platinum Jubilee logo was also done ion the occasion. A number of events have been planned to be organized in the entire year for making a memorable Platinum Jubilee year. I am obliged to our Mentors and Research Council Members who have penned their inspiring messages on the occasion of our Platinum Jubilee. These messages have formed a distinct feature of this Platinum Jubilee Annual Report.

On the front of the R&D outputs of the last fiscal we exceeded our targets of 140 SCI publications. Our research work could take form of 159 SCI Journal papers. We could file six patents and one copyright. In addition, a significant number of patent drafts emanated from the joint R&D with industries are still under consideration at the collaborator's end. We could file one industrial design in this fiscal as well. Our customers rated us highly hence we achieved a customer satisfaction index of 4.8 alike to our set target. With respect to the technologies, we have transferred five technologies. The technologies transferred to industries and MSME included: Know-how for the development of Ti3AlC2 MAX phase ; Licensed to M/s. Global Nanotech, Goregaon; Know-how for the development of Magneto impedance-based array sensing device for detection of carburization and defective welds- MagRays; Licensed to M/s. Accelor Microsystems, Chandigarh; Process flow-sheet for production of self-healing coating and primer suitable for application on rusted steel; Licensed to M/s. Asianol, Kolkata; A pyro-hydrometallurgical process for holistic recycling of variable zinc dross, high and low grade, to recover zinc metal and its salts; Licensed to M/s. Chandigarh Technologies, Haryana; and Know-How to recover saleable products of Cu, Al, and Au as Metals/ salts from waste PCBs, Licensed to M/s. Eyantram Waste Management Private Limited, Bangalore.

We have also developed few technologies in this fiscal; those are Magnetoimpedance (MI) based array sensing device for detection of carburisation and defective welds: MagRays (Technology Readiness Level- 7); An improved hot dip coating process (Technology Readiness Level- 6); Colorized galvanizing coated steel products and their process (Technology Readiness Level- 6); Recovery of Zinc as the valuable product (Zinc sulfate monohydrate/ zinc carbonate/zinc/metal) from lean grade zinc dross (Technology Readiness Level- 9); and Cost-effective hot-rolled steel with ultrahigh strength and excellent toughness (Technology Readiness Level- 5). The external cash flow (ECF) remains at Rs. 20.13 Crores; out of the total ECF, around 75%

was generated from the industrial sources, which is quite significant and reflects upon our alignment with our vision of a self-sustained technology centre. We are hopeful that the collaborations and agreements that are in pipeline with the industries and ministries will be finalized soon and convert into contract research projects. We have signed 27 agreements/memorandum of understandings with national and international industries and academia in the last fiscal. Two foreign collaborations with a) Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia on the Titanium-vanadium recovery process; and, b) Lyten Inc, USA Lyten to develop the Downs cell for Li production and purification; has been achieved. We are expecting to finalize the underway collaborations with M/s CMPDIL, Ranchi for the Analysis of Coal Samples and with M/s IREL for the development low-carbon aluminium steel with the addition of rare earth metals / mischmetal. Another collaboration with Gati Shakti Vishwavidyalaya, Vadodara and RDSO Lucknow for undertaking Research & Development for Metallurgy and testing of Rail / Wheel and related components is in the process.

Significant number of flagship projects are on track. The deliverables of the project on Technology development for holistic utilization of red mud for extraction of metallic values & residue utilization have been completed on 100kg scale for all red mud, and demonstration has been given to all industry partners. The project is currently being pursued for separation of REEs and Ti as well as data consolidation for the completed work. Battery to Battery Recycling and Waste to Wealth creation are other areas of focus for the laboratory. In another initiative the technology development for extraction of critical metals (niobium, tantalum, scandium) from secondary resources/potential wastes have been taken up. In our flagship initiatives with Magnesium Pilot Plant, the scale-up activity for vacuum distillation is continued to establish process technology at 5-6 kg scale in semi-continuous mode. Piloting activities for commercial grade high pure magnesium metal from Indian dolomite resources, further initiated. The proposed pilot plant is designed for 120-150 kg Mg metal/day with ~2 TPD feed of dolomite. The pilot plant is designed with NML's retort technology (improved Pidgeon Process) and continuous vacuum distillation refining technology. Foundation stone of the proposed pilot plant is laid by Hon'ble DG, CSIR and Secretary, DSIR Dr. (Mrs.) N. Kalaiselvi.

Under the initiatives undertaken for the national facility creation a) Battery Recycling Pilot Plant: CSIR-NML has commissioned 1TPD battery dismantling setup, along with 100L Metal extraction and 10L Solvent Extraction facility. The pilot plant is first of kind Hire-Operate-Transfer (HOT) platform for MSMEs and Entrepreneurs in India. b) Urban Ore Recycling Centre (UORC): The Centre is dedicated for the development of application oriented e-waste recycling processes consisting of pre-treatment (physical/pyrolysis/chemical) followed by processing using advanced separation techniques to recover value added products (salts/metals) of rare, rare earth, precious metals and non-ferrous metals fulfilling zero waste concepts under the collaborations with national and international research institutes and industries, c) Centre for Excellence (Wear and Corrosion Resistant Coating Technology): with the funding of Department of Science & Technology, Govt. of India under its 'Advance Manufacturing Technology' scheme, this center has been established to facilitate the SME, MSME and large scale industries including Academia to do research in Wear and Corrosion specifically, in the eastern zone of India, d) Marine Corrosion Research Station and Skill Development Centre, Digha was revamped at Digha, near Bay of Bengal.

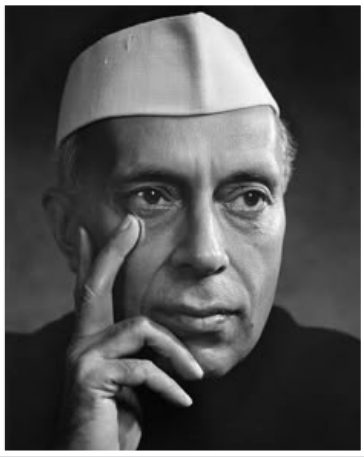
The year, our talented researchers and staff/employees were conferred with a number of highly coveted awards: Rashtriya Vigyan Puraskar: Vigyan Yuva - Shanti Swarup Bhatnagar 2024; Young Metallurgist Award (Metal Science), 2023; Ministry of Steel; IEI Young Engineers Award 2024-25; Metallurgical and Materials Engineering; Raman Research Fellowship 2024-25; MS Khan Memorial Award 2024; and Acta Student Award 2024-25. I congratulate all the colleagues for bringing honour to the laboratory.

As we are celebrating 75 Glorious years of our existence and endeavours, our efforts will be continued in developing indigenous technologies for Viksit Bharat.

Sandip Ghosh Chowdhury

Photo Source: Google

75 Years of R&D Journey



"...I wish that our young men and women who come here should have a zeal for working out problems which would have great consequence. That would give vitality to these Institutes. They should realize that service to science is real service to India – no, even to the whole world – science has no frontiers".

--Pandit Nehru in the Inauguration of NML (1950)

The foundation stone for National Metallurgical Laboratory was laid by Hon'ble Sri C. Rajagopalachari on 21st November, 1946. It was formally inaugurated and dedicated to the nation on 26th November, 1950 by Pandit Jawaharlal Nehru and stands as a cornerstone of India's scientific and industrial progress. The laboratory was an element of Sir Shanti Swaroop Bhatnagar's vision of providing cutting edge technologies for the sustainable utilisation of India's mineral resources, fostering self-reliance in metals and materials sector. NML's significance lies in its role as a catalyst for industrial growth, addressing critical challenges in metallurgy, material science, and allied fields. By bridging the gap between laboratory research and industrial application, NML has empowered sectors like steel, aerospace and energy with indigenous solutions. The laboratory's contributions extend to process optimization, waste management, critical metal extraction and the development of advanced materials, aligning with national priorities like Samarth Bharat, Shashakt Bharat, Kaushal Bharat and Atmanirbhar Bharat. NML's strategic location in Jamshedpur, India's steel hub, enhances its impact, leveraging proximity to industry for collaborative innovation. Its enduring commitment to excellence has positioned it as a global leader in metallurgical research, driving economic and technological advancements. Through its 75 years of efforts, NML continues to shape a robust and sustainable future for India's industrial landscape.

Glorious Past

Staring from 1950, CSIR-NML had played a significant role in the industrial revolution of India, especially, in the areas of mineral processing, iron and steel making, ferroalloys, and extraction of non-ferrous metals, notably magnesium. Asia's largest creep testing facility was also set up at CSIR-NML in the early 1970s, and even today it ranks as the second largest creep testing lab in Asia. Since origin, CSIR-NML has diversified its research areas ranging from extractive metallurgy, alloy development and import substitution, refractory material development, corrosion studies, mathematical and physical modeling of metallurgical processes, mineral research, advanced materials and materials tailoring, integrity evaluation of critical industrial components, surface engineering and cleaner and sustainable metals production. The Laboratory has made notable contributions in the areas of mineral beneficiation and agglomeration, ferrous and nonferrous metallurgy, alloy development and processing, materials science & engineering, and resource conservation & environment.

The history of achievements of this laboratory begins from the early nineteen fifties, when CSIR-NML developed a technology on the use of protective coating to prevent the oxidation of graphite crucibles. These crucibles were utilised by hundreds of SMEs around the country for manufacturing graphite crucibles for melting brass and other non-ferrous alloys. CSIR-NML filed the first patent

in 1957. This technology received interest from several industries and was commercialized in 1958, and process was initially licensed to five parties (a) Maheshwary Graphite Udyog Pvt. Limited, Vijayawada, (b) Mattapalli Satyam & Sons, Samalkot, Andhra Pradesh, (c) Patna State Graphite & Mining Co. Limited, Titlagarh, Orissa, (d) Circar Graphite Products, Rajahmundri and (e) J.D. Jones & Co. Limited, Jamshedpur through NRDC. NML in 1958 initiated work on producing dense carbon aggregate and Soderberg paste from indigenous raw materials. For the use of India's ferro-alloy and aluminium industries, the know-how for Soderberg paste and carbon refractories was developed then scaled up to a 500 kg pilot plant. Ten tonnes of soderberg paste was field tested by Mysore Iron & Steel Works in their electric pig iron furnace and 12 tons of soderberg paste was tested as electrode in the Submerged Arc Furnace of Ferro Alloy Corporation. A 15-ton/day pilot low-shaft furnace, one of the largest pilot plants established anywhere in the world, has been operational at NML since 1959. The plant, costing close to Rs 3 million (in mid-1950's) and supplied by the Demag-Humboldt Niederschachtofen, Duisburg, West Germany took nearly two years for construction. It required 100 tonnes of materials handling per day! The objective of having the plant was to assess the possibilities of making commercial grades of pig iron with raw materials like soft iron ores, iron ore fines, beneficiated magnetite iron ore, with various non-coking high ash coals or carbonized lignite, plentiful supplies of which exist in India but unsuitable for exploitation in conventional blast furnaces. This plant yielded the first pig iron in India from iron ore fines and coal - over a thousand tons of foundry grade pig iron was produced in 1959 itself.

As the resources of zinc were considerably less abundant than aluminium, and also the entire requirement of zinc in 1950's was imported, a pilot plant for aluminizing was established during 1960. The pilot plant worked on hot dip aluminizing of mild steel wire. A several-mile length of wires was supplied to Posts and Telegraph Department. Aluminized materials, assorted angles, and welded hardware items were supplied to the Railway Electrification authorities for their field trials. Auto-muffler parts and silencer pipes furnished by the army base camps and automobile industry were aluminized. Aluminizing of Bunsen burner was carried out for Department of Industry, Government of Punjab. The users also included Calcutta Bucket Manufacturers Associations who were supplied 100 aluminised buckets. The process was licensed to thirty clients for commercial exploitation. M/S John Miles and Partners Ltd. (London) in 1963-64 also used 152 aluminized steel tubes for heat-resistant applications at ICC, Ghatsila. The plant evoked considerable interest during the war periods in 1960s.

Development of substitute steels utilizing indigenous raw materials was a priority since the laboratory was established in 1950. The heart of the program initiated in 1954 was the development of tonnage scale (one ton heat in an electric arc furnace) nickel-free austenitic Cr-Mn-Cu-N stainless steels named as Thakeron Steel after the name of the then Director General of CSIR. Three types of Ni-free Cr-Mn-N stainless steels were developed. Another achievement in the development of Ni-free steels was the development of technology for substitute Ni and Co free electrical resistance heating elements which was transferred to M/s New Horizon, Pondicherry. Ni-free creep resistant austenitic steels was developed for exhaust valves for TATA D1 engine as well as Diesel Locomotives and the know-how was transferred to M/s Star Wire (India) Ltd. New Delhi in 1993. In 1968, NML developed a Cr-Mo-V type steel to replace Mo in the existing armour plate steel. A collaborative program with M/s Visvesvaraya Iron & Steel Ltd. led to process standardization of HSLA steels as well as vanadium and vanadium-niobium steels. These steels were produced at commercial scale in VISL, Bhadravati. In collaboration with RDCIS and MECON, Ranchi, a project on the development of Cryogenic Steel was initiated and pursued. Similarly, developmental work on high temperature creep resistant steels were undertaken jointly with BHEL in 1981 and within five years, various bolting steel, tubing steel, casting and forging steels were developed. In 1983, NML ventured into Wear & Abrasion Resistant Steels. Work was undertaken to develop the know-how for rolling of 14% manganese steel into plates. The entire substitute steels development program up to the 1980's was at tonnage scale, mostly in an electric arc furnace of 1 ton capacity. Later in 2006, a project on the development of silt erosion resistant material

for underwater components in a hydel power station was successfully taken up with support from Central Electricity Authority, New Delhi. In 2007, a comprehensive programme on the development & forming of Performance Driven Special Steels was taken up. In the late 1950's (1959), NML developed manganese brass in lieu of zinc brass for utensils and tin-less bronze (Zn-Al-Cu) because of the scarce resources of zinc and tin. Another development during this period was Al-Mg (7-10% Mg) alloys. In a pioneering effort, NML developed an exceptional aluminium alloy conductor designated as NML PM-2 to replace copper conductors. The development work on NML-PM2 alloy for various applications (PVC insulated wires, enamelled wire for signal relay, underground telephone wires and welding wires) were undertaken in collaboration with several industries such as Bharat Heavy Electricals Limited, Railways Design & Standards Organization, Gujarat Electricity Board and Indian Cable Co Ltd. Large quantities of these wires were supplied to Indian Railways. The process for the development of above alloys was patented in India and abroad and licensed to different industries. In recognition of the work on NML-PM2 aluminium alloy conductor, NML was awarded with 'Excellence in R & D Aluminium Cable & Conductor', instituted by The Cable & Conductor manufacturers' Association, by the President of India in 1975-76. A high strength aluminium alloy conductor was developed at NML (designated as NML-PM 215) and was produced industrially by Bharat Aluminium Company (Korba). A modified tool was developed at NML to extrude integrated shapes of magnesium based alloys for the Satellite Centre of ISRO at Bangalore in 1977-78. Rapidly solidified Mg-alloy ribbons were compacted and extruded to cater to the stringent needs of ISRO's space ventures.

The submerged electric arc furnace - ferroalloy pilot plant, built at a cost of Rs. 0.6 million then, went into operation in February 1962 in front of a large national & international audience who had come to attend the symposium on "Ferroalloy Industry in India". The furnace with a daily capacity of 1-3 tonnes, depending upon the type of ferroalloy, was the first of its kind to be installed in India and perhaps in the whole of the East. The heavy integrated Mineral Beneficiation Pilot Plant was built at a cost of Rs. 5 million as a part of the Third Five Year Plan in 1963. The plant was meant for round the clock operation to develop basic data for beneficiation of raw materials. The plant had a capacity to treat up to 5 tons of ore per hour depending upon the specific treatment and optimum upgrading cycle and was one of the best equipped integrated plants in the world for undertaking beneficiation and up-gradation of low-grade ores and minerals and for trials pertaining to agglomeration of concentrates. The plant was extensively used for mineral beneficiation studies; especially iron ore, limestone, dolomite, manganese ores, complex sulphide ores of base metals, graphite, coal, kyanite, wolframite, magnesite, barites, apatite, phosphate and fluorspar. Almost the entire steel industry of India (TISCO, IISCO, SAIL) used the basic data generated by NML to develop the flow sheet required for iron ore beneficiation and agglomeration of iron ores. Similarly, both the major copper plants of Hindustan Copper at Ghatsila and Mallanjkhand adopted the flow sheets developed by NML for the production of copper concentrates. Several of the graphite beneficiation plants and the fluorspar plants in India owe their existence to NML. The plant upgraded in 1998, has contemporary facilities. Today, Mineral Processing Division of National Metallurgical Laboratory can boast of over 800 sponsored investigations to its credit covering almost the entire spectrum of ores and minerals including coal. Major beneficiaries includes Tata Iron & Steel Co. Ltd., all the steel plants under Hindustan Steel Ltd. [now Steel Authority of India Ltd. (SAIL)], Mineral Development Corporations of Gujarat, Rajasthan, Tamilnadu, Andhra, Bihar and several other states, Hindustan Copper Ltd., National Mineral Development Corporation, Indian Rare Earth and many others. The list also includes several overseas clients from Nepal, Bhutan, Thailand, Kazhakstan, Syria, Egypt and United Kingdom.

Scarcity of Magnesium metal in the country during the war with China in 1962 triggered a demand from the Government to develop a technology for the production of the metal on commercial scale. A committee headed by Homi Bhaba directed NML to set up a plant for the demonstration of the technology and produce the metal on a scale of 250 tonnes per annum. Work started on the construction of the plant in 1969 and trial production commenced in 1971. The plant included calcination

facilities, gas and electricity fired vacuum retorts and remelting facilities for magnesium. The plant was dedicated to the nation in November 1972 by Shri Mohan Kumaramangalam, Union Minsiter of Steel and Mines. Commercial production at a capacity of 250 tonnes/annum (which was the total country's demand then) continued for the next thirteen years. The plant and technology were subsequently transferred to an industry, the Southern Magnesium Ltd. The industrial plant had an installed capacity for producing 600 tonnes of magnesium per annum. This technology won the World Industrial Promotion Award for CSIR . In view of the importance of manganese, a beneficiation plant which included a separate thermal beneficiation section for magnetising roasting was conceived as a separate entity for manganese ores. In the subsequent years, the extensive data generated on mineralogy for manganese ores from all over the country, led to the preparation of a monograph on "Beneficiation of Low-grade Indian Manganese Ores" in 1959-60 and manganese constituted an important chapter in the subsequent publications, e.g. 'Ores & Minerals of India – Beneficiation & Agglomeration Technique for Industrial & Economic Exploitation' published in 1981. The technologies for all grades of ferromanganese was developed, using submerged arc furnace and aluminothermic reduction, and transferred to a large number of ferroalloy producers in India. NML also perfected the technology for the production of electrolytic and chemical manganese di-oxide. Based on the know-how developed, technical assistance was rendered to Central Research Organisation, Rangoon (Burma) for setting up a pilot plant for EMD. Notable beneficiaries of the manganese metal and manganese di-oxide research include Manganese Ore of India Ltd., and others such as T.K. Chemicals, Golden Edifice Elements Pvt. Ltd., Magno Mining Co. Ltd., and Indian Manganese Metals. In the late nineties, NML worked on a beneficiation process to enrich nickel from 0.5% to about 2% through chemical route. In collaboration with Tata-Steel the process was scaled up to 50 Kg/ batch semi pilot scale.

NML attached considerable importance to preserving this traditional knowledge and heritage. A process was developed by NML in 1964 for imparting black colour by immersion process to Bidri wares (in Zn-4% Cu wares) for All India Handicraft Board. Craftsman from Bidar, Mysore were trained on this. Casting of brass and bell metal for making lota, ghara and glass by the artisans in the rural district of Bankura in West Bengal has been a traditional activity for ages. NML, in 1987 came up with a total technology package for improving the quality and economy in the production of traditional items maximising the use of locally available raw materials and utilising the existing skill in the rural areas without tampering on the traditional knowledge. The technology package comprising of thermally efficient melting unit with lip pouring and tilting arrangements along with preheating chamber for mould preheating was developed and transferred. A similar package was developed for practising blacksmiths in rural sector between 1996 and 1999. Under a memorandum of agreement with Small Industries Development Bank of India, NML conducted training programmes for the rural artisans on Skill-cum-Technology Upgradation, Entrepreneurship Awareness and Development in the states of Jharkhand, West Bengal, Orissa, Andhra Pradesh, Punjab and Karnataka. NML Foundry Station at Chennai was inaugurated on December 14, 1965 by the former President of India Shri.R Venkatraman especially to assist the foundries at Coimbatore. Later on, it became a full-fledged centre (NML Madras Centre) within the administrative ambit of the CSIR Madras Complex. Although the initial activities of the Centre were on foundry materials and practices, it subsequently developed into a strong centre for excellence in mineral beneficiation. The notable achievements of the Centre include (i) Flow sheet development for the beneficiation of Sivaganga Graphite Beneficiation Plant and (ii) Development and commercialisation of column flotation technology. NML Madras Centre also established facilities for chemical analysis, thermocouple calibration and metallurgical characterization and failure analysis and has a large clientele in these areas. It today has accreditation from National Accreditation Board for Laboratories in these areas for calibration and testing. The 'Foundry' at NML was set up in 1964 having an 'arc furnace' of 30 kg (ferrous melting) capacity and a 1 ton/hour hot blast cupola. Apart

from helping the small scale industries in designing and setting of cupolas, renovations in cupola design like 'divided blast', `oxygen enrichment' were advised through the field stations'. Gradually the foundry activities focussed on 'alloy development' shifting from innovative 'moulding methods'.

The development of various improved designs of Cupola at NML in the early 1980's was a milestone in foundry research. It was shown that simultaneous adoption of the oxygen and the hot air blast substantially enhances the temperatures achieved. For every 100°C increase in temperature of the air blast along with every one percent enrichment of air blast by oxygen, the molten metal temperature increased by 30 to 40°C. A mini cupola was also designed, fabricated and commissioned at NML. The other major milestone was the design, development, commissioning and plant trials of an eco-friendly cokeless cupola of 1 and 2 tonnes/hour capacities in order to provide indigenous technical know-how to the clusters of foundries located at various places in the country especially the Taj Trapezium at Agra.

NML developed a wear resistant cast iron (designated as NML-WEARNOT) from indigenous raw materials without Ni and Mo during the period 1976-1986. This alloy was produced in a 500 kVA (capacity 800 kg) electric arc furnace at NML and on a 4000 kg electric arc furnace on an industrial scale. Impeller blade for shot blasting machine made from the above material was supplied to TELCO, Jamshedpur and it was found that wear of this alloy was 8.5% compared to 16.3% recorded for imported Mo containing bearing alloy. This material in the form of 'Top peripheral liners' was also supplied to Damodar Valley Corporation, Chandrapura and was found to have a life of 4000 h against 2000 h for conventionally used chilled cast iron. The know-how of the process was transferred to M/s. Mining & Allied Machinery Corporation, Durgapur. The development of aluminium cast iron (23% Al, 1.8% C, 1.2% Si) was started in 1970s to substitute conventional heat resistant cast iron which normally contains Cr, Ni and Mo. During 1980s, NML also developed a heat resistant cast iron (designated as NML-Pyroloy-1000), suitable for use up to temperatures of 1050°C, which was claimed to be better than the conventional heat resistant alloy steel containing high Cr- and Ni. This alloy underwent field trials at Stanton Pipe & Foundry Co. Ltd, Ujjain, TISCO and TELCO, Jamshedpur and showed comparable or superior performance to some of the existing alloy steels.The modern Powder Metallurgical (PM) route for making components in India initiated only in 1950s. At NML, the research activities on Powder Metallurgy started in the year 1949, ahead of any other Indian institute. The initial activities were focused on metal powder production by electrolytic route, inert gas condensation (IGC) and purification of low grade powder. Recovery from low-grade Metal powder production at NML was not limited to only atomization routes. Based on the specific requirements, metal powders through chemical and/or electro-chemical routes were also explored. As early as 1950, NML developed an electrochemical process for production of stainless steel powders. Moving forward, NML developed a number of technologies for production of iron, copper, nickel, cobalt, silver etc. powders from various sources through electro-chemical routes. Several of these technologies were patented (I.P. Nos: 76997/1962; 1233/DEL/91; 700/DEL/2000) and transferred to industries (M/s Tapadia & Co/1983; M/s National Aluminum House/1993; M/s Nitu Electronics/1991). Synthesis of fine metal and alloy powders is still an active area at NML. One of significant events at NML on powder metallurgy was the hosting of the eleventh national Powder Metallurgy conference jointly with the Powder Metallurgy Association of India in Feb. 1985. The importance of refined grain structure in cast alloys led NML to develop inoculants/grain refiners for Mg- and Al-alloys during 1963-64. Grain refinement of Mg and its dilute alloys were based on the additions of small amounts of alloying elements such as Al (0.5-4%), Cr (0.01-0.1%), Ni (0.01-0.05%) or Mn. The techniques of refining hypo- and hyper-eutectic Al-Si alloy developed at NML was licensed to a West German firm in 1965.

The history of corrosion research at NML is outstanding and inspirational. Studies on the atmospheric corrosion of various materials were initiated way back in 1956. The first atmospheric corrosion results were reported on TISCOR steel. These steels as well as samples of Ni, Cu, brass, Zn, aluminized steel components and various other steels (including Ni-free stainless steel) were exposed

to atmosphere and corrosion monitored for a period up to ten years since 1956. The meteorological data, SO2 concentration in air as well as the microstructure and properties of the exposed samples were continuously monitored and recorded on monthly basis for more than fifteen years. Investigation into the corrosion of rails used in Indian Railway tracks was carried out in 1963. Studies at NML on the corrosion resistance of the Delhi iron pillar, the iron beams of the Konark sun temple, the ancient steels of Southern India and the steels made by the Adivasis since the early 1960's were pioneering contributions. The establishment of a Marine Corrosion Research Station (MRCS) at Digha in 1963 enabled corrosion studies in saline atmosphere. A major initiative to design the corrosion map of India was taken up in early seventies. In this program, various metals and alloys were exposed to different climatic locations of India for close to five years. The data collection and their analysis were carried out by a team of NML scientists and a corrosion map was designed and published. This map is still being used as reference by designers, architects and various government agencies for materials selection.

Polymetallic sea nodules obtained from the depths of the ocean floor contain valuable metals such as Cu, Ni, Co and Mn. The absence of economic resources of the strategic Ni & Co together with the fast depleting Cu resources was the prime motivation for exploitation of the renewable sea bed deposits of Cu, Ni, Co & Mn, from the Central Indian Ocean Basin. National Metallurgical Laboratory started this work in 1983 towards developing a suitable technology for extraction of these metals from sea nodules, which was financially supported by the Ministry of Earth Sciences (previously Department of Ocean Development), Govt. of India. NML has developed a process, starting from the bench scale to the validation of results on large scale, for the metals extraction from the sea nodules following "Reduction roast - Ammonia Leaching - Solvent extraction – Electrowinning - Leach residue treatment" route. NML's process has been scaled up to 100 Kg/day continuous reduction roasting, 12 Kg scale ammoniacal leaching and 1000 liter/day continuous solvent extraction-electrowinning. Average metal recoveries after conducting a large number of campaigns on the above scale, are: 95% Cu, 95% Ni and 75% Co. In order to recover Mn from the leached residue, bench scale trials have been carried out in a 50 KVA submerged electric arc furnace on 10-20 Kg scale to produce Fe-Si-Mn alloy. Subsequently, a pilot plant to treat 350 Kg/day leached residue has been set up in 2007 and standard grade Fe-Si-Mn with 75% manganese recovery, has been successfully produced in the pilot scale.

Creep testing at NML started in a modest way in the early sixties. With a set of 12 machines, it initially catered to the lab research works on indigenous high temperature alloy development. The need for a central large scale creep testing facility was realized in the late sixties. India was totally dependent on import of creep resistant steels. Although the indigenous steel makers had the expertise to make creep resistant steels, in the absence of creep data, users were not ready to accept them for their applications. The creation of a large scale creep testing facility was recommended in a get together (in mid sixties) of steel makers (like SAIL and Mahindra-Ugine), users (BHEL) R&D organizations (NML, RRC-Kalpakkam) and statutory bodies (then ISI, DGTD) and others. This led to the establishment of large scale creep testing facility with 150 test points (all the equipments were donated by UNIDO) in 1972. Subsequently, an indigenous program on development of creep resistant steel was initiated under the overall guidance of Indian creep panel (a voluntary body consisting of all the above organizations with secretariat at NML). Primary challenges successfully met was: rationalization of creep resistant steel from a jungle of specifications available, designing of test program for acceptance of the indigenous steels and commercial production followed by long term creep evaluation of the indigenized alloys. The main grades of steel indigenized were: high temperature bolting steels (CrMoV with and without Ti, B, EN20), super heater tubing steels (1Cr½Mo, 2¼Cr1Mo, ½Cr½Mo¼V) and forgings grade steel (CrMo, CrMoV). NML generated up to 30000h creep data base on these steels and compared it with international standards. Based on these evaluations, central boiler board approved these indigenous steels in Indian power plants. NML played a major role in the materials evaluation and

qualification program, especially with respect to creep damage for the Fast Breeder Reactor Program of the Department of Atomic Energy. NML has the unique distinction of carrying out the longest creep test in India of 140,000 hours for stainless steels to be adopted in the Fast Breeder Reactor at IGCAR, Kalpakkam. During late 80's and early 90's a series of Al-based alloys were developed. Notable among them were Al-transition metal-Ce for aerospace application, Fe-Al intermetallic alloy for high temperature application, Al-Fe-Mischmetal and Al-Mn-Mishmetal for possible substitution of the expensive Ti-based alloys for aircraft application.

Certified Reference Materials (CRMs) are benchmarks to calibrate the analytical instruments and to validate the measurement methods. Certified reference materials were not readily available in the 1950's and were expensive. NML recognized the importance of producing quality and reliable CRMs for metallurgical applications very early. An ambitious project to produce CRMs was initiated in 1963 and successful commercialization of the Cast Iron, Plain Carbon Steel and Brass CRMs to 11 Indian industries was first achieved in 1965. This was a huge step to making India self reliant in the field of CRMs. Later, in 1969 through a collaboration, NML produced and supplied two ferro-alloys (Fe-Ti & Fe-Mn) to National Bureau of Standards (NBS), USA presently known as NIST.

Metallurgical characterization and failure investigation of components in railways, power plants, petrochemical industries, power distribution systems, chemical and fertilizer plants, paper mills, automobile components and steel plants have remained a routine affair since 1954. Failure analysis studies at NML took a new dimension after the coming up of the Large Scale Creep Testing Facility which was extensively used for damage and remaining life assessment. In June 2000, the Center for Military Airworthiness and Certification (CEMILAC) accorded approval to NML for taking up work in the area of failure analysis and life evaluation of aircraft/helicopters/engine components. NML has since offered failure analysis reports and expert opinions often sought by IAF/CEMILAC/HAL for military aircraft accidents or major aircraft failures.

The activity on the development of Magnetic Materials at NML goes back to the days of Dr. E.G. Ramachandran. Initial work centred on setting up of a magnetic characterisation facility based on an indigenously developed ballistic galvanometer method. Activities on development of Alni and Alnico types of permanent magnets started in 1954 as an import substitution initiative, ultimately leading to transfer of its production technology to M/s Permanent Magnets, Bombay. During '60s, rapid growth of electronic and other industries enhanced the demand for magnetic materials many fold, leading to intense activity at NML on the development of cheaper ferrite magnets based on mixed oxides of the type MO.6Fe2O3 (where M=Ba or Sr).Since the '90s, activities were focussed on the development of soft magnetic materials.

National Metallurgical Laboratory initiated a major activity in 1999 to develop comprehensive process models to generate knowledge base on various phenomena occurring in iron making blast furnace. The program had financial support from Ministry of Steel under "Steel Development Fund" scheme. The project was taken up on a network mode with two steelmaking companies (SAIL and Tata Steel) as the beneficiaries of the outcome and academic institutes like IIT–Kharagpur, IIT-Bombay and IIT-Madras as collaborating partners. The blast furnace was divided into a few conceptual zones and appropriate process sub models were developed to characterize the various zones. The models include a Burden distribution model for bell less top charging system to predict trajectory of the material during fall, layer profile and radial distribution of voidage; Thermo-chemical model to calculate radial and axial distribution of temperature and composition of both solid and gas; Raceway model to provide gas temperature, composition and velocity distribution in two dimensions in the raceway and a Freezeline model to predict the location of the 1150°C isotherm in the hearth. Literature information, plant data and experimental results were initially utilized to validate the models and were subsequently tuned with operational data.The first version of the process models and the Real Time Process Simulator was installed at BF-5, Bokaro Steel Limited. NML's history of processing metal-containing wastes dates back to 1959 when NML developed and transferred

processes for extraction of Cu & Ni from Cu-Ni alloys and Zn from coinage alloys. Soon thereafter, in the early 60's, processes for recovery of metallic values from industrial brass dross and aluminium dross in 1962 and utilisation of ferromanganese slag was developed. The process of electrolytic recovery of tin from tinplate scrap was implemented at Tinplate Company of India Ltd in 1963.

The journey of coatings development at NML, since its origin in 1950 is a colourful and fascinating journey. The first coatings activity at NML was the electroplating of Ni, Cr, Cu and Ag on Al and its alloys and brass plating from non-cyanide bath in 1954 all of which were released to the industries. Cementing of Cu on mild steel wire by immersion was developed in 1959 for telegraph and transmission lines. These coatings showed no damage even after extruding the wires. Subsequently aluminizing of ferrous components at large scale to replace galvanizing remained a major activity for more than a decade. To enhance paint life, the process of phosphating of steel surfaces was developed in early 60's. In 1962, hard Cr coatings/ plating with 950-1100 Vicker's hardness was developed for automobile components (cylinder, brake, bearings). An improved immersion process was developed for the All India Handicraft Board to impart black and other colours on engraved surfaces for 'Bidar' vases of Mysore (1964). With the increased popularity of nano-materials, a variety of nano-composite coatings (Ni-B, Ni-P, Ni-P-Si, NiP-CeO2, TiB2, CN, SiCN, TiBC, TiSiBC,TiSiBCN, Al2O3-SiO2, Al2O3-TiB2, Fe-Al2O3) including graded and multilayer coatings on metal, super alloys, silicon surfaces for wear and corrosion resistance applications have been developed in recent times. Processes adopted include Electroless, Physical Vapour Deposition, Chemical Vapour Deposition, plasma & HVOPF and thermal spray. Water research at NML had a modest beginning in the late nineties when investigation on arsenic remediation for drinking water was taken up. Three different approaches i.e., low cost arsenic adsorbents, controlled aerial oxidation and bioremediation as well as oxidation by electro-flotation were adopted. NML undertook an exploratory groundwater quality survey of Sahebgunj district belonging to the then Bihar and presently Jharkhand. Subsequently, in 2007-08, NML in collaboration with UNICEF and Government of Jharkhand carried out complete groundwater quality mapping of Sahebgunj and Rajmahal blocks with reference to arsenic, fluoride, nitrate and iron. This was the first comprehensive mapping of its kind in this part of the country. A number of hot spots with regards to these parameters were identified and high arsenic tube wells were marked. The results were shared with Government of Jharkhand which served the basis for future remediation programmes.

A Subterranean Arsenic Removal (SAR) Technology was also developed by a consortium of European and Indian partners involving Queen's University Belfast, UK and NML, Jamshedpur in the early years of this millennium. An extensive database on naturally occurring minerals as water purifiers developed at NML is available in www.safewater.in. The design, development and fabrication of several furnaces both at laboratory and pilot scale as well as controllers of various kinds were initiated in the late fifties (1958) at NML for various useful applications. In the early 1960's, a platinum resistance furnace as well as a molybdenum wound furnace with special temperature controllers were developed at NML. Pilot scale horizontal and vertical reduction furnaces were also developed and fabricated at NML for the beneficiation of Ferruginous Manganese ores. During the same period, special electric furnaces such as multizone zig-zag silica tube furnace for chlorine heating (700-750^{0}C) for the production of anhydrous magnesium chloride were developed and fabricated. In 1966, NML developed and fabricated a graphite furnace having a hot zone dimension of 76dia x 280mm length with a power requirement only 24KW for 3000^{0}C temperature. An electron microscopy lab was established at NML and a TEM (Metro Vickers Co., U.K.) was installed in 1960 to study the newly developed steels and non-ferrous alloys. A finch type electron diffraction camera was also installed in 1961 for recording selected area electron diffraction patterns from samples. Selected area electron diffraction patterns from nickel free stainless steel was recorded and reported as early as 1963-64.

Although the history of mineral processing activities is six decades old, research on flotation reagents at NML is more recent. In search of a new methodology for flotation, studies on separation of complex ores were carried out at NML for developing

new reagents/reagents schemes for improved metallurgical performance. In collaboration with M/s Somu Organo-chem (P) Ltd., Bangalore, NML has developed innovative flotation reagents for beneficiation of coking coal and iron ore fines. These have been commercially adopted at M/S Jindal Steel Works, Bellary. Research on column flotation and electro-flotation was initiated at NML Madras Centre during mid-1980s as an alternative to conventional flotation technology, to treat finely disseminated low grade ores. An automated 3.0 inch dia laboratory column was developed first time in our country and extensively field tested in various mineral processing industries such as Hindustan Copper Ltd., Kudremukh Iron Ore Company Ltd., Hindustan Zinc Ltd., Gujarat Mineral Development Corporation Ltd., Bharath Gold Mines Ltd. Encouraged by the acceptance of the industry, a pilot scale column of 0.5m dia with necessary controls was developed and field tested in the on-stream conditions of various processing plants. This exercise has resulted in gaining the confidence of the flotation circuit operators as well as the management to establish columns for commercial operations. Presently, there are three columns in operation established by NML technology, namely, IREL, Chatrapur (150 tpd) and IREL, Chavara (150 tpd) for sillimanite beneficiation and Calpro Mineral Technologies India Private Ltd., Salem (150 tpd) for limestone beneficiation. For effective marketing and commercializing the technology, in the year 2008, NML has signed an MOU with M/s.McNally Bharat Engineering Co. Ltd., one of the leading engineering consultancy firms in our country. Under the agreement, a commercial flotation column (700 tpd) is being commissioned for M/s Indian Barytes and Chemicals Ltd., for beneficiation of low-grade barites at Mangampet, Cudappah, AP.

The first issue of 'NML Technical Journal', a quarterly publication, was launched in February 1959 to disseminate the results of R&D to the metallurgy community and the people at large. The Journal was renamed in January 2000 as 'Journal of Metallurgy and Materials Science'.

Industry-Orientation

During 2011-12, the shift in the laboratory's focus towards conducting industrial R&D started. The new vision of the laboratory surfaced, i.e., "to become a global leader and an internationally benchmarked laboratory in mineral and metallurgical research and development". The laboratory aimed to attain self-sustainability in the long run by enhancing industry-collaborative research and industrial ECF. This caused alignment of the internal ecosystem towards understanding the current and future needs of the industries and developing technologies hand-in-hand with the industry partners. The Public-Private Partnership model between Tata Steel and CSIR-NML became a grand success for the laboratory in the forthcoming years. Several projects for fundamental scientific Investigations, research towards industrial solutions, and new product/process development contributed to this success. For the statistics, nineteen collaborative research projects and many other R&D projects were initiated under this partnership. Until 2020, this count increased to more than 150 sponsored and collaborative projects. This mutual and synergistic collaboration was rewarding for both organizations. As a result, more than 40 joint patents and joint SCI publications were produced. Many projects were commercialized, and the joint project of making tiles from slag was revitalized. A protocol of ultrasonic NDT was developed and implemented to minimize spalling losses and the failure of rolls led to complete elimination of roll failures, the development of a palletisation process developed for LD steelmaking was adopted in Tata Steel, another joint project led to the development of improved as cooled rebars and the work on the development of plasma coating enabled Tata Steel to go for a 5000 tons/month plasma coated rebar plant. The iron-based IR thermography sorting device was commercialized. The second partner, Graphite Coated Steel's project, had won the prestigious Tata InnoVista Award in 2015, the first time a non-Tata partner company had received this award. Being a public funded laboratory, we aimed to develop industry-based technologies and to spread socially useful technology, science, generate employment through skills and training, and preserve traditional craftsmanship. Our relationship with Tata Steel over the last one and a half decades has been fruitful and productive for both. Two devices a) Zincometer- A sensing device for real-time Zinc coating weight measurement of steel wires in the galvanised line, and b) FOBOP - Fibre Optic based

Break Out Prediction technology for Billet Caster, were developed in collaboration with Tata Steel and are being commercialized as recently as 2024. The total number of collaborative products with industries to date is about 218, and our industrial external cash flow (ECF) on average makes up 50-60% of our total ECF.

Flagship Research and Development

During 2011-17, the 12th five-year plan projects were being executed at the laboratory, and three CSIR-flagship projects towards technology development in partnership with the relevant industries were ongoing. The activities included the development of technology for cold-rolled grain steel, the development of energy-efficient technology for magnesium, and dry beneficiation for coal. Development of technology for high-grade CRGO steel at a pilot scale, under which a pilot plant (3-5 tonnes) was proposed to be set up along with necessary melting, refining, strip casting, and hot/cold rolling facilities with annealing furnaces. MECON, as the Engineering Consultant, prepared the DPR of a 3 to 5 tonnes CRGO pilot plant. The detailed project report DPR on "CRGO Steel Pilot Plant was prepared and sent to the stakeholders for their approval. The project cost for "Plot Plant for development of Cold Rolled Grain Oriented (CRGO) Electrical Steel and other Value-Added products' was projected to be Rs 494.65 Crore. The High Value Hot Dip Galvanizing Simulator (HDPS) was set up at CSIR-NML with the joint initiative of Tata Steel and the Ministry of Steel for the development of high-grade steel. This enabled our activities for the development of advanced steel for the automobile, power, oil and gas, and nuclear industries in the country.

The mission project on "Development of Zero Waste Technology for Processing and Utilization of Thermal Coal taken up to develop a dry beneficiation technology for coal and for the gainful utilization of (for pavement blocks & tiles) and recovery of valuables from combustion products (cenospheres, rare/rare earth metals such as Ga, Se, Te, Gd, Nd, Sa etc.) was in progress. For the development of dry fixation technology for coal, a pallow sheet (of 150 kgs watch) at laboratory level for fine (22 mm) beneficiation from three coal blocks at Ukra, Gare, and Rajmahal and CIMFR Dhanbad was developed. A method of sorting chorus cole using a ray-based sorter was also developed. The dry beneficiation process flowsheet for high ash coarse coal had been developed, and an Eco-friendly large-scale process technology for Geopolymer cement from fly ash was developed for bulk utilization of fly ash, which incorporated the use in concrete, bricks and blocks. Geopolymerization technology for the combustion product (geopolymer cement from fly ash) was developed in partnership with Tata Power. The recovery of valuables from combustion products (cenospheres, rare/rare earth metals such as Ga, Se, Te, Gd, Nd, Sa etc. So far, the recovery of cenosphere through processing of fly ash sample and dry separation and the investigation on the recovery of rare metal were underway.

In 2018-19, the national mission programme on Advanced Ultra Super Critical (AUSC) Power Plant Technology, coordinated by IGCAR, Kalpakkam, started having CSIR-NML as one of the major research partners. In this programme, CSIR-NML was executing four projects addressing materials qualification and NDT protocols. Additionally, and in the same theme, three research projects, Creep-fatigue interaction behavior of ODS- austenitic steels and ODS-iron and nickel aluminides, Development of Advanced NDE based Diagnosis and Prognosis Protocols for AUSC Power Plants, High Temperature Oxidation and Hot Corrosion behavior of selected materials for Clean Coal Technologies for Power Plant Applications, were also initiated. creation of a National Centre for Development of Advanced Materials and Manufacturing Processes for Clean Coal Technologies for Power Applications was also undertaken. The laboratory was also pursuing a pilot-scale project to develop Amorphous electrical steel for energy applications. The latter projects were sponsored by DST, with ARCI, Hyderabad, as the coordinating organization. The first pilot plant in the country for amorphous steel production, for use in transformers and other applications, was planned to be set up soon by CSIR-NML, through funding provided by the Ministry of Steel. CSIR-NML developed a technology for the production of DRI from mill scale and lean grade coal in Tunnel Kiln by using iron ore fines and non-coking coal. To date, no process has been developed to utilize mill scale and lean grade coal for the production of DRI in the

Tunnel Kiln without pre-induration of pellets. CSIR-NML also provided consultancy on setting up the first pilot plant for sodium production.

In the shadows of the Pandemic in 2019-20, the economic growth around the world, as well as in India, was low, R&D investments were consequently muted. It was a year, when three of our dear colleagues left us forever. However, some of other impactful accomplishments of this duration were: Development of a Smart Sensing System for Cold Drawn High End Wires, Self-healing Coating for Corrosion Protection of Steel and Aluminium Alloys, Annealing simulator integrated with online process control sensors for run out table process simulation, Scale up and commercialization of indigenously developed hydrogen We have also been able to mark our presence in the area of E-waste management. As a part of this initiative, several processes and technologies were developed at CSIR-NML and commercialized to the industries, including MSMEs. The technologies included: Know-how for the extraction of precious metals (Au, Pt and Pd) from the metallic concentrate of PC-PCBs. Several projects have been carried out and processes developed in the matters of recovery of Germanium as metal/ salts from secondary resources, Graphene based membranes from Graphite ore for desalination, feasibility studies on recovery of barite from drilling mud by flotation, development and transfer of a technology for the production of electrolytic zinc powder from zinc dross and development of high strength Zn-based biodegradable alloys for orthopedic applications. We started the first of its kind, urban ore recycling centre in the country. CSIR-NML, through the establishment of an "Urban ore recycling centre" and a proliferation of activities on e-waste utilization, has emerged as possibly the most comprehensive laboratory in industrial waste utilization. The focus is now on the extraction of Rare Earths from all possible sources, to replenish the mushrooming needs for these elements for critical applications. A few ambitious projects ongoing in this area are: Recycling of graphite from spent lithium-ion batteries for high-energy Li-ion capacitors, Extraction of Cu, Al, and Au from waste PCBs, Recycling of lithium-ion batteries (LIBs) to recover valuable metals/ materials.

The need to use secondary and tertiary resources, including industrial wastes, is a top priority for our country, given the severe shortage of primary resources for several strategic metals. In 2022, NITIAYOG had instructed the creation of a consortium of three research institutes and three industrial organizations to collaborate and arrive at a holistic solution for red mud, with emphasis on Rare Earths recovery. CSIR-NML is the nodal laboratory coordinating this effort. The collaboration with Hindalco, Nalco, and Vedanta, as industrial partners, and CSIR-IMMT and JNARDDC, as research partners, has been formalised and activities initiated. This marks the first large scale collaborative effort on holistic utilization of red mud. The urban ore recycling centre created at CSIR-NML, has been instrumental in developing a number of technologies and at present is flooded with requests for either technology transfer or collaborations, from multiple entities across the country. A CSIR mission on "Bulk Chemicals" had identified NML as the nodal laboratory for developing Li extraction technology from end-of-life batteries. In 2021-22, CSIR-NML developed CSIR's first complete and holistic TRL-4 process for the extraction and separation of Lithium, Nickel, Cobalt, Manganese, Iron, Aluminum, Copper, and for the recovery of graphite from spent Lithium batteries of mixed origin. The pilot plant, slated to be commissioned at CSIR-NML the first of its kind Hire-Operate-Transfer (HOT) platform for MSMEs and entrepreneurs in India. Installation and commissioning of 200 tonnes per day flotation column for fine coal flotation at Belatinda Coal Preparation Plant of Tata Steel, using CSIR-NML's column flotation technology, and Industry scale trials (5 tonnes per hour) of the newly developed environment friendly flotation reagent for sillimanite is in progress at Kerala Minerals and Metals were done. The processes to reduce mineral matter in coking and non-coking coals through oil agglomeration were developed through two R&D projects sponsored by Coal India (CIL) and Mahanadi Coalfields (MCL). Three technologies were developed in the reporting year and five technologies were transferred. One technology developed by CISR-NML has been selected as a finalist in the prestigious Tata Group Innovista awards (Innovative partner category). As of 2024, the ongoing mission mode activities under this

area are: Technology development for extraction of critical metals (niobium, tantalum, scandium) from secondary resources/potential wastes, Extraction of Vanadium as High Pure V2O5 & Ni-Salts from Pet-Coke/Coal Gasification Cinders. standard in steel, and others, Recovery of Metal Values from Spent Lithium Ion Batteries and Fabrication of New Lithium Ion Batteries [A Circular Economy Approach-Battery to Battery (B2B)], Development of Process for Large Scale Production of Electrolytic Mn Metal (EMM) from $MnSO_4$ Liquors and Technology development for holistic utilization of Red Mud for extraction of metallic values & residue utilization in collaboration with Vedanta, Hindalco, NALCO, IMMT, and JNARDDC.

Around 2020-21, the development of biodegradable Mg and Zn-based alloys for orthopedic implants with the required mechanical strength was completed, with an industrial sponsorship. In the areas of mineral processing, advanced gravity concentration of tailings of chromite beneficiation plants was carried out, and concentrate with an assay of 40% Cr_2O_3 was produced, and around 32 % of chromite was recovered. Studies on the beneficiation of low-grade manganese ore samples, involving gravity, magnetic, and reduction-roasting, were carried out, and a process route for upgrading low-grade manganese ore for application in the production of ferro-manganese was developed. In 2021-22, CSIR-NML, in association with an engineering partner, successfully installed and commissioned a 200 tons per day flotation column for fine coal flotation at Belatinda Coal Preparation Plant. Pilot plant scale trials (1 ton per hour) of newly developed environment-friendly flotation reagents for limestone beneficiation at M/s Vedam Calcimin, Telangana, were conducted. One important activity, accounting for significant ECF for the laboratory, evolved to be the Coal Core Analysis. Almost 15000 refereed samples and 5000 band-by-band coal core samples are continuing to be analyzed annually. For the last six decades, CSIR-NML has been contributing to Magnesium Metal R&D and piloting it with a capacity of 250-500 Tonnes Per Annum plant at Jamshedpur. CSIR-NML has been actively engaged in pyrometallurgical routes based on the silicothermic reduction of calcined dolomite. Over the last 10 years, a knowledge base for Mg extraction using its Pidgeon/Retort process was established, in which a single retort prototype for 14-15 kg feed/charge and 2.5-3.0 kg Mg metal was being successfully developed. The vacuum distillation-based Mg-refining process was also developed at a 1.5 kg scale for refining of commercial Mg and its scrap. Presently, the scale-up activity for vacuum distillation is continued to establish process technology at a 5-6 kg scale in semi-continuous mode. Piloting activities for commercial-grade high-purity magnesium metal from Indian dolomite resources have been further initiated. The proposed pilot plant is designed for 120-150 kg Mg metal/day with ~2 TPD feed of dolomite. The pilot plant is designed with NML's retort technology (improved Pidgeon Process) and continuous vacuum distillation refining technology, and a slag valorization facility. Under the pilot-plant facility, there would be three primary components (a) Raw material preparation, which comprises sizing, calcination, grinding and briquetting, (b) reduction-vacuum distillation, which will include retort-based reduction of briquettes and refining of Mg crowns, (c) Vacuum-casting facilities for refined magnesium. The end product targeted is Commercial Mg metal of ASTM B92 9980 (~99.8%) and high-purity Mg (>99.95%). DPR preparation for commercialization is to be taken up as follow-up activities for piloting the extraction and refining at 120 kg /day metal output towards commercialization. The pilot scale data would help design strategies for the commercialization of primary and refined magnesium technologies.

Contribution to Strategic Sectors

CSIR-NML made several contributions to the strategic sectors. In the fiscal 2016-17, a project on Gadolinium extraction by fused salt electrolysis, supported by the Department of Atomic Energy, was initiated, and proof of concept was demonstrated. CSIR-NML's research and developments on tungsten extraction from scraps, which have resulted in several technology commercializations, were complemented by the Defence Research and Development Organization-sponsored project on Tungsten recovery from low-grade tailings. The development of geopolymer cement for immobilization of radioactive waste was done, and 100 kg of cylinder samples were prepared and supplied to BARC for evaluation. The failure analysis

of critical assets of the Air Force and other defence organizations continues to be pursued. During 2001-2024, around 80 failure investigation activities were undertaken by CSIR-NML for the Indian Air Force. An umbrella agreement was signed between IAF and CSIR-NML in 2020 for enhancing cooperation and promotion of R&D in the area of mutual interest. Several materials evaluation studies were in progress for nuclear power plants. In 2020, a project on the Destructive test and Analysis for establishing Life Estimation Matrix (LEM) for Vikramaditya Boiler Tubes for the Central Boiler Inspection Unit, Mumbai, Indian Navy was undertaken. CSIR-NML is involved in qualifying materials and components in use for the aircraft carrier Vikramaditya as well. An important strategic development was a technology for on-board spacecraft life detection, for which the device Electronic Package for ultrasonic Flow Meter was fabricated and delivered for testing in early 2021-22. It is currently implemented and utilized at LPSC-ISRO. In niche research for the Indian space programme, the effect of processing parameters on cryo impact properties of cast alloys was carried out. CISR-NML also generated a forming limit diagram (FLD) of welded and non-welded aluminium sheets for space applications. We also completed material analysis and reclamation of gas collectors for INS Ekshila. Various RLA studies, failure investigations, and root cause analyses were carried out for diverse sectors, including Railways, Petrochemicals, Chemicals, Power, and other sectors. SAIL has entrusted CISR-NML with the assessment of the corrosion behaviour of different rail steels, taking into consideration the operating environments.

Contributions to Society

Connecting society at all levels and generating scientific awareness in society has always remained a priority for the organization. In this connection, the laboratory participated in a number of programs like: School-NML Interaction Program(SNIP) and Jigyasa. Under the GOI's mission "Skill India", the CSIR-Integrated Skill Initiative program has endeavoured to train people in different areas. In the reporting period, more than 300 people were trained in metals, metallurgy, manufacturing, waste utilization, soft skills, and entrepreneurship. Under the DST project "Women Technology Park (WTP)". We have undertaken project on developing a Detailed project report (DPR) on common facility centre for silver cluster of West Bengal. Based upon the inputs of Industrial Development Officer (IDO) of District Industry Centre (DIC), artisans, site survey, and discussion with vendors at their site, the intended Detailed Project Report (DPR) has been prepared which contains the basic details of the cluster, benchmark survey, proposed business model, machinery required, bill of quantity for civil estimation, commercial viability and demand and scope for diversification."Brass Melting Furnace", which had several advantages over the in-use furnaces including increased productivity and lower pollution, has penetrated into the masses. This dissemination has been spearheaded by the MIDCO, Moradabad, and has received favourable and popular mention in the media. CSIR-NML continued its substantial activities in structural health monitoring, values additions to metallurgical processes wastes and electronic wastes, beneficiation from and extraction from lean ores, technological intermediations and solution provisions to industries.We have undertaken project on developing Detailed project report (DPR) on common facility center for silver cluster of West Bengal, the intended Detailed Project Report (DPR) has been prepared. The project "Science Technology and innovation Hub" in village Gamharia, Saraikela Kharsawan block, West Singhbhum District, Jharkhand State aims to improve the livelihood of the ST community in the Gamharia village by technological intervention. Different skill-based and entrepreneurship development-based trainings will be provided to the targeted community by XITE and CSIR-NML. Under the Skill India Initiative Societal Training Program, Professional Training Program, Corporate Training Program and Others Training Program a total of 3578 individuals were trained between 2021- 25. Under the Jigyasa 2.0 program 6310 students were trained between 2021-25.

Looking forward, NML aims to advance cutting-edge solutions in clean energy, smart materials, and circular economy practices to meet global challenges. By fostering industry collaborations and nurturing scientific talent, NML is poised to lead India's metallurgical innovation for decades to come.

“Excellence is a continuous process and not an Accident”.

APJ Abdul Kalam

Platinum Jubilee Celebration-Messages

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Message

On this landmark occasion of the National Metallurgical Laboratory's 75th anniversary, I am privileged to congratulate NML and everyone who has contributed to its extraordinary journey over the decades. This milestone represents not only a celebration of past achievements but also a moment to reflect on the institution's pivotal role in shaping India's technological and industrial future.

The establishment of NML was driven by a vision to transform India from an agrarian economy into a global leader in technology and innovation. Over the years, NML has become a centre of excellence, advancing metallurgical science and contributing significantly to the nation's economic progress. Today, the laboratory stands as a shining example of the foresight of luminaries like Dr. Shanti Swarup Bhatnagar, whose vision continues to inspire its mission.

The expertise and innovations developed by NML over the last 75 years have not only strengthened India's industrial capabilities but have also positioned the institution as a critical player in addressing the challenges of an evolving global landscape. As the world reorganizes supply chains and nations strive for greater self-reliance, NML's work is key to enabling India to emerge stronger, resilient, and ready to lead.

Looking ahead, the next 25 years will undoubtedly present new opportunities and challenges. I am confident that NML's dedicated team, under the leadership of Dr. Ghosh Chaudhary and supported by its collaborators, will continue to drive India's progress and prove our nation's mettle on the global stage.

Congratulations once again to the NML team on this remarkable milestone. May the 75th anniversary year inspire even greater achievements and strengthen your role as a cornerstone of India's technological advancement.

Yours sincerely,

Anand G. Mahindra
Chairman
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Message

I am glad to know that CSIR-National Metallurgical Laboratory (NML) , Jamshedpur is celebrating its Platinum Jubilee and a commemorative Annual Report is also being brought out on the occasion.

In recent times, CSIR-NML has spread its research horizons in Iron & Steel Making, Critical Metals Extraction, Urban Ore Recycling, Green Steel, Waste Valorization, Microstructural Engineering, Sensor & Devices, Minerals Processing, Advanced Materials & Corrosion, Coal Analysis, Materials Mechanics and Non-Destructive Evaluation. CSIR-NML continues to provide scientific solutions to industries in minerals, metals, and materials. The institution has also undertaken programs that have helped promoting the skill development and women entrepreneurship in the country.

It is remarkable how the CSIR-NML through its 75 years of journey has played a pivotal role in metallurgical research in the country. Looking at its history, one can marvel at the achievements this institute has, from lean grade ore beneficiation to extraction of iron and steel and from characterization of mineral and metals to processing of non-ferrous metals such as magnesium, lithium, nickel and cobalt. CSIR-NML is successfully executing projects related to extraction of various elements from secondary resources for rare earth elements extraction and utilization. CSIR-NML has been playing a pivotal role on new steel grades development in collaboration with Indian Steel Industries. This lab has become a HUB for the evaluation of high temperature mechanical properties of various high temperature materials which is critical for nation's effort in the area of defence and atomic enerw.

I feel that this institute has a more important role to play in the coming days in developing and piloting indigenous technology for critical metal and rare earth extraction as well as import substitution of various metallic alloys/ processes for self-reliant India.

I wish the Platinum Jubilee celebration a grand success.

New Delhi
12.03.2025

Dr. V.K.Saraswat

अमरेन्दु प्रकाश
अध्यक्ष
AMARENDU PRAKASH
Chairman

स्टील अथॉरिटी ऑफ इण्डिया लिमिटेड
STEEL AUTHORITY OF INDIA LIMITED

Message

CSIR-National Metallurgical Laboratory (CSIR-NML) is celebrating the platinum jubilee of its spectacular R&D journey. It is the right juncture for reflecting upon the contributions and achievements of this laboratory in Iron & Steel Making, Critical Metals Extraction, Urban Ore Recycling, Green Steel, Waste Valorization, Microstructural Engineering, Sensor & Devices, Minerals Processing, Advanced Materials & Corrosion, Coal Analysis, Materials Mechanics and Non-Destructive Evaluation.

The R&D of the laboratory is inclined towards industry-oriented research. It is strategically established next to the steel giant Tata Steel and in the mineral-belt of India. The laboratory has been engaged in a number of mission-oriented research and development projects as well.

The laboratory has a legacy of excellence in its core area of research and adapting to the needs of the country while providing technological solutions for the new age and futuristic industry problems. The laboratory follows a collaborative model in which the industries are major stakeholders in the development, implementation and commercialisation of the technologies in higher TRLs. The laboratory is also exploring newer research horizons like Internet of Things (IOT) and Artificial Intelligence (AI).

The Platinum Jubilee CSIR-NML Annual Report is informative and having rich content as it treasures the achievements of last 75 years of a national laboratory of significance.

On this momentous occasion I congratulate CSIR-NML for being one of the pioneers in the country and completing 75 years of remarkable service to the nation by science & technology.

I wish the laboratory success in its endeavours for the next 100 years to come.

Amarnendu Prakash
Chairman, Steel Authority of India, New Delhi

स्टील अथॉरिटी ऑफ इण्डिया लिमिटेड, इस्पात भवन, लोधी रोड, नई दिल्ली 110 003, दूरभाष : (011) 2436 7282, 2436 8094 फैक्स : (011) 2436 5051 ई-मेल : chairman.sail@sail.in
Steel Authority of India Limited, Ispat Bhawan, Lodhi Road, New Delhi 110 003, Phone : (011) 2436 7282, 2436 8094 Fax : (011) 24365051 E-mail : chairman.sail@sail.in
PAN No. AAACS7062F Corporate Identity Number : L27109DL1973GOI006454

सत्यमेव जयते

डॉ. आर बालमुरलीकृष्णन
उत्कृष्ट बैज्ञानिक एवं निदेशक
Dr R Balamuralikrishnan
Outstanding Scientist & Director

भारत सरकार, रक्षा मंत्रालय
Government of India, Ministry of Defence
रक्षा अनुसंधान तथा विकास संगठन
Defence Research & Development Organisation
रक्षा धातुकर्मीय अनुसंधान प्रयोगशाला
DEFENCE METALLURGICAL RESEARCH LABORATORY
कंचनबाग डाकघर, हैदराबाद – 500058
Kanchanbagh, Hyderabad - 500058

Dt.07 Feb 2025

Message

On the occasion of the Platinum Jubilee celebrations of CSIR-NML and the release of its Annual Report, I would like to extend my warmest congratulations to CSIR-NML for reaching this significant milestone completing 75 years of excellence in metallurgy and materials science.

It is truly inspiring to witness the remarkable contributions of CSIR-NML in advancing the field of metallurgy, particularly its pivotal role in supporting India's industrial growth. The commitment to innovation, research, and collaboration has not only strengthened national capabilities but also created lasting impact in areas critical to industrial development, including steel technology, advanced materials, and sustainability.

As fellow researchers and professionals working towards strengthening India's technological and defense capabilities, we at DMRL deeply value the collaborative spirit shared by our sister institutions. The strides made by CSIR-NML continue to motivate and guide our own pursuits in defense metallurgy, and we look forward to future opportunities to exchange knowledge and ideas to further our shared goals.

We commend CSIR-NML for its inspiring legacy, and we are confident that its future will continue to shine bright with innovation and excellence. We extend our heartfelt best wishes for continued success and growth in the years to come.

07/02/25

Dr. R. Balamuralikrishnan
OS & Director, DMRL

Tele: (Off.) +91-40-24340681, +91-40-24340233, Fax: +91-40-24340080, (Res.) +91-40-24072186
E-mail: director.dmrl@gov.in

Chaitanya Bhanu
Vice President
Operations Tata Steel, Jamshedpur

Message

I am glad to know that National Metallurgical Laboratory (NML) is celebrating its platinum Jubilee Year. In its existence over the last 75 years, it has established itself as a pre-eminent Research Lab in the area of Metallurgy, materials, mining and allied fields. Today apart from conventional areas of research the lab is active in Critical Metals, E-waste re-cycling and greener technologies with lower CO^2 footprint.

Both Tata Steel and NML have had a long symbiotic relationship leading to many collaborative projects. Many of them have benefited Tata Steel and the steel industry in general. I am happy to be a part of the Research Council of NML in this exciting period where the Government of India is pushing for development of indigenous Research and Technology in areas of interest for the nation.

I am confident that NML with a rich history & tradition behind it, will continue to foster talent and cutting-edge Research for many years to come.

I wish the NML family, both past & present my heartfelt wishes in its 75th year.

Chaitanya Bhanu

TATA STEEL LIMITED
Jamshedpur 831 001 India
Registered Office Bombay House 24 Homi Mody Street Fort Mumbai 400 001
Tel 91 22 66658282 Tel 91 657 2431072 6645718 e-mail chaitanya.bhanu@tatasteel.com
Corporate Identity Number L27100MH1907PLC000260 Website www.tatasteel.com

Message

I am honoured to be part of NML-CSIR family in celebration of a yearlong Platinum jubilee

It is a matter of pride that National Metallurgical Laboratory (NML) established on 26th November, 1950 has made significant contribution to the Nation in the area of extractive metallurgy, Lean Ore Processing, Comprehensive Mineral Processing, Valorisation of Industrial Wastes, Extraction of Critical Metals, Alloys Development, Advanced Materials Characterization and Evaluation, NDE and Structural Health Monitoring, Corrosion Protection, Advanced Coatings, Functional Materials and Coal Research.

On this occasion I congratulate entire NML family for making significant contribution in the industrial revolution of India starting from 1950, especially in the areas of mineral processing, iron and steel making, ferroalloys and extraction of non-ferrous metals, notably magnesium. Asia's largest creep testing facility was also set up at CSIR-NML in the early 1970s.

Since inception, CSIR- NML has diversified its research areas ranging from extractive metallurgy, alloy development and import substitution, refractory material development, corrosion studies, mathematical and physical modelling of metallurgical processes, mineral research, advanced materials and materials tailoring, integrity evaluation of critical industrial components, surface engineering and cleaner and sustainable metals production. The Laboratory has also made notable contributions in the areas of mineral beneficiation and agglomeration, ferrous and nonferrous metallurgy, alloy development and processing, materials science & engineering and, resource conservation & environment.

I am confident that under the visionary leadership of Dr. Sandip Ghosh Chowdhury, NML will meet the challenges of the global economy and develop Indigenous Technologies for Viksit Bharat. I wish the celebration of Platinum Jubilee year a grand success.

Jai Hind

25 February 2025

Dr. S. K. Jha
Former C&MD
Mishra Dhatu Nigam Ltd,
Hyderabad

Message

CSIR-National Metallurgical Laboratory (CSIR-NML) is celebrating the platinum jubilee of its spectacular R&D journey. It is the right juncture for reflecting upon the contributions and achievements of this laboratory in Iron & Steel Making, Critical Metals Extraction, Urban Ore Recycling, Green Steel, Waste Valorization, Microstructural Engineering, Sensor & Devices, Minerals Processing, Advanced Materials & Corrosion, Coal Analysis, Materials Mechanics and Non-Destructive Evaluation.

The R&D of the laboratory is inclined towards industry-oriented research. It is strategically established next to the steel giant Tata Steel and in the mineral-belt of India. The laboratory has been engaged in a number of mission-oriented research and development projects as well.

The laboratory has a legacy of excellence in its core area of research and adapting to the needs of the country while providing technological solutions for the new age and futuristic industry problems. The laboratory follows a collaborative model in which the industries are major stakeholders in the development, implementation and commercialisation of the technologies in higher TRLs. The laboratory is also exploring newer research horizons like Internet of Things (IOT) and Artificial Intelligence (AI).

The Platinum Jubilee CSIR-NML Annual Report is informative and having rich content as it treasures the achievements of last 75 years of a national laboratory of significance.

On this momentous occasion I congratulate CSIR-NML for being one of the pioneers in the country and completing 75 years of remarkable service to the nation by science & technology. I wish the laboratory success in its endeavours for the next 100 years to come.

February 07, 2025

Ms. Sukla Mistry
Director (Refineries)
Indian Oil Corporation Limited
New Delhi

Message

As a member of the Research Council, I am delighted to congratulate the CSIR-National Metallurgical Laboratory (NML) on its remarkable achievement of reaching the glorious 75th anniversary. Over the decades, the NML has been at the forefront of the metallurgical research and innovation, making invaluable contributions to the growth of India's industry and technological progress.

The Platinum Jubilee celebration highlights the laboratory's unwavering commitment to pioneering research and innovation, and its role in shaping the future of metallurgical sciences. It is truly inspiring to see the NML's dedication to fostering scientific excellence and nurturing the next generation of researchers and engineers.

As we reflect on this extraordinary journey, let us look ahead with optimism, working together to push the boundaries of science and technology for the betterment of the society.

Once again, heartfelt congratulations to the entire NML team on reaching this incredible milestone.

12 February 2025

Professor Karabi Das
Professor & Dean (Outreach)
Member, Board of Governors
Indian Institute of Technology Kharagpur

सी एस आई आर - राष्ट्रीय भूभौतिकीय अनुसंधान संस्थान
(वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद)
पो.ब. सं. 724, उप्पल रोड, हैदराबाद - 500 007, तेलंगाना, भारत
CSIR - NATIONAL GEOPHYSICAL RESEARCH INSTITUTE
(Council of Scientific & Industrial Research)
P.B. No. 724, Uppal Road, Hyderabad - 500 007, Telangana, INDIA

डॉ. प्रकाश कुमार,
एफ.एन.ए. एससीए एफ टी ए एस
निदेशक
Dr. Prakah Kumar, FNASc, FTAS
Director

28th March 2025

Message

CSIR- National Metallurgical Laboratory (NML) Celebrates Its Platinum Jubilee

The Platinum Jubilee of CSIR-NML is a momentous occasion that fills us with pride, not only for the laboratory but for the entire CSIR community. This milestone is a reminder of the laboratory's founding mission — to drive the development of industries in metals, minerals, materials, and mining. Over the years, CSIR-NML has steadfastly fulfilled this mission, making invaluable contributions to the technological progress of these sectors.

As a pioneer in its field, CSIR-NML boasts a rich legacy of research and development spanning more than 75 years. Its exceptional achievements in areas like Iron & Steel Making, Minerals Processing, and Microstructural Characterization stand as a testament to its expertise and commitment. Beyond its historical accomplishments, the laboratory continues to play a critical role in addressing contemporary and future challenges. Its ongoing research in areas such as Critical Metals Extraction, Urban Ore Recycling, Green Steel, Waste Valorization, Sensors & Devices, and Advanced Materials is vital for the country's growth and sustainability.

In celebration of this special occasion, CSIR-NML proudly presents its Platinum Jubilee Annual Report for 2024-25. This report will undoubtedly showcase the laboratory's remarkable achievements and offer a glimpse into its future endeavors. As a member of the Research Council, I extend my heartfelt congratulations to CSIR-NML and wish the team continued success in all its future initiatives. The strength and potential of Team NML are truly inspiring, and I am confident they will continue to excel in the years ahead.

Congratulations once again on reaching this incredible milestone!

28/3/2025

Prakash Kumar

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वेब साइट / Website: www.ngri.res.in
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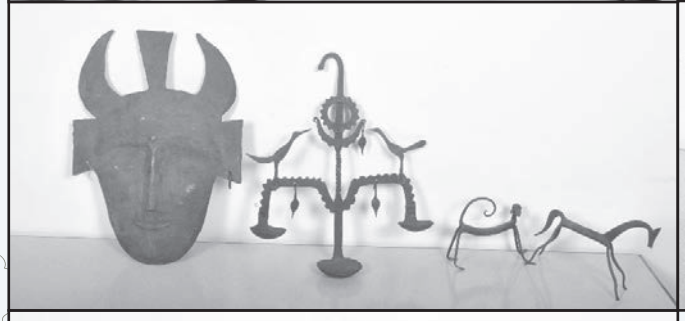
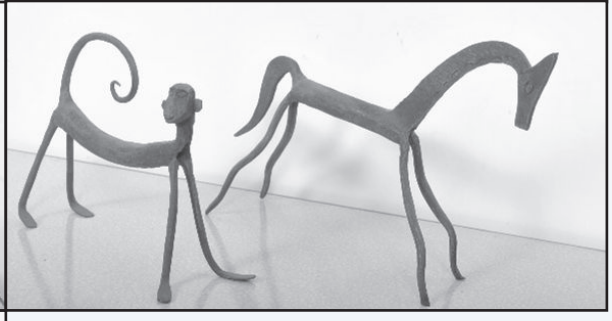
Enabling Artisanal Technology





From agricultural implants to art objects through improved blacksmithy and furnace design and more ...

Performance Targets Achieved in 2024 - 2025

Sl No	Objectives	Planned	Achieved
1.	Total External Cash Flow (ECF)	30.0 Crores	**20.13 Crores**
2.	Industrial ECF (a part of ECF)^	16.0 Crores	**14.62 Crores**
3.	Customer Satisfaction Index	4.8 (Max 5)	**4.8**
4.	SCI Publications	140	**159**
5.	Non-SCI Publication	-	**25**
6.	Patents Filed Industrial Designs	10 -	**6** **1**
7.	Copyrights	5	**1**
8.	Technologies Developed*	5	**5**
9.	Technologies Transferred#	5	**5**

Cash flow generated from sponsored projects of industrial, PSU and government agencies.

* Technologies Developed:

1. Magnetoimpedance (MI) based array sensing device for detection of carburisation and defective welds: MagRays (Technology Readiness Level- 7)
2. An improved hot dip coating process (Technology Readiness Level- 6)
3. Colorized galvanizing coated steel products and their process (Technology Readiness Level- 6)
4. Recovery of Zinc as the valuable product (Zinc sulfate monohydrate/zinc carbonate/zinc/metal) from lean grade zinc dross (Technology Readiness *Level- 9)*
5. *Cost-effective hot-rolled steel with ultrahigh strength and excellent toughness (Technology Readiness Level- 5)*

Technologies Transferred:

1. Know-how for the development of Ti3AlC2 MAX phase ; Licensed to M/s. Global Nanotech, Goregaon
2. Know-how for the development of Magneto impedance-based array sensing device for detection of carburization and defective welds- MagRays; Licensed to M/s. Accelor Microsystems, Chandigarh
3. Process flow-sheet for production of self-healing coating and primer suitable for application on rusted steel; Licensed to M/s. Asianol, Kolkata
4. A pyro-hydrometallurgical process for holistic recycling of variable zinc dross, high and low grade, to recover zinc metal and its salts; Licensed to M/s. Chandigarh Technologies, Haryana
5. Know-How to recover saleable products of Cu, Al, and Au as Metals/ salts from waste PCBs, Licensed to M/s. Eyantram Waste Management Private Limited, Bangalore

Major Technological & Scientific Targets Planned and Achieved in 2024-2025

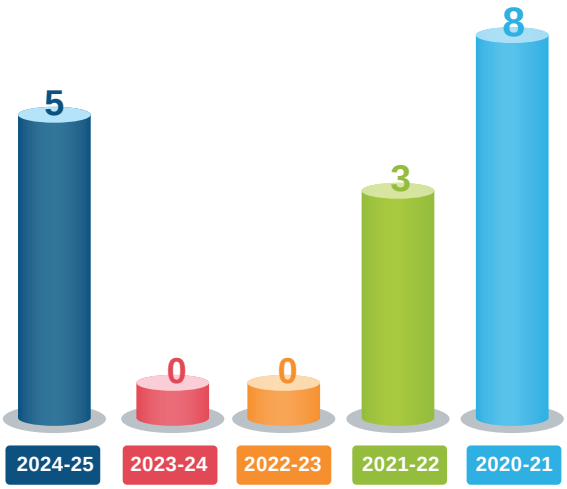
Planned for 2024-2025	Achieved in 2024-2025
Applied & Analytical Chemistry	
Coking coal assessment through Artificial Intelligence	The respective project has been approved by Coal India Ltd, and the project work is in progress.
Direct regeneration of spent LIBs cathode material and reuse in energy storage device	The development of the process is almost complete. One SCI publication in progress.
Coal characterization and analysis	A large number of Coal sample characterizations and analyses have been done for various industries and subsidiaries of Coal India Ltd. In the past fiscal and, the activity is ongoing.
Ceramic primer for rusted steel.	Technology has been developed and transferred to M/s. Asianol BioTech, Kolkata.
Development of different grades of coal CRMs of Indian coals.	Three Grades (G10, G13 & Steel Grades) of Coal CRMs (In a lot of approx. 700 bottles of 50 gm pack size of each CRM) have been developed based on the Indian coal base.
Development of eight grades of Indigenous iron ore CRMs from 40% Fe to 67% Fe for XRF analysis.	The development of eight grades of Indigenous Iron Ore CRMs from 40% Fe to 67% Fe for XRF analysis has almost been completed. In progress.
Development of different grades of Bauxite and Dolomite CRMs.	Half of the development work has been completed, related to the CRMs for Bauxite & Dolomite. In progress.
Development of 6063 grade Al disc standard (500Nos.)	Most of the work has been completed, related to the development of the 6063 grade Al disc standard (500 Nos.). In progress.
Development of two different grade Pb base disc CRMs (500Nos. of each grade).	Half of the work has been completed, related to the development of two different grades of Pb base disc CRMs (500 Nos. of each grade). In progress.
Development of four different grade Chromite ore CRMs (200Nos. of each grade).	Four CRMs 181, 182, 183 & 184 (In a lot of 200 bottles of 100gm pack of each CRM) have been prepared.
Development of an alternate reagent for the elimination of mercury effect for reliable analysis of Hg in coal and coal fly ash samples.	The undesirable "Memory effect" for the analysis of Hg in the ICP system can be eliminated by the addition of Au in the rinsing solution. However, the application of gold is expensive and not practically feasible for commercial laboratories. In the current study, we have successfully evaluated and proposed L-cysteine as a low-cost additive reagent to minimize the memory effect, without compromising the desirable analytical characteristics for the analysis of Hg in coal samples.

Materials Evaluation	
Powder production for additive manufacturing: Steels and Amorphous alloys	Achieved
Scaling up of armour steel to achieve (TRL-7)	In progress
Metals Extraction & Recycling	
Pidgeon process for the production of magnesium metal.	Production from prototype equipment has been done at 2kg/ batch scale.
Critical metals from the primary and secondary resources under Mapping & Tapping of Critical Minerals mission of CSIR	Three projects were started under this mission of the CSIR. Currently, initial studies are ongoing.
Development of self-healing geopolymer under CSIR first scheme	One project on self-healing geopolymer was sanctioned under the CSIR First scheme and is ongoing.
Development of technology for Extraction of zinc metal and salts from zinc dross.	Technology developed and transferred to M/s Chandigarh Chemicals.
Mineral Processing	
Development of process for beneficiation of lean grade iron ore having less than 45% Fe content	Achieved as per plan (Ministry of Steel granted the project)
Recovery of lithium concentrate & other critical minerals from Lithium ore of Jharkhand	In Progress. Discussions are ongoing.
Bench Scale Beneficiation and Pelletization Studies of Iron Ore Samples from ISMQ, Egypt.	In Progress. Discussions are ongoing.
Extraction of vanadium as high pure V_2O_5 and TiO_2 from Vanadium titaniferrous magnetite ore	The proposal was submitted to the CSIR Critical Mineral Mission but could not be approved
Beneficiation and palletisation on tailing from Kiriburu mines, Meghatuburu mines and composite sample of both tailings	Participated in the tender, but the tender was cancelled by SAIL
Advanced Materials & Corrosion	
Commercialization of Billet Mould Break-out detection Technology.	Transferred to Industry.
Implementation of LTCC based eddy current sensor for real time creep damage monitoring in one of the power plant components.	In progress
Implementation of AI based technology for thermal mapping of downcomer of pellet plant in a steel plant.	Project is completed and deliverables are achieved
Performance evaluation of Ultrasonic Flowmeter in the space environment.	In progress
Establishment of Ultrasonic imaging technique to assess the quality of connecting rods of Tata Cummins.	Project is completed and deliverables are achieved
Design, fabrication and transfer of Binder Gauge device.	Project is completed and deliverables are achieved

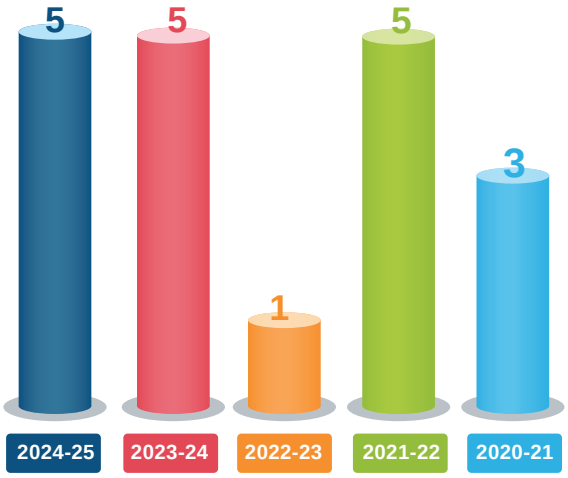
Set up development for 3.5 cm X 3.5 cm and 5 cm X 5 cm AEM alkaline electrolyser cell for green hydrogen	Developed 3cm X 3cm cm AEM alkaline electrolyser sell for green hydrogen.
Development of biodegradable Zn-alloys for implant applications	Biodegradable Zn alloys developed
Development of multilayer Zn coated high strength Mg-based biodegradable alloys	Multilayer Zn coated high strength Mg-based biodegradable alloys developed
Design and development of Iron amorphous alloy powders for thermal spray coatings.	In Progress
Fe-Nitride powders for hard magnets through Ammonia gas nitriding route.	In Progress
Application of GMI based sensor "MagRays" in structural integrity assessment of components in cement industry	Technology on GMI based sensor "MagRays" developed and transferred to Accelor Microsystems, Mohali, Punjab
Development of working prototype of Planar flow Castor (5kg) for producing thin metallic strips.	Working prototype of planar flow Castor (5kg) is developed
Development of ferrochrome slag coating for continuous steel caster rolls	Project is completed and deliverables are achieved
Development of antimony chalcogenide-based photo absorber coatings for photovoltaic applications	Project is completed and deliverables are achieved
Development of Zn-Al-Mg based hot dip coating for cold rolled steel sheet (RDCSI)	An MoU has been signed between RDCSI-NML. Experimental work will start after a one-time service of HDPS.
Development of Fe-based amorphous alloy and its coating by HVOF for hydro turbine components	Fe-based amorphous alloy powder preparation through gas atomizer is In process
An energy-efficient phase specific process for ZnFe-alloy electroplated high strength steel for automotive application	Project is completed and deliverables are achieved. Findings are submitted for the CSIR-URDIP report
Electrodeposited corrosion-resistant carbide coatings on SS 316L for Sink Roll applications in Continuous Galvanizing Lines	Patent File: CSIR No: 0257NF2024. Achieved TRL-6. The industry partner will provide a CGL sink roll to attempt a technology demonstration at Ahmedabad Plant.
Advanced Colorized Hot Dip Galvanising Zn-X (X-Mn, Ti, Co) Alloy Coating with Excellent Powdering and Corrosion Resistant	Project work is in progress. Uniform color coating is achieved on the large-sized steel sheet (22 cm X 11 cm). A technology demonstration will be carried out in wire galvanizing plant.
CEMILAC certification for Binary Zn-Mn Alloy Coatings to Replace Toxic Cd Coated High Strength Steel Aerospace Components	The CEMILAC certification process is currently in progress for binary Zn-Mn alloy coatings.

R&D Outputs

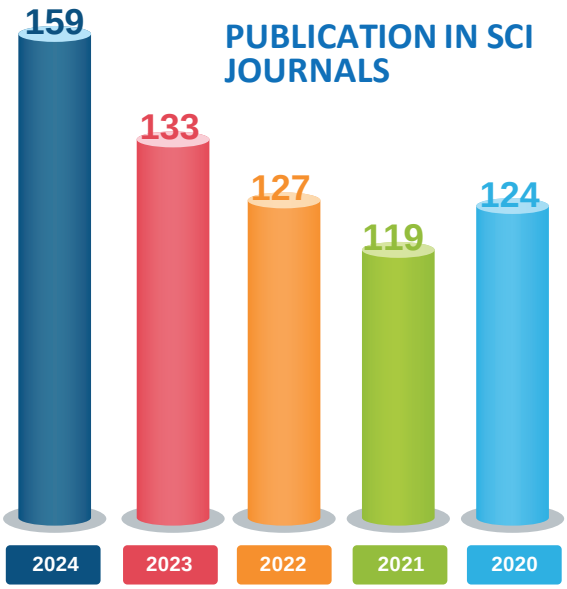
TECHNOLOGIES DEVELOPED



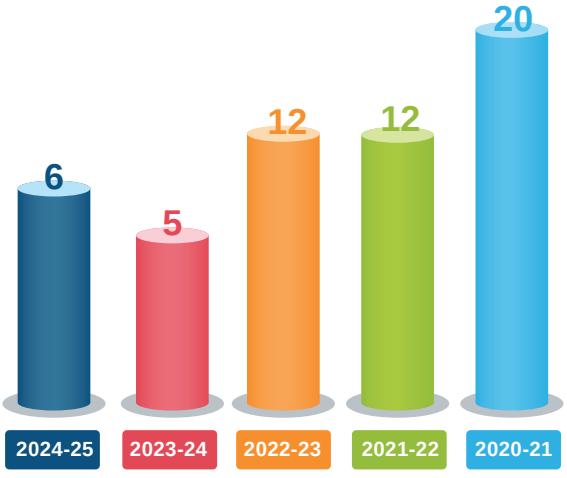
TECHNOLOGIES TRANSFERRED



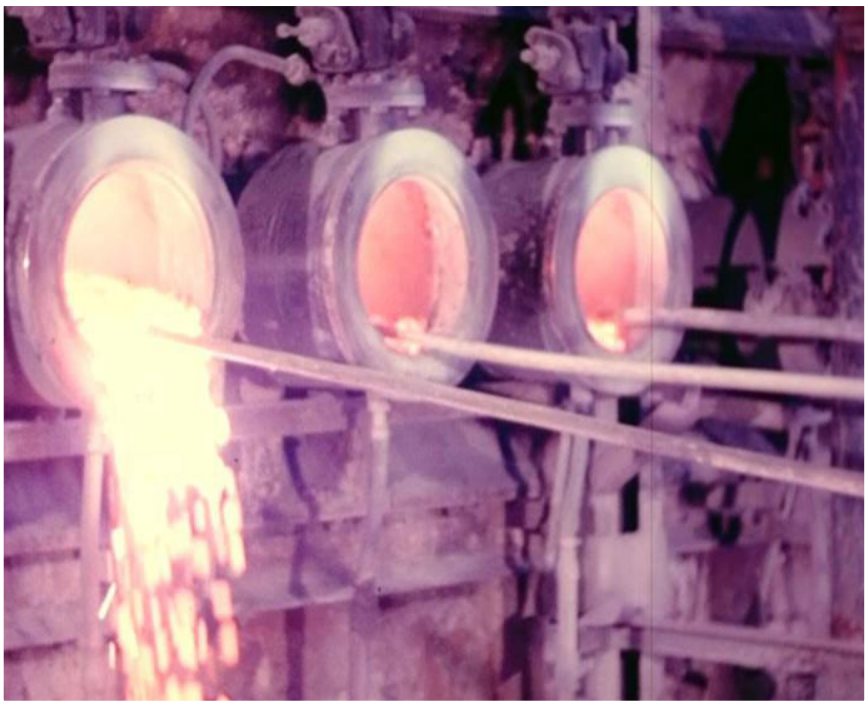
PUBLICATION IN SCI JOURNALS



PATENTS FILED



Magnesium Plant



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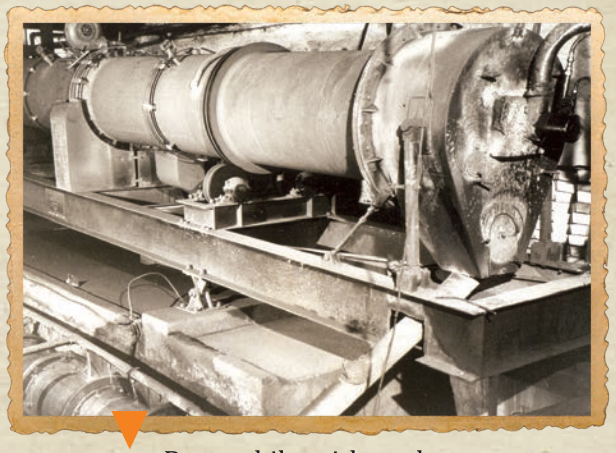
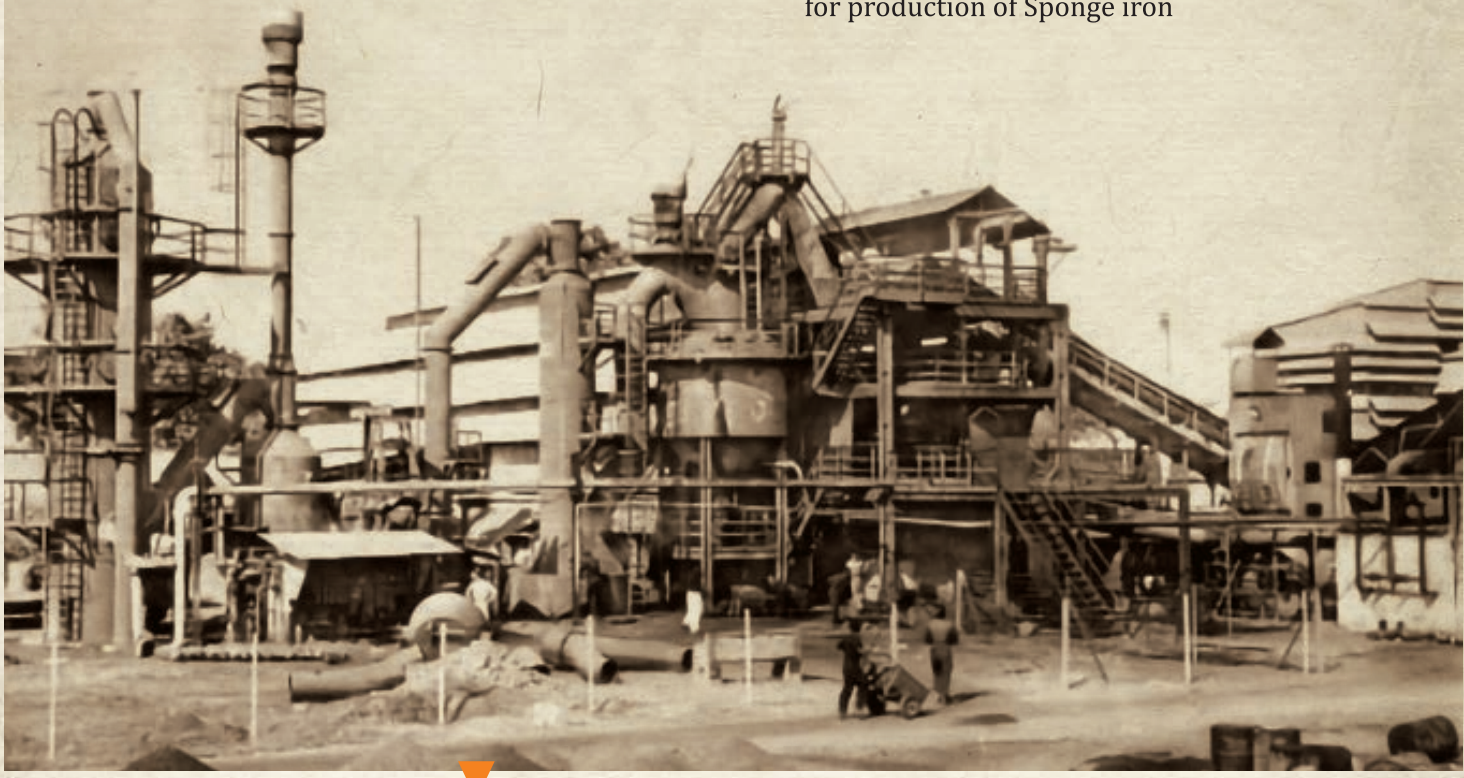
Technology & Impact

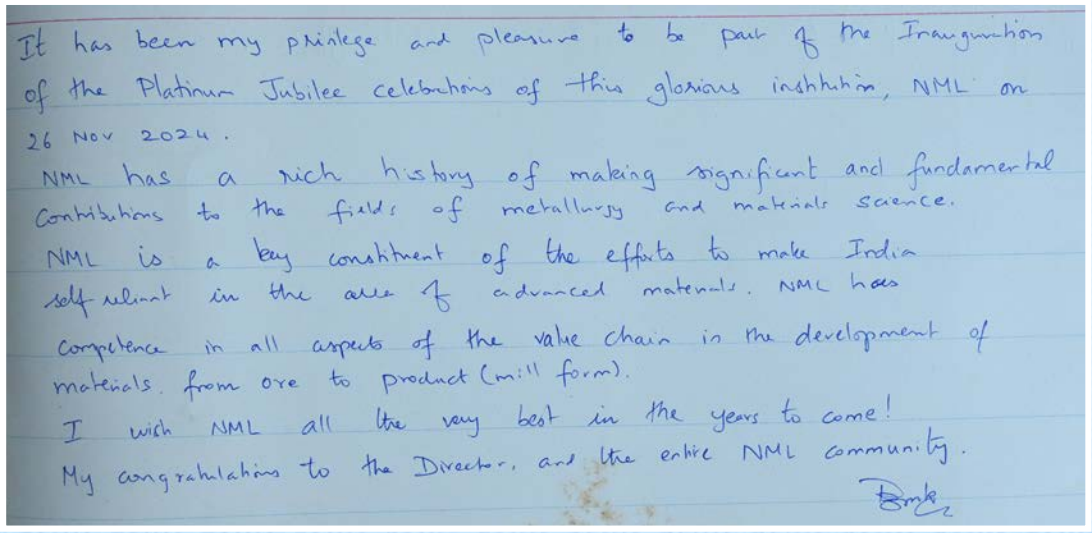
Visit of JRD Tata



Rotary kiln with cooler
for production of Sponge iron



Sponge Iron Plant (Low Shaft)



It has been my privilege and pleasure to be part of the Inauguration of the Platinum Jubilee celebrations of this glorious institution, NML on 26 Nov 2024.

NML has a rich history of making significant and fundamental contributions to the fields of metallurgy and materials science.

NML is a key constituent of the efforts to make India self reliant in the area of advanced materials. NML has competence in all aspects of the value chain in the development of materials from ore to product (mill form).

I wish NML all the very best in the years to come!

My congratulations to the Director, and the entire NML community.

"It has been my privilege and pleasure to be part of the Inauguration of the Platinum Jubilee celebrations of this glorious institution, NML on 26 Nov 2024.

NML has a rich history of making significant and fundamental contributions to the fields of metallurgy and materials science. NML is a key constituent of the efforts to make India self-reliant in the area of advanced materials. NML has competence in all aspects of the value chain in the development of materials, from ore to product (mill form). I wish NML all the very best in the years to come! My congratulations to the Director, and the entire NML community."

Dr. R.Balamuralikrishnan,

DIRECTOR

Defence Metallurgical Research Laboratory (DMRL),

Hyderabad, Telangana

27th Nov 2024

Technology Profile

Magnetoimpedance (MI) based array sensing device for detection of carburisation and defective welds : MagRays (Technology Readiness Level - 7)

The device probe comprises arrays of rapidly quenched nanostructured wires prepared in our laboratory. The device has an array of sensing elements which not only gives a larger probe footprint to assess the carburization level in Johnson Screens. It can detect signals by these elements through scanning of the desired location. The device can be operated independently or remotely through a computer. Giant Magneto-impedance-based array sensor for detection of carburization in austenitic steels/components can be used in petrochemical refinery units. The frequency and current in the device can be altered as needed. The outputs include the sensor output of each of the 16 elements and their averages. The device has been patented under application no. 2111039713.

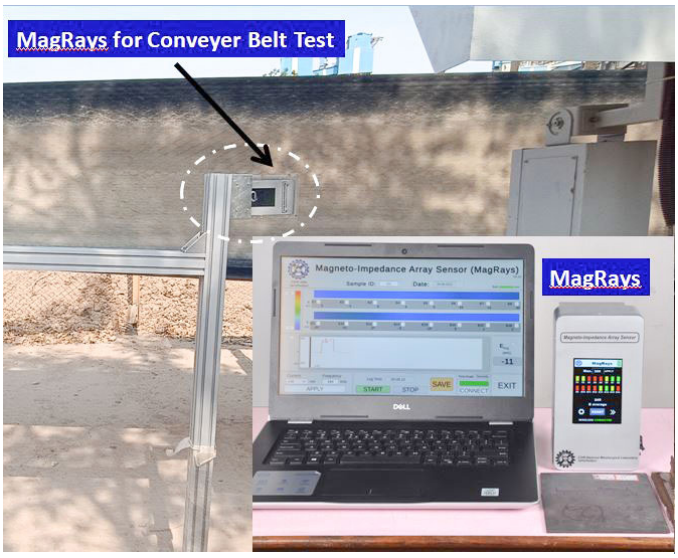


Figure 1: MagRays Device

An improved hot dip coating process (Technology Readiness Level- 6)

The galvanizability issue of advanced high strength grade of steel sheets for automobile and structural applications has been mitigated through the improved process of hot dip coating using prior sol-gel iron based layer (nm) on the steel surface. (CSIR Patent Grant Number: 201911002746) The improved hot dip galvanizing coating process have salient features as:

- Effective suppression of surface selective oxidation of steel alloying elements during annealing and improved galvanizability by the thin metallic pre-layer on the steel surface
- Enhanced reactive kinetics between steel surface and zinc alloy bath
- Applicable to all grades of steel sheet
- Applicable to all baths of hot dip coatings (GI, GA, ZAM, Galfan, Galvalume, Al-Si)
- No need to vary the annealing atmospheric conditions of gas mix and dew point
- Versatile and industrially convenient, economically feasible process compatible to CGL line
- Increased corrosion performance and mechanical adhesion of modified GI coating

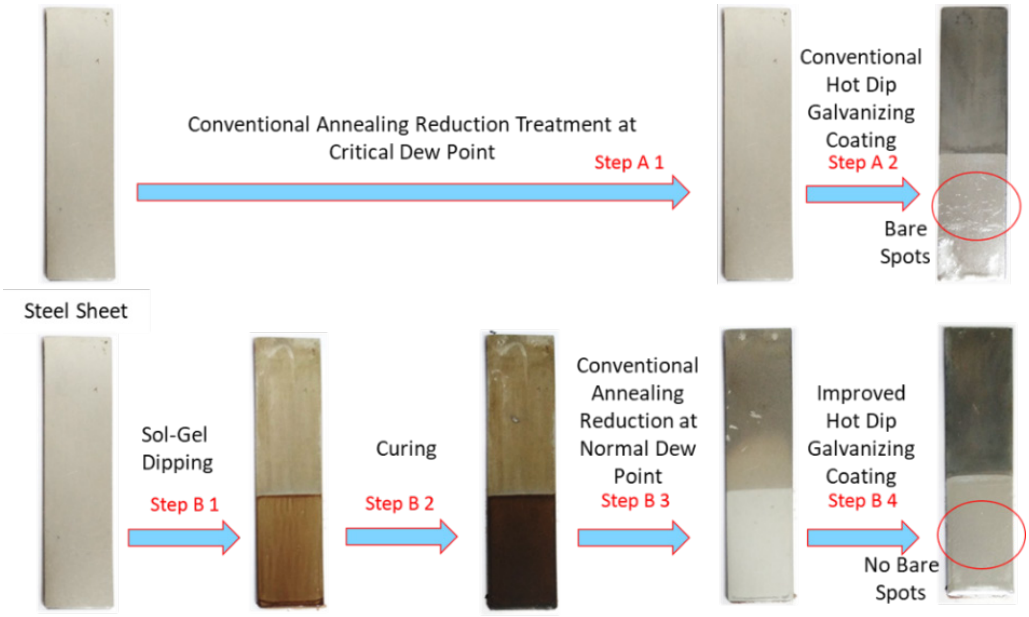
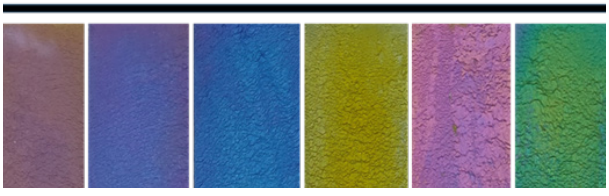


Figure 2: Schematic flow chart for the conventional hot dip galvanizing process and the modified hot dip galvanizing process for AHS steel sheet.

Colorized galvanizing coated steel products and its process (Technology Readiness Level- 6)

The colorized hot dip galvanizing coating with different shades has been obtained with ease and stable commercial operations in single dip process for batch as well as continuous hot dip techniques in protective corrosion resistance coatings applications of steel components. (CSIR Patent Filed Number: 202411025006) Zinc base alloy coating with the colorized surface appearance has salient features as:

- Better Chromaticity (~ 65-75%)
- Reduced coating thickness (~ 35-45 µm)
- Enhanced stability of the colour obtained in normal air cooling
- No need for variation of bath composition
- Least dipping time (~ 4-15 s) as well as no need of water quenching
- Resistance to powdering and scratch
- Inherent sacrificial cathodic protection capacity (~ -1060 mV OCP)
- No colour fading for indoor applications
- Better resistance to colour fading for outdoor applications etc.



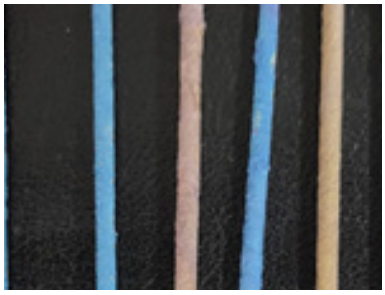


Figure 3: Images of typical silvery-white GI coating along with the colorized surface shades of the hot dip Zn alloy coated steel materials produced at increasing hot dip galvanizing bath temperatures without varying content within less dipping time, followed by normal open-air cooling at room temperature.

Recovery of Zinc as valuable product (Zinc sulfate monohydrate/zinc carbonate/zinc/ metal) from lean grade zinc dross (Technology Readiness Level- 9)

This technology enables recovery of value-added zinc products from waste dross from galvanizing industries and converting them into useful products for the fertilizer and metal industry. This is a hydrometallurgical process for the recovery of zinc from zinc dross as zinc sulfate monohydrate, phosphate, and carbonate. A vacuum distillation process for the recovery of zinc as metal from zinc dross. The CSIR Patent no:- 201811006332; 201911027234; The Technology Readiness level is 9.

The features are:

- High-quality products for fertilizers
- Low-cost metal separation system
- Better profitability
- Sustainable use of water
- Lower carbon footprint
- Processing: Pyro and hydrometallurgical

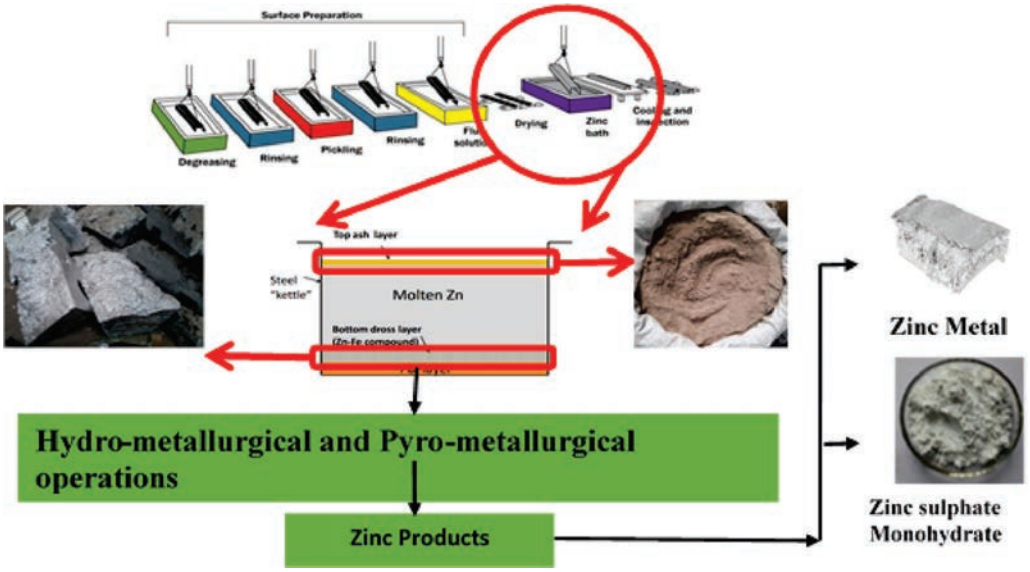


Figure 4: The Process

Cost-effective hot-rolled steel with ultrahigh strength and excellent toughness (Technology Readiness Level- 5)

The existing ultrahigh-strength steel grades (with a tensile strength around 2 GPa) require substantial amounts of costly alloying additions, which lead to numerous challenges during welding, forming, and other post-processing operations. Moreover, achieving adequate ductility and toughness at such high strength levels necessitates several energy-intensive heat treatment processes. To overcome these limitations, a team from CSIR-NML has developed an innovative, cost-effective steel composition (total alloying below 5% with a low carbon equivalent of <0.6) and an industrially feasible, energy-efficient process technology (see Figure 5), validated at a laboratory scale (TRL-5, 40 kg melting). A comprehensive microstructural engineering over the past several years has led to the identification of a novel multiphase microstructure with optimized fraction, composition, size and morphology of various microstructural constituents, leading to superior performance, especially in terms of tensile strength (up to 2 GPa), Charpy impact toughness (40 J at RT), and fracture toughness (85 MPam1/2), as detailed in Table 1. The developed technology is patented by CSIR, and further efforts are underway to advance the TRL level.

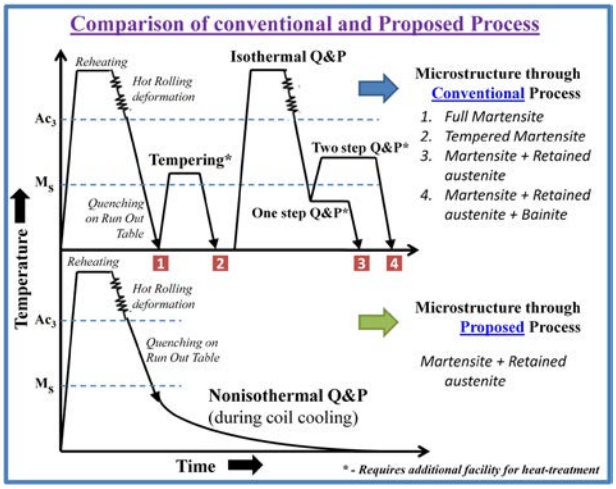


Figure 5: Schematic of the conventional and proposed approach of processing and heat treatment

Table 1: Comparison of NML developed steel and existing steel grades

Details	Existing Top Grade	NML Develope Steel
Total Alloying (other than Fe)	9.73	4.00
Carbon Equivalent	1.14	0.58
Thickness	Variable	5 and 15mm
Processing conditions	Hot Rolled+ Tempered	Hot Rolled (No Tempering)
Microstructure	Tempered Martensite	Martensite + RA + Carbides
Hardness (HV)	550	475
Yield Strength (MPa)	1500	1250
Tensile Strength (MPa)	1900	2000
Total Elongation (%)	9	10
CIT at RT (J)	30	40
CIT at –40°C (J)	20	25
Fracture Toughness ($MPam^{1/2}$)	85	85
CIT : Charpy Impact Toughenss, RT : Room Temperature		

Certified Reference Materials

CRM Unit, AAC Division, CSIR - NML is a pioneer in developing certified reference materials that contribute to establishing the metrological traceability, calibration of instruments, and validating the analytical measurement methods. It is serving the nation with 35 nos. of CRMs having Accreditation as per ISO 17034:2016 as a competent RMP producer by NABL (Quality Control of India) since 2022 and valid up to January 2026. It produced CRMs, of different categories as;

- Metal & alloy has 11 nos. of CRMs in comprising Steel, Cast Iron, Si-Al Alloy & Brass.
- Ores/Coal has 7 CRMs mainly Iron Ore, Manganese Ore, Limestone & Coal.
- Ferro-Alloys & Allied Material has 9 CRMs.
- Spectrographic Standard has 4 Nos of CRMs in Plain Carbon Steel & Stainless Steel.
- 4 Newly Developed Gaseous CRM in Steel in PIN form are available –
  - Two for Hydrogen, Nitrogen & Oxygen (HNO in Steel)
  - Two high and low range CRM for Carbon & Sulfur (C & S in Steel)

Recently, we have developed 05 nos. of CRMs, which will be accredited in the coming future as –

Sl. No.	CRM No.	CRM Name	Date of Issue	Status
1	601	Benzoic Acid (Powder Form)	24.04.2024	New
2	181	Chrome Ore (Powder Form)	30.10.2024	New
3	182	Chrome Ore (Powder Form)	30.10.2024	New
4	183	Chrome Ore (Powder Form)	30.10.2024	New
5	184	Chrome Ore (Powder Form)	30.10.2024	New

08 Nos. of Old CRMs have been revalidated and issued with a new certificate during 2024-25 as-

Sl. No.	CRM No.	CRM Name	Date of Issue	Status
1	213	0.1% Carbon Steel (Turning Form)	28.08.2024	Revalidated
2	221	3% Nickel Steel (Turning Form)	28.08.2024	Revalidated
3	161.5A	Iron Ore (Powder Form)	03.04.2024	Revalidated
4	161.6A	Iron Ore (Powder Form)	03.04.2024	Revalidated
5	231	Ferro-Silicon	09.01.2025	Revalidated
6	233.1	L. C. Fe -Manganese	09.01.2025	Revalidated
7	234	Ferro- Titanium	09.01.2025	Revalidated
8	235	Ferro-Vanadium	09.01.2025	Revalidated

Many more CRMs like Steel turning, Disc CRMs for Aluminum base & Lead base, and Powder CRMs for Coals & Limestone for different grades are under preparation. All the above CRMs are import substitutions developed under the Atamnirbhar Bharat Concept given by the government of India.

Indigenous Coal CRMs for Indian Coal

The primary objective of this project was to develop high-quality CRMs for use in laboratories across industries such as steel, mining, and coal characterization. This initiative aimed to reduce dependence on imported reference materials and promote self-reliance in material characterization. The development of three grades of coal Certified Reference Materials (CRMs) on the basis of Ash, VM, and GCV of Indian origin includes **Sample Collection & Preparation, Homogeneity Studies, Characterization & Analysis, Stability, Certification, Traceability & Validation.** The project would develop and certify three grades of CRMs. These materials will be available for distribution to laboratories and industries for calibration and quality control purposes. Key benefits include:

- Enhanced accuracy and traceability in analytical practices.
- Reduction in dependency on imported reference materials.
- Promotion of self-reliance in material characterization for national industries.

Figure 6: Newly Developed CRMs

"...The Platinum Jubilee celebration event was organized very well. The display at the exhibition was impressive. It was heartening to see the growing collaboration and participation of industries in the research programs of NML. The involvement of your team in the adoption of artificial intelligence to develop new technologies is indeed noteworthy. We wish all of you a great future."

Dr. R. N. Ghosh

29th November 2024

Impact Making Technologies

Technologies Transferred/Licensed to Industries

Know-how for the development of Ti_3AlC_2 MAX phase

Licensed to M/s. Global Nanotech, Goregaon

Based on the high demand for highly emerging Ti_3AlC_2 MAX phase but low availability of Ti_3AlC_2 MAX with low purity and high cost, and unavailability in the Indian market, an indigenous simple pressure less sintering method for producing Ti_3AlC_2 MAX of high purity (98-99%) at lower cost was developed. Accordingly, a technology for developing high-purity Ti_3AlC_2 MAX was developed and transferred to an MSME. Efforts were put-in for the technology development for making the high purity Ti_3AlC_2 MAX phase. Therefore, the process was demonstrated to the party to develop the desired MAX phase at a scale of 200g. The process optimization has also been conducted to control the purity of the product.

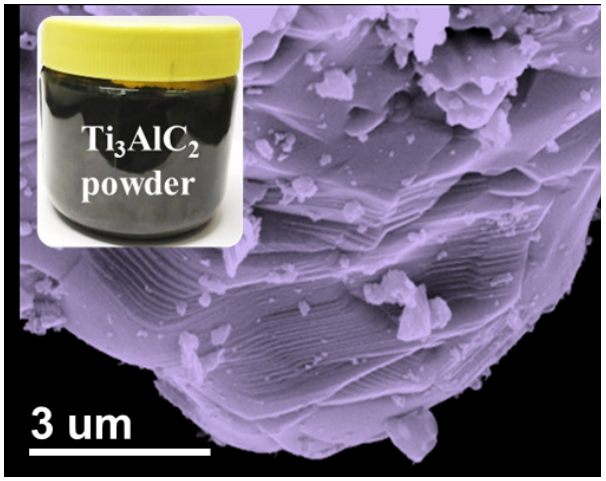
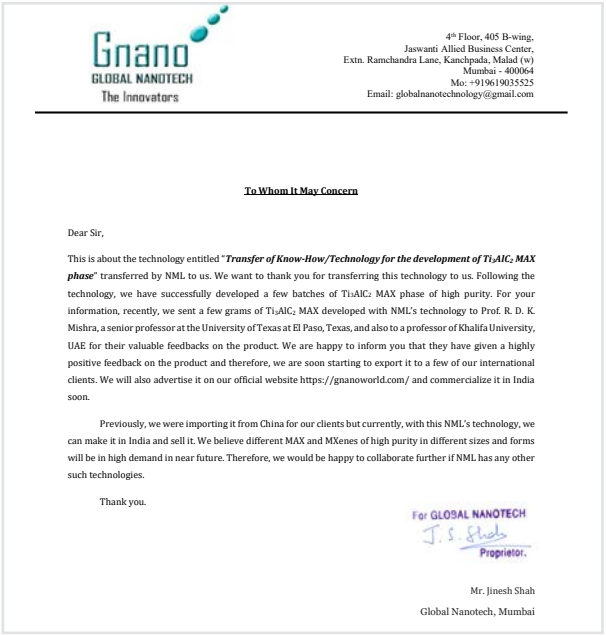


Figure 1:(a) MoU Signing with M/s. Global Nanotech; (b) Development of Ti3AlC2 MAX phase with layered structure



Gnano
GLOBAL NANOTECH
The Innovators

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Jaswanti Allied Business Center,
Extn. Ramchandra Lane, Kanchpada, Malad (w)
Mumbai - 400064
Mo: +919619035525
Email: globalnanotechnology@gmail.com

To Whom It May Concern

Dear Sir,

This is about the technology entitled "***Transfer of Know-How/Technology for the development of Ti_3AlC_2 MAX phase***" transferred by NML to us. We want to thank you for transferring this technology to us. Following the technology, we have successfully developed a few batches of Ti_3AlC_2 MAX phase of high purity. For your information, recently, we sent a few grams of Ti_3AlC_2 MAX developed with NML's technology to Prof. R. D. K. Mishra, a senior professor at the University of Texas at El Paso, Texas, and also to a professor of Khalifa University, UAE for their valuable feedbacks on the product. We are happy to inform you that they have given a highly positive feedback on the product and therefore, we are soon starting to export it to a few of our international clients. We will also advertise it on our official website https://gnanoworld.com/ and commercialize it in India soon.

Previously, we were importing it from China for our clients but currently, with this NML's technology, we can make it in India and sell it. We believe different MAX and MXenes of high purity in different sizes and forms will be in high demand in near future. Therefore, we would be happy to collaborate further if NML has any other such technologies.

Thank you.

For GLOBAL NANOTECH
J. S. Shah
Proprietor.

Mr. Jinesh Shah
Global Nanotech, Mumbai

In a letter, the party mentioned that they have successfully created a few batches of Ti_3AlC_2 MAX on their own and may start commercializing it soon.

Know-how for the development of Magneto impedance-based array sensing device for detection of carburization and defective welds-*MagRays*

Licensed to M/s. Accelor Microsystems, Chandigarh

Magneto-impedance sensors are gaining ground in industrial applications due to the enhanced sensitivity and portability of the device. These sensors typically contain amorphous/nanostructured soft magnetic microwires as the sensing element. The earlier developed Giant Magneto-impedance (GMI) sensor has only single sensor element which is a rapidly quenched amorphous microwire of diameter in the range of 80 to 120 micron. Therefore, the area of assessment was small. To address the limitations of "MagSys", CSIR-NML has developed a magneto-impedance-based array sensing device under a project sponsored by the CSIR. The said magneto-impedance (MI) sensing system is fabricated by M/s. Accelor Microsystem, Chandigarh by utilizing

the CSIR-NML's technical inputs and design. The device has been coined "***MagRays***". The device probe comprises arrays of rapidly quenched nanostructured wires prepared in our laboratory. The device has an array of sensing elements, which not only gives larger probe footprint to assess the carburization level in Johnson Screens; it has also the capability to detect signals by these elements through scanning of the desired location. The device can be operated independently or remotely through a computer. The remote connectivity facilitates independent handling of probe units at desired industrial sites. In another application, MagRays can be used in petrochemical and thermal plants for assessments of welds. Scanning across the pipe weld, a nonmagnetic pipe made of stainless steel reveals a high sensor output if the root of the weld is undesirably filled with ferromagnetic carbon steel. Such dissimilar filler (stainless) and root (carbon steel) materials are detrimental to pipe welds. MagRays is lightweight and battery-operated. As the device can be used to scan over a desired area, it has potential scope for structural health monitoring of larger service exposed components wherein there is a change in their magnetic state. In addition to the detection of carburization and defective welds, MagRays have a potential scope in the structural health assessment of conveyor belts as observed in Cement plants.

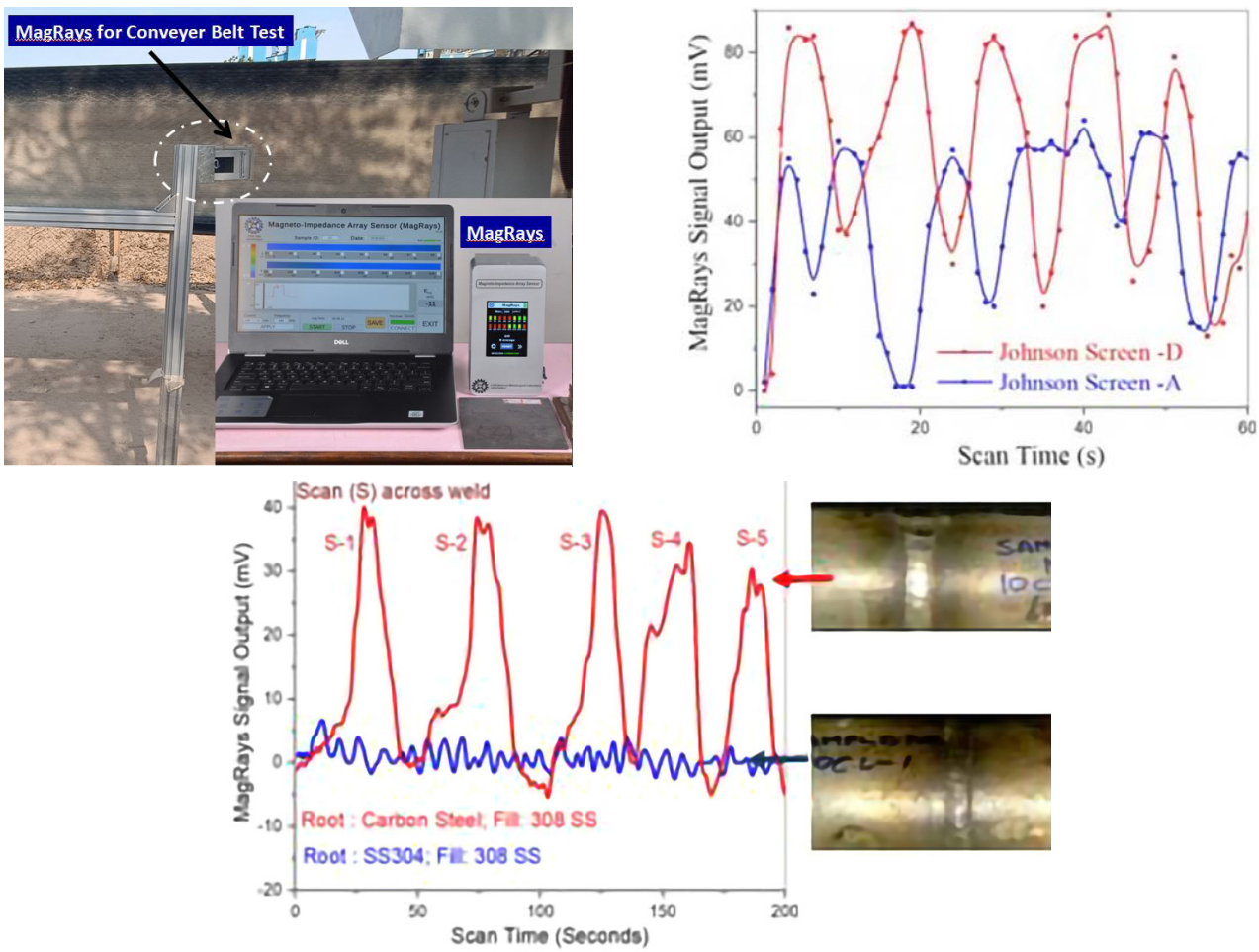


Figure 2: (a) Conveyer Belt Test MagRays; (b) Test on Johnson Screen using MagRays (c) Weld inspection data using MagRays

Process flow-sheet for production of self-healing coating and primer suitable for application on rusted steel

Licensed to M/s. Asianol, Kolkata

Corrosion of carbon steel is a major industrial challenge, with traditional polymer coatings failing within 6–12 months under harsh conditions. The CSIR-NML's ceramic primer called CERA PRIME, an eco-friendly magnesium phosphate cement-based coating that offers exceptional durability and performance. Using chemically bonded phosphate ceramic (CBPC) technology, it forms a protective magnesium iron phosphate alloy layer reinforced with a ceramic shield for long-term corrosion resistance, abrasion protection, and temperature stability up to 300°C. CERA PRIME requires minimal surface preparation and applies to rusted, damp, and salty surfaces, outperforming traditional coatings in durability, cost-effectiveness, and environmental safety. Validated through field applications and testing, CERA PRIME provides a sustainable, efficient, and versatile solution for hostile industrial environments. To further address the corrosion issue that arises due to the formation of cracks in the top coat due to several reasons like mechanical, heat, and UV light, CSIR-NML has developed a self-healing anti-corrosion coating that self-heals and repairs the cracks autonomously when it comes in contact with moisture/water. The active inorganic ingredients present in the coating react with each other when they come in contact with moisture/water to form a ceramic material and prevent the onset of corrosion at the crack site. The active ingredients used in the coating are commercially available, and hence production of the self-healing paint is commercially viable. Moreover, self-healing paints can be formulated from epoxy, polyurethane, of alkyd resins, depending on the type of application. One major advantage of the self-healing coating compared to market-available competitors is that the paint does not require any advanced application process. It can be applied onsite using conventional paint application processes like brushing, rolling, or spraying. The following table summarizes the differences between CERA PRIME with Self-healing top coat and traditional paint coatings:

Aspect	CERA PRIME	Traditional Paint Coatings
Surface Preparation	Minimal; applies to flash rust and bonded rust.	Intensive; requires grit blasting to Sa 2.5.
Durability	Chemically bonded layer ensures longevity.	Physical barrier prone to wear and damage.
Environmental Impact	Eco-friendly, non-toxic formulation.	Contains hazardous chemicals and VOCs.
Cost Efficiency	Reduces labour and maintenance costs.	Requires frequent reapplication.

Figure 3: Signing of Agreement with M/s. Asianol, kolkata

A pyro-hydrometallurgical process for holistic recycling of variable zinc dross high and low grade to recover zinc metal and its salts

Licensed to M/s. Chandigarh Technologies, Haryana

The technology is transferred to M/s Chandigarh Chemicals, Haryana, for scaling up and validation. The technology is successfully validated at 2.5T scale at plant-scale facilities at 20 KL and 10 KL scale, at the customer's premises. The technology is useful for the recovery of value-added zinc products from waste dross from galvanizing industries and converting them into useful products for the fertilizer and metal industry.

Figure 4: Plant Trials and Scale-up activities at the premises of M/s. Chandigarh Chemicals, Haryana

Know-How to recover saleable products of Cu, Al, and Au as Metals/ salts from waste PCBs

Licensed to M/s. Eyantram Waste Management Private Limited, Bangalore

The technology transfer aimed to enhance e-waste management by recovering precious metals from waste PCBs, which is increasingly becoming a significant environmental challenge. The technology shall be utilised to establish an e-waste recycling plant that aligns with the "Zero Waste" concept, promoting environmental sustainability and reducing the strain on waste disposal systems. The new plant will not only help reduce environmental pollution but also create employment opportunities, particularly for youth, and organize the informal waste sector. The NML-developed technology uses an environmentally friendly process to recycle waste PCBs, extracting metals like gold, copper, and aluminum through a combination of mechanical pre-treatment and hydrometallurgical techniques. The process ensures that extracted materials have a high purity level, providing an eco-friendly solution to the growing problem of e-waste. The new technology not only addresses environmental concerns but also has the potential to boost India's economy by supporting small-scale industries and creating new job opportunities. It is seen as a breakthrough in the country's e-waste management strategy and is expected to pave the way for similar initiatives in various sectors.

Figure 5: Agreement Signing with M/s. Eyantram Waste Management Private Limited, Bangalore

Technologies Commercialized by Industries

Know-how for the recycling of lithium-ion batteries (LIBs) to recover valuable metals/ materials

Licensed to M/s. Novasensa Pvt. Ltd., New Delhi

The recycling plant of M/s Novasensa Pvt. Ltd. is now operational at a pilot scale for the production of saleable products of Co, Li, Cu, Ni, and Mn from Lithium-Ion Batteries based on CSIR-NML technology.

The process of recovery includes step-wise treatment of the LIBs. Initially, the spent LIBs were discharged followed by shredding using a scutter cutter. Dry and wet gravity separation techniques were used to separate black powder, plastics, and metallic fractions. The black powder obtained was processed for the leaching of metals using chemical processing in a closed-loop system in a leaching reactor as per the CSIR-NML technological know-how and optimized conditions. The leached liquor generated was filtered using a filter press to separate the solution from the slurry whereas the leached residue (mainly graphite) was further treated and washed to make saleable graphite. The leach liquor was collected and kept in a storage tank to be further processed using advanced separation techniques. From, the leach liquor the selective separation of Cu and Ni was made using solvent extraction techniques. The obtained purified solution was processed for the recovery of Co, Li, and Mn using precipitation, evaporation, and electrowinning techniques.

Figure 6 (a): Technology Transfer to M/s. Novasensa Pvt. Ltd., New Delhi;

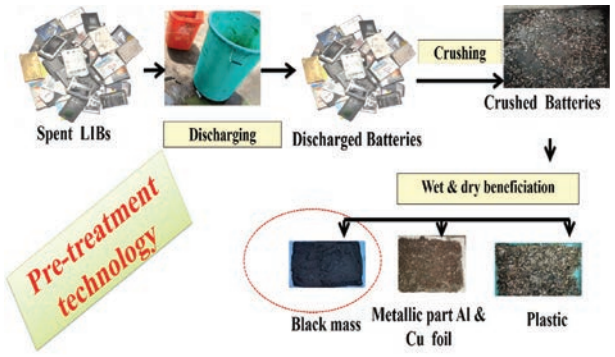


Figure 6 (b) Pre-treatment of spent LIBs to separate black powder, plastics and metallic fractions

Know-How for the extraction of Cu, Al and Au from waste PCBs

Licensed to M/s. Novasensa Pvt. Ltd., New Delhi

The recycling plant M/s Novasensa Pvt. Ltd. is now operational at a pilot scale for the production of saleable products of Cu, Al, and Au from waste printed circuit boards (PCBs) based on the technology of CSIR-NML.

The process of extraction includes step wise treatment of the waste PCBs. Initially, the PCBs are dismantled and depopulated. Further, pre-treatment and physical beneficiation of the crushed PCBs are carried out to separate, non-metallic (epoxies) and metallic concentrate (mainly copper). Hydrometallurgical recovery of Cu from metallic concentrate of PCBs is carried under the optimized condition followed by recovery of gold from the small depopulated components. Aluminum is recovered from the heat exchanger mounted on the PCBs.

Efficient Iron Ore Processing with Column Flotation Technology

Licensed to M/s JSW Steel, Toranagallu, Karnataka

CSIR - National Metallurgical Laboratory (CSIR-NML) has been at the forefront of indigenizing the 'Column Flotation Technology' for processing lean

Figure 7: (a) Technology Transfer to M/s Novasensa Pvt. Ltd., New Delhi;

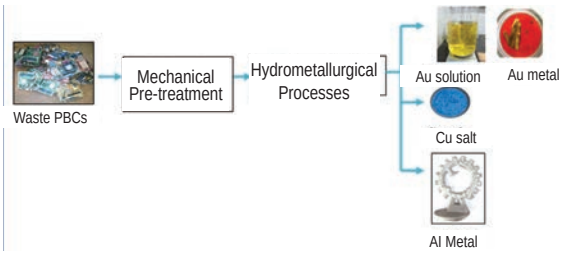


Figure 7 (b) Process flow sheet to recover Cu, Au and Al from waste PCBs

grade and fine-grained ores for over three decades. Laboratory scale (74mm diameter) and Pilot plant scale (500mm diameter) flotation columns were designed, fabricated, and field tested nationwide at various private and public sector mineral processing industries. Development of column flotation technology achieved Technology Readiness Level - 9, implying that it is ready for successful deployment at a commercial scale. The USP of CSIR - NML is that it provides a one-stop solution for the installation and commissioning of commercial scale flotation columns by collaborating and partnering with an EPC company, M/s Tega McNally Minerals Limited, Bengaluru, and reagents manufacturers and suppliers, M/s Sudarshan Chemical Industries Limited, Pune. Recent installations include a commercial scale flotation column of 120 tonnes per day (tpd) at the Mineral Separation Plant of M/s Kerala Mineral and Metals Limited, Chavara, Kerala, for sillimanite recovery, a 200 tonnes per day flotation column at Belatinda Coal Preparation Plant of M/s Tata Steel Limited for fine coal recovery, and a 0.5-meter diameter, 1.0 tonne per hour pilot plant scale flotation column at the BHQ Pilot Plant facility of M/s JSW Steel, Karnataka for reduction of silica in the pre-concentrate generated by the physical separation methods.

Figure 8: 150 tonnes per day commercial-scale flotation column at M/s IREL, Chavara, Kerala

Figure 9: Commissioning of a pilot plant at the Premises of at M/s JSW Steel, Toranagallu, Karnataka.: CSIR-NML designed an entire system for processing low-grade iron ore using column flotation.

Zincometer Technology

Licensed to M/s. Refosteel Instruments

Zincometer finds its application in the Galvanised (GI) lines of moving wires. It is a low-cost, make-in-India device that can assure uniform coating weight across the length of the wire in the production line. Zinc coating is the most effective and widely used process to prevent corrosion and increase the longevity and performance of steel wire. Zinc coating is generally applied to steel wire by hot-dip galvanizing (HDG) process. In this process, the steel wire is passed through a bath of molten liquid zinc or zinc alloy resulting in a protective layer. Zinc coating on steel wire is done by two wiping technologies; Nitrogen (N2) wiping for thick coating lines (100-500 GSM) and pad wiping for thin, commercial (30-90 GSM) lines. M/s QED, Canada

[https://www.qedwire.com/wiping-systems] and M/s FIB, Belgium [https://www.fib.be/uk/our-divisions/galvanizing-plant-equipment] are the two renowned manufacturers of such wiping systems. The N2 wiping system is equipped with a sensor-based closed-loop zinc control system for controlling individual wire coating weight. However, the same facility does not exist in the thin coating line. The present practice is to cut a small piece after each shift and measure the coating weight by dissolving zinc in a solution. This does not assure uniformity of the coating weight along the few km length of the wire. It results in over-coating and also under-coating of GI wires. Hence requirement of real-time coating weight measurement in the thin coating line to ensure uniform coating weight along the length remained as an unmet requirement. CSIR-NML developed the technology for coating weight measurement of steel wire in the GI line in a thin coating line (Patent filed: 202111002156). The successful trial was made in the thin as well as thick coating GI lines at the most renowned wire mill in India. The sensing device was benchmarked w.r.t the existing imported one in the thick coating line and was found at Par with the imported system. A system with 3 sensors has been installed in the pad wiping line at Tarapur Wire Mill (TWM) of Tata Steel and is successfully operating to date. The device along with the installed sensors at 3 lines is depicted in Figure 7. The performance of the Zincometer was as desired by the plant and the result shows the variation within ±5 GSM. The technology has been transferred to a Gamharia based MSME company, M/S Refosteel Instruments for its commercial deployment. Zincometer was showcased at the World's Largest Wire Trade Fair "Dusseldorf Wire" in Germany by the Licensee (Figyre 9). Order for a 5-Channel System from Tata Steel has been approved. Received an oder for a 5-Channel System from Tarapur Wire Plant 2 of Tata Steel. Trial of a 2-channel system is going on at Vedmutha Industries, Mahashtra.

Figure 10: Zincometer system with 3 sensors installed in the pad wiping line at Tarapur Wire Mill (TWM) of Tata Steel

Figure 11: Showcasing of Zincometer at the World's Largest Wire Trade Fair "Dusseldorf Wire" in Germany M/S Refosteel Instruments

Ultrasonic flowmeter for on-board propellant gauging of spacecraft

(Licensed to M/S Electrical and Engineering Pvt Co. India Ltd. (EECI), Mumbai)

Spacecraft propellant gauging is one of the important activities that allow for estimating the amount of propellant available onboard a spacecraft. The propellant availability dictates the life of the spacecraft; also the data related to the propellant availability determines the mission sequence and decisions. The conventional methods (like pVT and bookkeeping) are used to calculate the remaining propellant after orbit transfer whereas more than 80% of the propellant is consumed during apogee raising maneuvers. As both pVT and bookkeeping methods are starting their evaluation at the beginning of satellite orbital life, the accuracy of the remaining propellant mass prediction is eventually driven and limited by the precision in the estimation of the quantity of propellant consumed during Liquid Apogee Engines (LAE) firing. CSIR-NML along with LPSC, ISRO, Bangalore is in a project to fabricate systems using flight-qualified electronics for on-board propellant gauging of spacecraft. This project is the outcome of the success of CSIR-NML in fabricating and developing a system for measuring the flow rate of fluids through a narrow tube. Qualification tests of the devices for continuous and pulsating modes for further use in Indian spacecraft have already been carried out on the ground. The final tests in the space environment will be conducted once the system is fabricated using the space-qualified components. It has been also apprehended that on successful demonstration of the system, this technology can be in use in the "Bharatiya Antariksh Station" for refueling of space craft. The technology has been transferred to an Indian Manufacturer; M/s. Electrical and Engineering Pvt Co. India Ltd. (EECI), Mumbai for its fabrication. CSIR-NML has received a tender notification from ISRO to fabricate two more ground station applicable propellant gauging systems after successful demonstration of the system to Dr. V. Narayanan, Director LPSC (Present Chairman, ISRO).

Certified Reference Material (CRM) Services

CSIR-NML is a pioneer in developing certified reference materials that contribute to establishing the metrological traceability, calibration of instruments, and validating the analytical measurement methods. CSIR-NML has 35 nos. of CRMs having Accreditation as per ISO 17034:2016 as a competent RMP producer by NABL (Quality Control of India) valid up to January 2026, in various categories. Metal & Alloy has 11 nos. of CRMs comprising Steel, Cast Iron, Si-Al Alloy & Brass. Ores/Coal has 7 CRMs mainly Iron Ore, Manganese Ore, Limestone & Coal. Ferro-Alloys & Allied Material has 9 CRMs. Spectrographic Standard has 4 Nos of CRMs in Plain Carbon Steel & Stainless Steel. Four newly developed Gaseous CRM in Steel in PIN form are available – Two for Hydrogen, Nitrogen & Oxygen (HNO in Steel) and Two high and low range CRM for Carbon & Sulfur (C & S in Steel). In the reporting year the CRMs supplied to various national and international customers, have generated more than a crore of external cash flow. All CRMs are suitable for Import substitution, developed under the Atamnirbhar Bharat Concept given by the Gov. of India. Details of all available and upcoming CRMs are available with their compositional values in the CRM brochure on the CSIR NML official website (www.nml.res.in).

Creation of National Facilities

Center of Excellence for Corrosion and Wear Resistant Coating Technologies

A report from the International Zinc Association (IZA) in March 2021 estimates that wear and corrosion-related losses in India account for approximately 5-7% of the country's annual Gross Domestic Product (GDP). Eastern India, known for its rich mineral resources, hosts numerous industries focused on metal production and its diverse applications. Given the significant economic and environmental impact of material losses due to wear and corrosion, the Advanced Manufacturing Technologies (AMT) initiative under the Technology Development Programmes (TDP) of DST, India has recognized the need for a coordinated effort to establish a Centre of Excellence for Wear and Corrosion Resistant Coatings Technology in the region. The center will serve as a collaborative hub for both industry and academia, providing advanced facilities in one location. CSIR - National Metallurgical Laboratory (NML) in Jamshedpur has been entrusted with the responsibility of setting up the center, owing to its strong infrastructure and expertise in developing wear and corrosion-resistant coating technologies.

Objectives:

A. Creation of an integrated facility in the eastern zone of India to address the problems of material degradation encountered by industries due to wear and corrosion.

B. Translation of laboratory-scale research to industries at all levels (small scale, medium, and large scale).

Focussed Themes

High performing Zinc and Zinc alloy coating ● Automobiles, infrastructure, ● Zinc, Zinc alloys & color Zinc	**Non-metallic coatings** ● Infrastructure & extreme corrosive environment ● Self-healing, Ceramic-based primer
Upgrading material performance at High Temperature ● Thermal power plant, CSP & Aerospace ● NiCr, NiCr-SiC, MAO coating ● Microstructure tailoring	**Erosion/ wear resistant coating & SCC corrosion fatigue mitigation** ● Hydro power plant, nuclear industry & Railway ● Fe-amorphous, Alloyed Zn Coatings

Marine Corrosion Research Station at Digha, West Bengal

Corrosion poses a major threat to civil and utility infrastructure, ships, offshore structures, and port facilities, resulting in structural damage, safety risks, and environmental pollution. Research into atmospheric corrosion of materials began at CSIR-NML, Jamshedpur and in 1956, and in 1963, CSIR established the Marine Corrosion Research Station (MCRS) in Digha, West Bengal. The MCRS offers a unique facility designed to replicate the corrosion conditions of the Bay of Bengal and the surrounding coastline. Its primary mission has been to conduct research focused on corrosion in marine environments, and it played a key role in developing India's first Corrosion Map, published in 1975.

As industrial growth continues to accelerate, the economic impact of corrosion has become a global challenge. To combat corrosion-related issues in India's coastal areas, the Marine Corrosion Research and Skill Development Center in Digha is being revitalized. With state-of-the-art infrastructure, this center will serve as a vital hub for addressing challenges such as coating development, premature

machinery and equipment failures, structural collapses, damage to solar panels, explosions caused by leaks in corroded pipelines carrying flammable substances, and predicting the lifespan of metals and alloys. Since its inception in 1963, the centre has addressed the issues regarding degradation behaviour of materials and coatings in an actual saline environment, and today the station has set future aims and targets that necessitate its revival. Exchange of ideas and sharing of improved R&D outcomes through interaction amongst R&D Laboratories and Institutions, Industry, Students, and Society, Collaboration, and minimizing dependency on foreign know-how. The field data generation concerning materials and coating life will help industries and R&D institutes to develop new products and accurate models. The centre will provide real-life data on materials performance and accelerate new product developments.

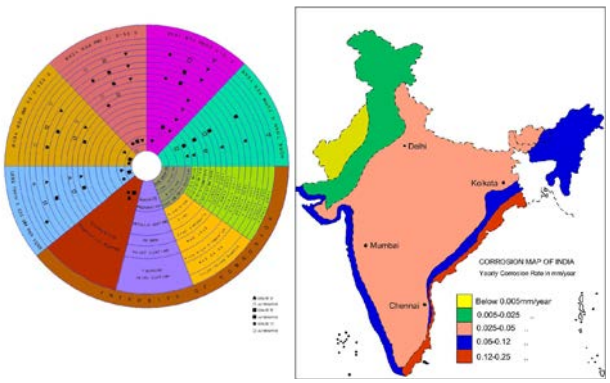


Figure-1 : First Corrosion Map of India (1975)

Centre of innovation & manufacturing eco-system for sensors (CIMES) in industry IOT

The objective of the project is to explore the commercialization of sensor technologies in the area of structural and geo-technical instrumentation and industrial process control monitoring. and to establish a centre of innovation & a manufacturing eco-system for sensors (CIMES) for Industrial IoT (IIoT) in Kolkata, West Bengal. The project will be carried out with the support of West Bengal Electronics Industry Development Corporation Limited (WBEIDCL), a nodal agency of the Department of Information Technology & Electronics, Government of West Bengal along with other industry partners and stakeholders. The centre will be developed by pooling complementary competencies of five CSIR laboratories having excellence in sensor development and field application in the areas of geotechnical and structural health monitoring and industrial process control instrumentation with well-defined application domains as demanded by the stakeholders and industry partners. The broader aims of the proposed centre are: (1) enabling a start-up and innovation ecosystem in the country as a solution provider in the sensor and instrumentation for industrial IOT; (2) creation of a knowledge and resource centre for Indian industries; and (3) placing India in the global market of sensors and instrumentation in the domain of geotechnical and structural health monitoring and industrial process control instrumentation. To this end, CIMES is a consortium of five CSIR Labs (CSIR-CGCRI, CSIR-NML, CSIR-SERC, CSIR-CRRI, CSIR-CIMFR) where CSIR-CGCRI is the nodal laboratory. For the establishment of the centre, procurement is underway. Discussions with various MSME companies for technology transfer is in progress.

Battery Recycling

CSIR-NML has commissioned 1TPD battery dismantling setup, along with 100L Metal extraction and 10L Solvent Extraction facility. The pilot plant is first of kind Hire-Operate-Transfer (HOT) platform for MSMEs and Entrepreneurs in India. Currently, it has signed agreements with five Indian firms with whom technology transfer is on anvil, and more are in the queue. Dr. V.K.Saraswat, Member, Niti Aayog, in his maiden visit to CSIR-NML, inaugurated the CSIR's First Battery Dismantling and Metal Extraction setup installed in the Critical Metal Processing Pilot Scale Facility at its Nildih Campus . This facility was developed as a part of the patented CSIR's first holistic hybrid mechanical-hydrometallurgical process that generates high quality black mass and can tackle any type of Lithium based batteries, to extract and separate high pure salt products of

100l Black Mass Leaching Facility

Solvent Extraction Facility

CSIR's First Battery Dismantling & Black Mass Retrieval Facility (1TPD)

Lithium, Nickel, Cobalt, Manganese, Aluminium, Copper, and Reusable Graphite.

Current Impact: The facility is earmarked as the source of electrode material generation and hydrometallurgical processing to obtain battery metal salts which will be processed by CECRI into second life batteries (18650 cells). This facility also led to signing of few MoUs/NDAs on battery material recycling with start-ups and recyclers.

Future Roadmap for Utilisation:

- Catalyst for start-ups and recyclers in spent battery processing
- Processing of 50 tons Spent LIBs at NML and usage of black mass
- Augmentation of existing metal separation facilities
- Large volume extraction of critical metal salts by hydrometallurgical processing of spent lithium-based batteries (LCO, NMC, NCA, LMO, LNA, LFP)
- Separation of battery grade materials of Li, Mn, Ni, Co as nitrate/carbonate/sulphate
- Separation of battery grade mixed precursor oxides of Li, Mn, Ni and Co
- Transfer of Technology to Potential Recyclers

Urban Ore Recycling Centre (UORC), CSIR-NML Jamshedpur

The generation of electronic waste (e-waste) at a disquieting rate has become a global concern. About 80% of the valuables present in these wastes are being trashed due to illegal recycling activities i.e. incineration and landfilling. Despite of the strict regulations imposed by Government for the proper treatment of these electronic scraps, only 20% of them are getting recycled in an organized manner by the formal sector. In developing countries, there is lack of proper collection system and mostly illegal recycling is carried out the informal sector in an unorganized manner, which adversely affects the environment. Therefore, there is a need for an effective, feasible technology with minimum environmental impact for the recovery of valuable metals/materials from e-waste. Recycling is the only and most effective solution to the growing problem of e-waste. Due to the presence of several valuable metals/materials, recycling of e-waste has become a significant economic activity. Major fraction of e-waste comprises of personal computers, mobile phones, batteries, magnets, fluorescent tubes, etc. Printed circuit boards (PCBs) of personal computers contain Cu, Ni, Sn, Pb, Au, Ag, Pt, Pd, etc., whereas, PCBs/connectors of mobile phones contains mainly precious metals Au, Ag, Pt, Pd and Cu. The magnets present in different electronic

items contain rare earth metal Nd, whereas the lithium-ion batteries (LIBs) is composed of rare as well as strategic metals, viz. Co, Li, Ni, etc., which should be recovered in an eco-friendly manner. CSIR-NML, Jamshedpur has established the first Urban Ore Recycling Centre (UORC) at its premises. The Centre is dedicated for the development of application oriented e-waste recycling processes consisting of pre-treatment (physical/pyrolysis/ chemical) followed by processing using advanced separation techniques to recover value added products (salts/metals) of rare, rare earth, precious metals and non-ferrous metals fulfilling zero waste concepts under the collaborations with national and international research institutes and industries. Various sustainable technologies related to (i) Recovery of Precious metals (Au, Ag, Pt, Pd) from scrap telecommunication devices, Medical equipment's, Key Boards, and Printed Circuit Boards (PCBs) of various E-waste ii) Recovery of Lithium, Cobalt, Copper, Nickel, Manganese and recyclable Graphite from waste Li-ion (LIBs) and Ni-Metal Hydride (NiMH) batteries iii) Recovery of Rare earth metals (Nd, Sm) from various Magnets of Wind Turbine and E-waste iv) Recovery of Rare earth metals (Nd, Ce and La) from electric vehicle (Ev) batteries v) Recovery of Rare earth metals (Y, Eu, La, Ce and Tb) from waste Fluorescent Lamps vi) Recovery of Strategic metal Germanium (Ge) from Telecom Optical cables and Solar Panels have been developed under the banner of UORC at CSIR-NML, Jamshedpur. Under the banner of UORC, CSIR-NML has transferred e-waste recycling technologies to various industries for the recovery of rare, rare-earth, precious, and strategic metals. The transfer of technologies is contributing towards the "Swachhata Abhiyan" initiated by the Government of India. This initiative promotes self-employment, entrepreneurship, and cottage industries.

Figure 7: Urban Ore Recycling Centre

Performance Targets planned for 2025-2026

Sl No.	Objectives	Planned
1.	External Cash Flow (ECF)	30.0 Crores
2.	Industrial ECF (a part of ECF)	18.0 Crores
3.	Customer Satisfaction Index	4.8
4.	SCI Publications	160
5.	Non SCI	30
6.	Patents	12
7.	Copyrights	5
8.	Technologies to be Developed	5
9.	Technologies to be Transferred	5

Major Technological & Scientific Targets Planned for 2025-2026

Applied & Analytical Chemistry

- Assessment of coking coal quality concerning the active component present in coking coal.
- Chemical & mineralogical analysis of coal and non-coal samples from CMPDI.
- Value-added chemicals/materials from coal, industrial waste, low-value precursors, and low-value products (Target: 03 SCI publications).
- Metal oxide/sulphide/phosphate for electrochemical application (Target: 02 SCI publications).
- Chemical characterization and analysis of coal from various industries and subsidiaries of Coal India Ltd.
- Development of alternate reagents for the elimination of mercury effect for reliable analysis of Hg in coal and coal fly ash samples (Target: 01 SCI publication)
- Assessment of Refuse Derived Fuel (RDF) characteristics and its impact on the clinker quality at high Thermal Substitution Rate (TSR) (Target: 01 SCI publication)
- Evaluation of cement quality by blending of high MgO content limestone (Target: 01 SCI publication)

Materials Evaluation

- Hot forging, hot rolling followed by salt bath heat treatments of alloy steels
- Development of high Mnwear resistant steel
- Process development for making ultra-thin foil from complex alloy steels
- Tri-Party agreement between CSIR-NML, RDSO-Lucknow and GSV-Gujrat to bring R&D, end-user and academics under single roof for serving the requirement of Indian railway
- Technical audit of product/ metallurgical process – rail manufacturing at Bhilai Steel Palnt
- Implementation of LTCC based eddy current sensor for real time creep damage monitoring in one of the power plant.
- Performance evaluation of Ultrasonic Flowmeter in the space environment.

- Transfer of FOBOP: Breakout detection of Billet Mould Technology
- Development of AI-based model for welding parameter optimization to achieve defect-free weld joints.
- Development of GUI for 'Automated estimation and reporting of the debonding area in Connecting rods using Ultrasonic testing and image analysis'
- Development of Pulse Eddy Current probe to detect corrosion under insulation
- Evaluation of AM components for aero engine applications
- High temperature fatigue behavior of Ni base super alloys

Metals Extraction & Recycling

- To set up a 100 kg/day magnesium metal production capacity pilot plant under the CSIR-funded CSPS project
- To initiate the research activities on the extraction of high-purity silicon metal by recycling of solar panels
- To complete the project 'holistic utilization of red mud' at 100 kg scale and release the completion report through Niti Aayog

Mineral Processing

- Reduction of silica in dolomite and limestone for utilization in iron & steel making.
- Feasibility study of dry beneficiation of non-coking coal by FGX dry coal separator.
- To carry out a Process audit of the installed fine coal circuit at 5.0 MTPA Patherdih NLW Coal Washery, BCCL.
- Extraction of vanadium from dune sand.
- Process Audit of the Existing Copper Beneficiation Plant at Malanjkhand to study the feasibility of capacity enhancement.
- Dry silica sand beneficiation for utilization in glass making.
- Low-grade iron ore beneficiation.
- Beneficiation of copper ore using column flotation.
- Rare Earth Mapping from coal overburden.
- Selective flotation of iron minerals from Ferruginous Manganese Ores.

Advanced Materials & Corrosion

- Implementation of "MagStrics" sensor for health monitoring of thermal power plant
- Colorized GI wires and their process
- Development of molten salt corrosion-resistant microstructure
- Development of additive manufacturing grade soft magnetic powders

NML Madras Centre

- Feasibility studies on the beneficiation of secondary phosphate ore
- Feasibility study on the beneficiation of tailings from an industrial beneficiation plant
- Metallurgical failure analysis of low-pressure (LP) steam turbine blades

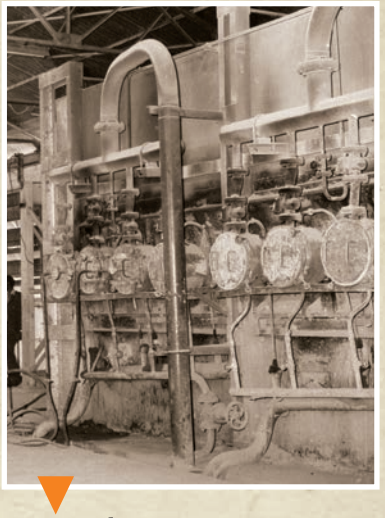
Information Management & Dissemination Centre

- Purchase of books as per the requirements of the library users
- Recruitment of a librarian having a degree in Library Science in consultation with HRG
- To organize eleven Skill Development Training programs with 140 nos. of participants
- To increase the participation of students under the Jigyasa program up to 1100 nos.

1966-75

Research & Development

Creep Laboratory



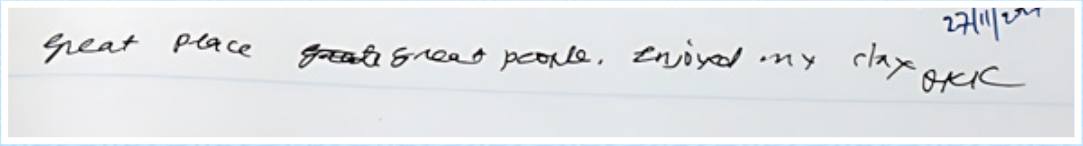
Pidgeon process
Magnesium Plant

Mg-Al Alloy: Minting
Coins for the Country

Mg Crowns from 250 TPA plant

Visit of Dr. H.J.Bhabha, F.R.S

Impression



"Great place great people, Enjoyed my day."

Professor S. K. Kawatra

Chair & Professor

Michigan Technological University, USA

25th March 2025

Flagship Projects & Focus R&D Areas

Flagship Projects

Technology development for holistic utilization of red mud for extraction of metallic values & residue utilisation

With the joint funding of CSIR along with industrial partners (NALCO, HINDALCO and VEDANTA) to the tune of Rs. 5.12 crores, CSIR-NML is working on the development of a holistic process to extract Al, Fe, Ti and REEs from three red mud samples of India. This work is monitored by NITI AAYOG.

CSIR-NML has completed all project deliverables by processing 100kg red mud, and demonstration has been given to all industry partners. The salient achievements of the project are as follows:

- 87% Alumina recovery with 99% Purity
- 93% Fe recovery with 99.7% Purity
- 86% Titania recovery with 90% Purity
- 90% REE recovery with 90% Purity

The project is being planned to scale-up to 10 ton per day demonstration plant by NALCO and VEDANTA.

Figure 1: Extraction of metallic values from red mud

Flagship initiatives with Magnesium Pilot Plant at CSIR NML

For the last six decades, CSIR-NML is contributing in Magnesium Metal R&D and piloting it with a capacity of 250-500 Tonnes Per Annum plant at Jamshedpur. CSIR-NML has been actively engaged in pyrometallurgical routes based on the silicothermic reduction of calcined dolomite. Since the last 10 years, knowledgebase for Mg extraction using its Pidgeon/Retort process was established, in which a single retort prototype for 14-15 kg feed/charge and 2.5-3.0 kg Mg metal was being successfully developed. The vacuum distillation based Mg-refining process was also developed at 1.5 kg scale for refining of commercial Mg and its scrap. Presently, the scale-up activity for vacuum distillation is continued to establish process technology at 5-6 kg scale in semi-continuous mode.

Piloting activities for commercial grade high pure magnesium metal from Indian dolomite resources,

further initiated. The proposed pilot plant is designed for 120-150 kg Mg metal/day with ~2 TPD feed of dolomite. The pilot plant is designed with NML's retort technology (improved Pidgeon Process) and continuous vacuum distillation refining technology, and slag valorization facility. Under the pilot-plant facility, there would be three primary components (a) Raw material preparation, which comprises sizing, calcination, grinding and briquetting, (b) reduction-vacuum distillation, which will include retort-based reduction of briquettes and refining of Mg crowns, (c) Vacuum-casting facilities for refined magnesium. The end product targeted is Commercial Mg metal of ASTM B92 9980 (~99.8%) and high pure Mg (>99.95%). DPR preparation for commercialization is to be taken up as follow-up activities for piloting the extraction and refining at 120 kg /day metal output towards commercialization. The pilot scale data would help design strategies for commercialization of primary and refined magnesium technologies. Figure 2 below shows the current status of technologies incorporated in piloting activity for reduction, refining, and recycling.

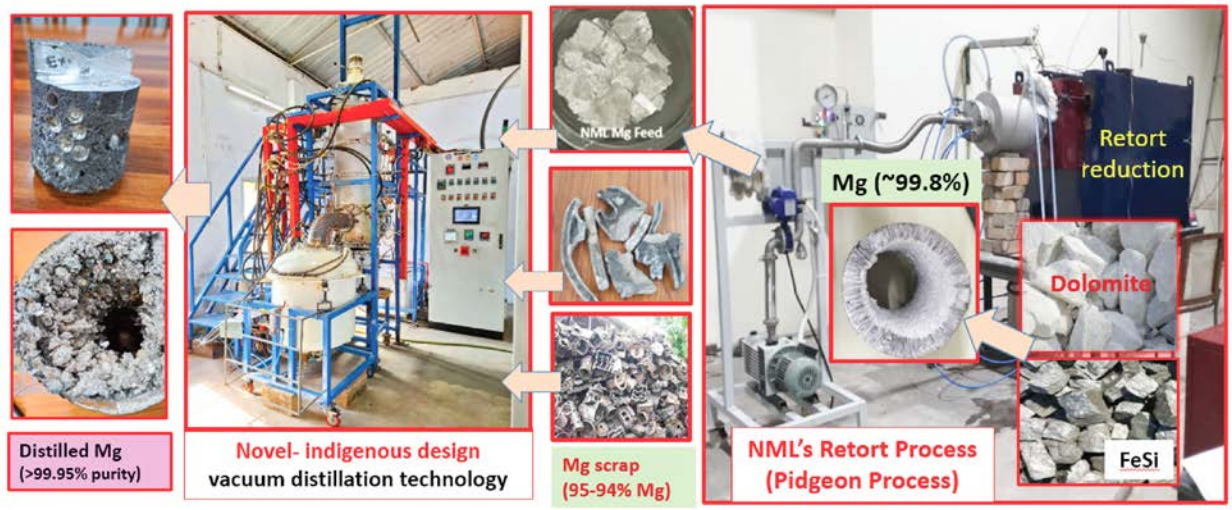


Figure 2: Vacuum Reduction integrated with vacuum distillation for primary and recycled magnesium metal and prototypes demonstrated at TRL5 with dolomite and scrap Mg alloys as raw material.

Foundation stone of the proposed pilot plant was laid by Hon'ble DG, CSIR and Secretary, DSIR Dr. (Mrs. N. Kalaiselvi) on November 26th, 2024, the 75th Foundation day of CSIR NML at the magnesium plant complex in Jamshedpur

Figure 3: Foundation stone laying by DG, CSIR in the presence of NML-Research Council members, Director CSIR-NML, Former Directors, CSIR-NML and other dignitaries on November 26th, 2024 at Magnesium Plant Area

Focus Areas

Coal Characterization and Analysis

Quality assessment and grade declaration of Indian coal are crucial for national development, as coal is the country's primary energy source. To achieve this, borehole coal cores are analyzed through visual separation and characterization of different bands within the coal seams. This band-by-band analysis enables qualitative and quantitative estimation of exploitable coal reserves, which is essential for planning and development of coalfields. Coal core samples are identified lithologically based on depth and weight, and their ash and moisture content. The actual lithology of each band is then calculated for each borehole, providing valuable insights into coal seam quality and its potential uses. The results of this analysis are used to create coal seam maps using latitude and longitude data, which informs price evaluations for mining agencies and facilitates informed decision-making. Following band-by-band analysis, overall seam analysis is conducted to characterize individual coal seams. Parameters such as ash, moisture, gross calorific value, ash fusion temperature, ash composition analysis, ultimate analysis, and hard groove index are determined to understand coal characteristics, as advised by mining agencies. This comprehensive analysis enables the identification of coal deposits with optimal quality and properties, which can be utilized for various industrial applications, including power generation, steel production, and cement manufacturing.

Analytical Method Development and Chemical Analysis of Western Region NGCM Samples

Geochemical mapping of any nation is useful for mineral exploration and environmental studies. The Geological Survey of India (GSI), under the aegis of the Ministry of Mines, Govt. of India, has been actively involved in the geochemical mapping of the whole country. Several soil and stream sediment samples are being supplied by GSI, under the National Geochemical Mapping programme (NGCM). These samples are being analyzed very accurately to make a database on the abundance of various elements for possible mineral exploration as well as a precaution for the environment hazardous substances. Wavelength Dispersive X-ray Fluorescence (WD-XRF) is a fluorescence-based, non-contact, non-destructive, robust technique used to measure the elemental composition of different types of materials such as metals, alloys, ores, minerals, etc. However, a well-fitted calibration curve is necessary for quantitative elemental analysis in XRF. Unlike XRF, Inductively Coupled Plasma Mass Spectrometry (ICP-MS) is a destructive analytical technique that has been used to measure elements at trace levels (parts per billion or parts per trillion) in solution /or fluids. ICP-MS is very useful for the quantitative analysis of rare earth elements (REEs) as well as ultra-trace elements. It is aimed to develop analytical methods and chemical analyses of major elements, trace elements, ultra-trace elements, and rare earth elements in soil and stream sediment samples using XRF and ICP-MS instruments.

Band-by-Band and Overall Coal Core Study of Rasulpur and Shrimatpur Area through Chemical and Physical Characterization

Quality assessment and grade declaration of the coals produced by various sectors in India is a job of national importance. The study of borehole coal cores involves the visual separation of different bands present in the coal seams and its characterization for qualitative and quantitative estimation of exploitable reserves of the coal block. Band-by-band analysis of coal core samples is investigated to understand the quality of coal seams. The coal core samples are lithologically identified according to the depth and weight of the band. The ash and moisture of each band are determined. Finally, the actual lithology of each band is calculated for each borehole. This is very important to understand the quality of the coal

seam of the individual borehole coal core. The result of all the band-by-band coal core samples is coal seam mapping using actual latitude and longitude data. This information is very useful for the mining agency for price evaluation of each coalfield. This project aims at band by band and Overall study of coal core samples of Rasulpur and Shrimatpur area through chemical and physical characterization using the state-of-the-art coal characterization laboratory.

Lean Grade Ore & Dry Beneficiation

Mineral Processing Division of CSIR-NML pioneers in mineral beneficiation with a strong National & International Presence. The laboratory has state-of-the-art advanced beneficiation facilities capable of processing all types of ferrous, non-ferrous, industrial, strategic, and critical minerals and coal. The core competency of the Mineral Beneficiation Division is to develop process flowsheets for the upgradation of low/lean grade ores and extraction of valuables from mining and metallurgical waste to maximize resource utilization. The processing of low/lean grade ores employs various novel routes like advanced gravity separation techniques, chemical-aided magnetic separation techniques, etc. The division is also carrying out research in the "waste-to-wealth mission," transforming metallurgical waste into valuable products. In addition to that, the Mineral Processing Division has specialized facilities and expertise in Dry beneficiation, particularly for coal and Iron ore. Dry Beneficiation process know-how has been developed for Indian non-coking coal with the collaboration of government and private industries intending to not only reduce the water consumption but also to reduce the downstream processing steps to make the process economical and viable.

Figure 4: Low-grade iron ore beneficiation products after processing through advanced gravity separation

Microstructural Engineering

In these unprecedented times of emerging materials with superior properties, microstructural engineering holds a key significance in materials research. It provides an opportunity to cater to the ever-increasing demand for enhanced mechanical/physical/corrosion properties by means of altering the phase fraction/distribution/morphology/partitioning coefficient, grain boundary character/distribution/connectivity, chemical segregation at boundaries etc. Globally, microstructural engineering has revolutionized the entire gamut of materials engineering by allowing researchers to attain unparalleled properties/performance with leaner compositions and simpler processes (such as thermo-mechanical processing, annealing, rapid cooling till metastable transformations etc.). At CSIR-NML, with the aid of state-of-the-art microstructural and mechanical characterization tools along with material processing facilities, microstructural engineering has been the forte of Materials Engineering Division, by virtue of which advanced grades of steel, cast iron, Ni-base superalloys, additively manufactured alloys, aluminum alloys, and high entropy alloys are being developed. With these advanced grades of alloys, sectors such as automotive, railways, mining, mineral processing, aerospace, power plants, power transmission and distribution, space, etc. have been targeted for application.

Iron and Steel

Ferrous metallurgy is one of the major thrust areas with focus on agglomeration, raw materials characterization, ironmaking, steelmaking, modeling and simulation, and ferroalloy making. CSIR-NML is involved in developing innovative technologies for process optimization, quality improvement, and reducing energy consumption. From the very beginning, Ferrous process group has continued to support ferrous industries with its cutting-edge research and development. CSIR-NML contributed significantly in the ironmaking area, starting from development in low shaft ironmaking for non-coking coal utilization to a modern blast furnace for modeling, simulation, and productivity improvement. It also has a significant contribution to steel and ferroalloy making. Ferrosilicon has been prepared from siliceous iron ore like Banded Hematite Jasper (BHJ) and Banded Hematite Quartzite (BHQ) using reactive coal. In the recent past, the process parameters for a 6 MTPA capacity new pellet plant at Tata Steel have been studied, which helped to improve pellet quality and productivity of the pellet plant. Various innovative processes in agglomeration areas have been developed, which include cold bonded CO_2 treated binder less fluxed pellet for utilization of steel plant wastes in blast furnace-basic oxygen furnace (BOF), pellet sinter composite agglomerate to increase micro fines utilization of sintering and reduce energy consumption and CO2 emission, and replacement of bentonite in palletisation using calcined lime. Direct reduced iron making (DRI) making through tunnel kiln is also a successful technology that is implemented commercially, wherein low-grade non-coking coal and low-grade iron ore were utilized. Some of the ongoing and future planned activities are preparation of DRI using pure hydrogen in a shaft furnace, and also in a fluidized bed reduction technique. The preproduction of chromite and manganese ore using hydrogen or hydrogen-containing gas is also in the planning.

Upgradation of lean grade ore/ slimes through reduction roasting to develop blast furnace grade pellet

The conventional mineral beneficiation of lean-grade iron ores and slimes having less than 55% Fe has difficulties in enriching the assay value to an acceptable limit because of the complex mineralogical characteristics and liberation at the finer size. Moreover, due to the depletion of high-grade iron ores and the availability of vast amounts of unutilized lean-grade ores in India, developing an alternative mineral beneficiation technique is imperative for fulfilling the demand of the Indian iron and steel industries to meet that target of 255 MT of steel by 2030. Therefore, reduction roasting of low-grade ores has been developed (a) to beneficiate 48% Fe low-grade iron ore/fines to 60-62% Fe beneficiated ore suitable for making BF-grade pellets; b) 56-58% Fe ore fines (used in sinter making) may also be attempted to achieve 66% Fe, making them suitable for producing DRI-grade pellets. Pelletization of magnetite concentrates has been executed to prepare the blast furnace (BF) grade pellets.

Decarburization of High Carbon Ferro Manganese for Preparation of Low Carbon Ferro Manganese

Presently, the Majority of ferromanganese is produced by smelting the reduction of Mn ore with coke as a reducing agent in either a blast furnace or an arc furnace (EAF/SAF). Ferro-manganese produced through this route contains high carbon, i.e. 6-8% C, 72-82% Mn, and 1.5% Si (HC-FeMn). Due to high carbon saturation (6-8 wt %) in Fe-Mn, producing the low carbon (LC) Fe-Mn by carbothermic reduction in EAF/SAF in a single stage is not possible. On the other hand, silico-thermic

and alumina-thermic reduction of Mn ore is highly cost-intensive, and there is a very high carbon footprint for the production of reducing agents like Al or Si metal. Recently, industries have been moving towards carbon-free technology or net–zero emissions. The greenhouse gas footprint for ferroalloy production was 1.8 kg CO_2/kg of FeMn. However, CO_2 emission has been estimated to be 8-10 kg/ kg Fe-Mn for the aluminothermic process and 5-6 kg/ kg Fe-Mn for the silicothermic process. These indicate a very high carbon footprint, as well as high cost, in the existing process of LC-Fe Mn production. Given the above, CSIR NML has developed the process for decarburization of high carbon ferroalloys by CO_2 gas purging in the presence of MnO-rich slag in the melt to prepare the low carbon ferromanganese.

Inclusion Control and Modification of Steel with the Addition of Rare Earth Metals

The demand for high-quality and extra-clean steel with affordable cost has recently increased for various special applications. Automobile and aerospace industries demand high-quality steel for improved performance during the service of their components. The cleanliness of the steel (inclusion-free) mainly depends on the amount, morphology, size, and distribution of inclusions present in the steel matrix. A significant improvement in the mechanical properties of the steel can be achieved by controlling and modifying the non-metallic inclusions, as these detrimental inclusions cause the failure of the materials by providing crack initiation sites during various forming operations. Researchers have adopted different approaches to obviate calcium treatment by modifying the inclusion composition, morphology, size, and distribution within the steel matrix. One of the suitable alternatives to the calcium treatment would be using Rare Earth Metals (REMs)/alloys in steel to control harmful inclusions. The use of REMs is also expected to refine the as-cast structure and improve the hot workability of the steel. Further, adding Rare Earth Metals (REMs) /alloys might promote steel properties such as impact toughness, magnetic properties, and corrosion resistance. Moreover, it is noted that the effectiveness of REM additions depends on many factors, including steel composition, amount, method, and sequence of introducing REs into the liquid steel bath. Therefore, the treatment/addition of rare earth metals (Ce, La)/ mischmetal in steel by various methods of addition such as (a) addition through a refractory/ceramic tube into a steel bath; (b) ladle bottom addition during tapping with appropriate stirring; (c) direct addition of rare earth mischmetal has been studied.

Flux treatment for the dephosphorization of steel in MgO lined Induction Furnace

Generally, the steelmaking route is categorized into two methods: (i) primary steel sector (BF-BOF) and (ii) secondary steel sector (DRI-IF/EAF). Primary steel sectors produce the steel through the BF-BOF route, whereas secondary steel sectors produce the steel from DRI/Sponge iron/ Steel scrap using either an electric induction furnace (IF) or an electric arc furnace (EAF). According to BIS standards, the phosphorus content in any structural steel varies between 0.03%.to 0.06%, depending on the grade of steel. The presence of high phosphorus in engineering steel components causes cold shortness and increases the brittle-ductile transition temperature. However, the Induction Furnace route has its limitations for refining liquid metal, mainly for producing low phosphorus and sulphur steel. Given the above, CSIR-NML has developed the flux for the dephosphorization of steel in a basic lined induction furnace.

Green Steel Making in Induction Furnace using Hydrogen-based DRI and Slag-Metal-Refractory Interactions During Green Steel Making

As stated earlier, currently the steel production methods are classified into two categories: (i)

primary steelmaking sectors (BF-BOF/LD) and (ii) secondary steel sectors (Electric Arc Furnace / Induction Furnace). The secondary steel sectors (EAF/IF) contribute around 57 % of the total steel production for both BF and DRI-making units. The coke/coal has been used as a reducing agent for the reduction of iron oxide, which releases the gases of CO and CO_2. However, the steel industry alone contributes to 8-7% of global CO_2 emissions as steelmaking (BF-BOF) accounts for 1.85 tons of CO_2 equivalent per ton of hot-rolled coil. Therefore, to reduce CO_2 emission in steel making, hydrogen is used as a reducing agent for the preparation of hydrogen-based DRI from iron ores and pellets, followed by melting and refining in an induction furnace (IF) / electric arc furnace (EAF) has been studied. The melting and refining behavior of carbon-free DRI in acidic/basic lined induction furnaces has been studied to understand the dissolution kinetics, interaction between slag-metal, slag- refractories, refractory-metal and Influence of different ratios of H_2-based DRI in feed on metallic yield, power consumption, steel, and slag chemistry has been studied.

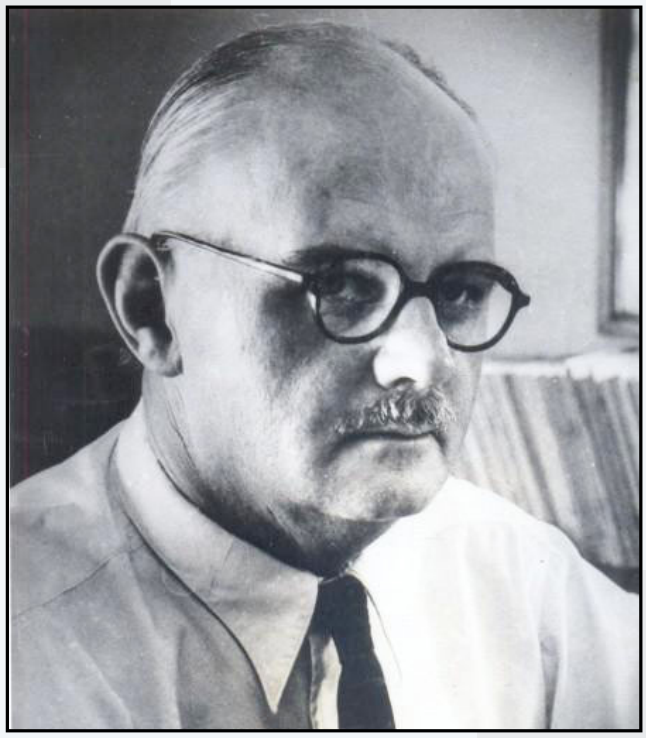
Recovery of Metal Values from Mining and Steel Plant Wastes

In an integrated steel plant, a substantial quantity of ferruginous solid waste such as iron ore fines (30 – 35% of the total iron ore mined), B/F sludge (15 to 20 kg/ton), LD sludge (15-16 kg/ton) and mill scale (18-20 kg/ ton) are being generated during processing and or production of steel. BF sludge contains 28 to 35 % iron and almost a similar amount of carbon whereas LD sludge contains 65 -70% iron along with 8 -10% lime. These ore/fines and BF sludge are partially used in sinter-making in an integrated steel plant whereas LD sludge is treated as waste. No commercial process for effective recovery of metallic value from mining and steel plant waste has been so far developed. Thus, it is either dumped or exported at a very low price. The recovery of metallic value from these wastes or converting it into a value-added product thus remains a challenging task for the iron and steel industries. In view of this, it is envisaged to develop a process for the recovery of metal value from mining and steel plant waste such as iron ore slime, iron ore fines, BF sludge, LD sludge, and mill scale.

The objective of the process is to develop a technology for the production of DRI cylinders utilizing these steel plant wastes in as received condition (without pre-processing). DRI cylinder thus produced will be suitable for steel making in IF, EAF, and BOF as a substitute for scrap. Laboratory scale experiments for reduction kinetics of the DRI cylinder are carried out and process parameters are optimized for the production of a DRI cylinder suitable for steel making. Based on the laboratory-scale investigation, pilot plant trials are planned to be conducted in a commercial tunnel kiln. Raw materials are procured and preparations of cylindrical agglomerate are in progress for the production of DRI cylinder. The workflow sheet for the production of DRI cylinder is given in Figure 1.

Figure 1: Recovery of metal values from mining and steel plant waste

Directors who led the Path on which we walk today...



Prof. George Sachs

(1896-1960)

Served as Director of CSIR-National Metallurgical Laboratory from 1949 to1950

Prof. George Sachs was a pioneering metallurgist and materials scientist known for his foundational work in physical metallurgy. He is best remembered for the Kurdyumov–Sachs orientation relationship, which advanced the understanding of phase transformations in steel. Sachs authored influential books and was widely recognized with honors such as the Carl-Friedrich-Gauss Medal. His legacy continues through awards and contributions that shaped modern metallurgy.

Critical Metals Extraction from Primary & Secondary Resources

With the recent announcement of critical metals for the Indian economy by the Ministry of Mines, Government of India, CSIR-NML has been recognized as one of the leading institutes working in devising extraction methodologies for critical metals. CSIR-NML has also developed a process to recover Ni from secondary products like Monel scrap, spent Ni catalyst, and chromite overburden. Extraction of lithium from spodumene and lepedolite was also established to meet lithium requirements. For strategic sectors, indigenous technologies for extraction of Mg from dolomite/scrap and W from primary resources and tool scraps were established at higher TRL and transferred to several Medium Scale Industries. Technology to extract potash from K-feldspar and Glauconite was established with the National Fertilizer Cooperation. To cater to the ongoing needs of the Steel Industry, extraction of Mn as Electrolytic Manganese Metal (EMM) and Electrolytic Manganese Dioxide (EMD) from ore/ lean grade resources and V as Ferrovanadium and V_2O_5 from spent catalysts, pet coke cinders, and slags were established at 1TPD scale. CSIR-NML has a wide range of experience in the extraction, separation, and refining of rare earth metals *via* molten salt electrolysis. With resources like Indigenous monazite, spent magnets, fluorescent tubes, and waste residue of industries like red mud, tin slag, etc, CSIR NML has demonstrated capabilities in developing unique processing schemes with the aim to holistically recover the rare earth along with value-added products.

Scale up study for the recovery of potash fertilizer and iron oxide from Indian glauconitic rocks

This work is sponsored under the mission mode project, 'Tapping of critical minerals'. Potassium (K) is one of the key macro-nutrient, essential for the healthy growth and development of crops with no substitute till date. Currently, the major sources of potash production are marine evaporative deposits and brines. More than 90% of these deposits are concentrated in countries like Canada, Russia, Belarus, and Germany, on which the rest of the countries (more than 170 countries) are dependent for potash fertilizer. India is currently importing 100% potash (>5 million tonnes) by spending 1.45 billion dollars per annum and projected more in the future if no indigenous production comes up. Therefore, the objective of this work is to utilize our natural resource (K-feldspar) for the production of different potassium salts as well as other valuable by-products like silica powder and ferro-silicon. The process is developed at a scale of 20 kg. The developed indigenous process could be helpful to reduce the import and meet the domestic demand for potash fertilizer in the country. This will also help to allow a stronger negotiation position in the agricultural world market and the use of our natural resources. Finally, this will lead to accomplishing the vision of making potash fertilizer in India.

Filling the gap in the silver recovery process

The project aims to analyse the existing technical and quality system of the silver metal manufacturing process cycle from input to finish goods and to standardize the system of metal accounting/metal balance for silver recovery at the sponsor's metal plant, Uttarakhand. The sponsor approached CSIR-NML to solve the silver recovery fluctuation problem (between 95 and 99%) in their existing process. Accordingly, CSIR-NML visited their plant to observe the process chain. Based on the observation and technical discussion with the shop floor personnel in charge of the unit, CSIR-NML understood that each unit operation for every batch had an important role in determining the final silver metal recovery quantitatively and qualitatively. Therefore, CSIR-NML stressed on the requirement for batch-wise data of each unit operation (monthly) for better estimation of

the silver metal recovery and evaluation of the performance of each unit operation. Accordingly, six integrated study cycle batches were operated at the plant as suggested by CSIR-NML team. The samples generated during the study cycle batch were characterized in detail at CSIR-NML. CSIR-NML also performed material balance for each unit operation/process followed by theoretical analysis of various unit operations and processes by thermodynamic tools to find out critical process parameters for optimum efficiency of each unit system/furnace. The project will help the sponsor in proper accounting of silver during raw material processing till the final products produced at their metal plant. The outcome of the project will also assist in taking the necessary measures to achieve the goal of consistent recovery and increase profitability

Recovery of lithium from potential Indian primary resources for battery applications

The demand of lithium is projected to increase by 1.5 times by 2025. At present, the recovery of lithium values is not practiced in India and hence, the entire requirement of lithium and its compounds is exclusively fulfilled through imports. Thus, it is the need of the hour to utilize the available resources judiciously. Even after the discovery of lithium-inferred resources in Karnataka, Rajasthan, and Jammu, its potential needs to be explored for the production of lithium salts required for manufacturing battery. Given the above, studies on characterization, beneficiation, and extraction of lithium values in a marketable form from two potential Indian deposits will be undertaken in the proposed research investigation. The project aims to develop the process flowsheet for the preparation of Li-battery from potential Indian primary resources such as (i) Reasi deposit in Jammu and Kashmir (J&K), (ii) Bihar mica schist belt, (iii) Degana in Rajasthan, (iv) Amareshwar in Karnataka.

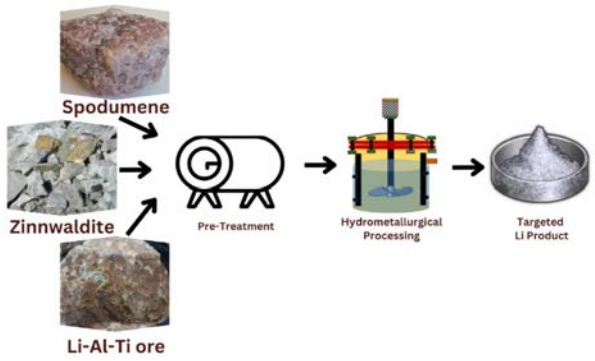


Figure 1: Processing of Indian Lithium Bearing Minerals to Extract Lithium Product (Salts).

Technology development for extraction of critical metals (niobium, tantalum, scandium) from secondary resources/potential wastes

Since there are no primary resources for critical metals like Niobium, Tantalum, and Scandium; it has been proposed to develop a technological flowsheet that caters to extraction and separation of these elements as pure oxide salts from hugely available and targeted secondary resources of Waste Electrical, Electronic Equipments (WEEE) capacitors and tin slag. Tin slag is a potential resource of Niobium (Nb), Tantalum (Ta), and other critical metals. It contains 8-10% Ta2O5, 14-18% Nb2O5. The feed material has been subjected to mineral liberation analysis and flotation circuits. The concentrate and as-received samples have been subjected to hydrometallurgical processes. The Pregnant Leach Solution (PLS) generated is tested for separation of the desired metals like Nb, Ta, Ti, etc. To extract scandium, the Ministry of Mines supported a project to develop a novel hydrometallurgical technological process for the extraction and separation of scandium from tin slag. The extracted PLS is now being pursued for separation of Scandium (Sc) from other impurities. Ta-based capacitors serve as a critically important waste resource of Ta including Ag. In a project under Mission Waste-to-Wealth of CSIR, it is aimed to process these capacitors (Surface Mounted Device(SMD) and Multi Layer Ceramic Capacitor(MLCC)), to extract and separate Ta as

99% pure salt/oxide at CSIR-NML, which will be subjected to making of tantalum metal by NIIST.

Figure 2: Processing of Industrial and Electronic Wastes in Recovering Critical & Strategic "Tantalum"

Extraction of Vanadium as High Pure V_2O_5 & Ni-Salts from Pet-Coke/Coal Gasification Cinders

Coal gasification generates a residue (left-over) known as coal cinders, which is about 3 – 5% of the coal mass; wherein several critical and valuable metals that are present in the coal are enriched.

Figure 3: Pet-coke cinder obtained from M/s M3 MetTech Pvt. Ltd.

CSIR-NML has developed a bench-scale process for the economical extraction of vanadium and nickel from coal cinders as high pure V_2O_5 and Ni-salts. The process developed yielded higher than 85% overall metal recovery with no effluents. The process by-products are useful and saleable. This project, aims to further scale up the developed process at 100 – 200 kg/day scale coal cinder processing with participation from the stakeholders. During process scale-up (piloting), it is envisaged to generate and collect detailed techno-economic information, including process engineering data, that would be helpful for the preparation of a basic engineering/detail engineering package which is essential for further commercialization of the process. Major completed tasks include: complete revamping of the roasting–leaching pilot plant, large-scale procurement of required chemicals/ consumables including a collection of about 3MT coke gasification cinders from one of the Industrial partner (M3MetTech Pvt Ltd.), sizing (grinding & classification) of more than 1MT coke cinders, two large scale roasting campaigns with more than 100 kg coke cinders, and detail physico-chemical characterization of pet-coke cinder and their roasting products.

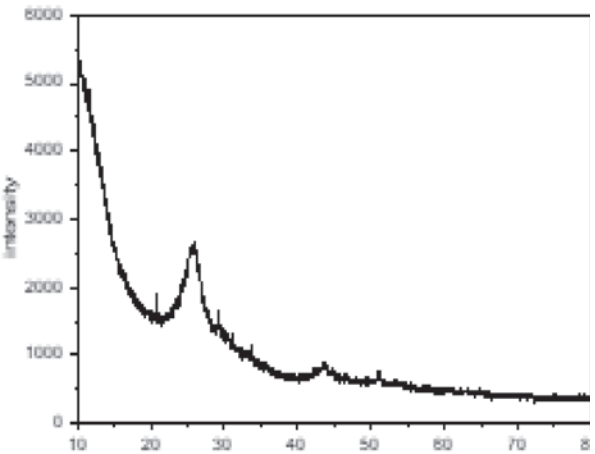


Figure 4: XRD of the Cinder Sample

Roasting and Hydrometallurgical Processing of Coal Slag

The sponsor of the project is setting up one of the world's largest coal gasification project (CTG) at their Jamnagar refinery complex with a total investment of USD 4.0 billion. The envisaged plant would treat more than 30 million tons of coal/ coke per annum for the production of fuel-grade synthetic gas (Syngas). It is further estimated that this plant would generate 200 – 250 kilo tonne/ annum gasification slag containing valuable metals such as V, Ni, etc (~6% V and 1.2% Ni). The sponsor has developed an in-house process in bench scale for extraction of vanadium (V) and Ni from such slag . The developed bench scale process comprised of the following major steps: alkali roasting of slag, leaching of roasted slag followed by purification of leach solution, precipitation of $FeO.V_2O_5$ form the purified leach solution and processing of the leaching residues for recovery of Ni. This bench scale process needs to be up-scaled with the generation of vital techno-economic data for further piloting and ultimate commercialization. Through this project, the sponsor has processed more than 4.5 MT coal gasification slag, by using CSIR-NML's pilot plant facility and expertise and produced more than 100 kg high pure Ammonium Meta-Vanadate (AMV) and ~ 40 kg high pure FeO. V_2O_5 for subsequent production of Fe-V through Al-thermic route.

Figure 5: The dried, pulverized and screened slag sample to be used for alkali roasting

Figure 6: Ammonium Meta-Vanadate produced from coal-slag.

Development of Process for Large Scale Production of Electrolytic Mn Metal (EMM) from $MnSO_4$ Liquors

Manganese is essential to iron and steel production because of its sulfur-fixing, deoxidizing, and alloying properties. Every metric ton of steel production requires about 5 – 10 kg of Mn depending on the grades. Besides, one of the fastest growing application sectors of this metal is Lithium Ion Batteries, where EMM has shown a promising material for the development of high storage "Manganese Rich Cathode". According to CPM Group "Manganese Metal Outlook-2012", about 97% of global EMM output was from China, followed by South Africa 2.1%, both virtually controlling the whole market. India, with manganese ore reserves of about 52 million tons hasn't produced EMM commercially to date, and there are ample scopes for indigenous production of Mn metal from various primary resources. Through this project, it is planned to produce Electrolytic Manganese Metal (EMM) indigenously by using the manganese sulphate liquor of the sponsor's Electrolytic Manganese Dioxide (EMD) plant. For this purpose,

the sponsor has supplied CSIR-NML 2.5KL of purified manganese sulphate solution. This solution was further fine-purified to remove the traces of Ni, Co, Fe etc., through sulfide precipitation. The final purified solution, which will undergo electrolysis has less than 1 ppm each of Fe, Co, Ni, Zn, etc. For electrolysis, a 500 L capacity double-chambered cell was designed in-house and fabricated through a local vendor. This cell is capable of producing 10 -12 kg of Mn metal per day. The large-scale campaigns for EMM production will start and the process will be demonstrated to the sponsor.

Figure 7: Large Scale set-up for production of EMM

Scale-up study for the recovery of potash fertilizer and iron oxide from Indian glauconitic rocks

This project intends to up-scale the lab-scale process for the production of potash fertilizer and iron oxide from Indian glauconitic rocks up to pilot scale level (10-20 kg) for better assessment of techno-economic feasibility. Glauconite is a naturally occurring group of dioctahedral, potassium, iron-rich micaceous clay minerals of marine origin with very low weathering resistance and easily available at the surface to sub-surface level. The biggest challenge to utilizing glauconitic is to break the alumina-silicate structure to recover potassium from this matrix in an economical and eco-friendly way. Along with potassium, iron is also considered a valuable element present in the glauconite. The previously studied and reported processes use a high concentration of acid, a high solid-to-alkali ratio, and hazardous salts such as fluorides, chlorides, etc., to achieve high dissolution of potassium only. For one reason or another, mainly due to the availability of highly soluble potash salt of marine origin and process economics, none of these processes has been commercially successful. A careful study of these attempts warrants the statement that the solution of this problem depends entirely upon the simultaneous recovery of high-value by-products along with low-value potash. The process developed at lab-scale is economic, environmentally friendly, and sustainable in comparison to earlier developed processes. From the overall composition of glauconite and basic structure analysis, it is evident that iron is only a weak link present in the complex structure of glauconite. It can easily change its oxidation number under different oxidizing and reducing atmospheres, thus can break the matrix easily during its conversion to form different species. Therefore, the subsequent attempt was made to break the structure by reduction roasting and redox roasting of glauconite before acid dissolution to recover maximum potassium

values. The process uses very mild acid for its dissolution, which makes the process cleaner. This process had the added advantage of simultaneous recovery of iron oxides along with the recovery of potash fertilizer. The overall research showed that the recovery of potassium is more than 98% and recovered in the form of soluble salts along with valuable by-products in the form of nano-sized iron oxide particles. The final product of this process is potash fertilizer, which is used by the fertilizer Industry, and iron oxide for the pigment industry. This will help more than 60% of India's population whose primary source of livelihood is agriculture. It will also help in reducing the 100% potash fertilizer import.

Rare Earth Recovery from Waste Magnet (NdFeB)- Waste Scrap to Metal/oxide/salt Product

To meet the country's requirement of rare earth metals, to decrease the dependence on primary resources, and to suppress the 100 % import dependence, this project proposal aims to develop a suitable and scalable know-how for the extraction of rare earth metal from waste magnet scrap (swarf and end-of-life scrap) in the form of metal, alloy, mixed oxide, and salts by using suitable pyro-metallurgical, hydrometallurgical, bio-hydrometallurgical and electrometallurgical routes. This proposal is crucial with the expected high demand (18600 MT by 2030) of rare earth metals (Neodymium and Praseodymium) in India for brimming current sectors like electric vehicles, wind energy mills under renewable energy and electronic sector against the current reliance on imports (100%) and aims to align with principles of circular economy. The mission project aims to develop a technology to extract rare earth metals from waste NdFeB scrap and magnets and to recover them as valuable and marketable products. This indigenous technology will help in creating an alternative stream of rare earth metals (predominantly Nd, Dy, and Pr).

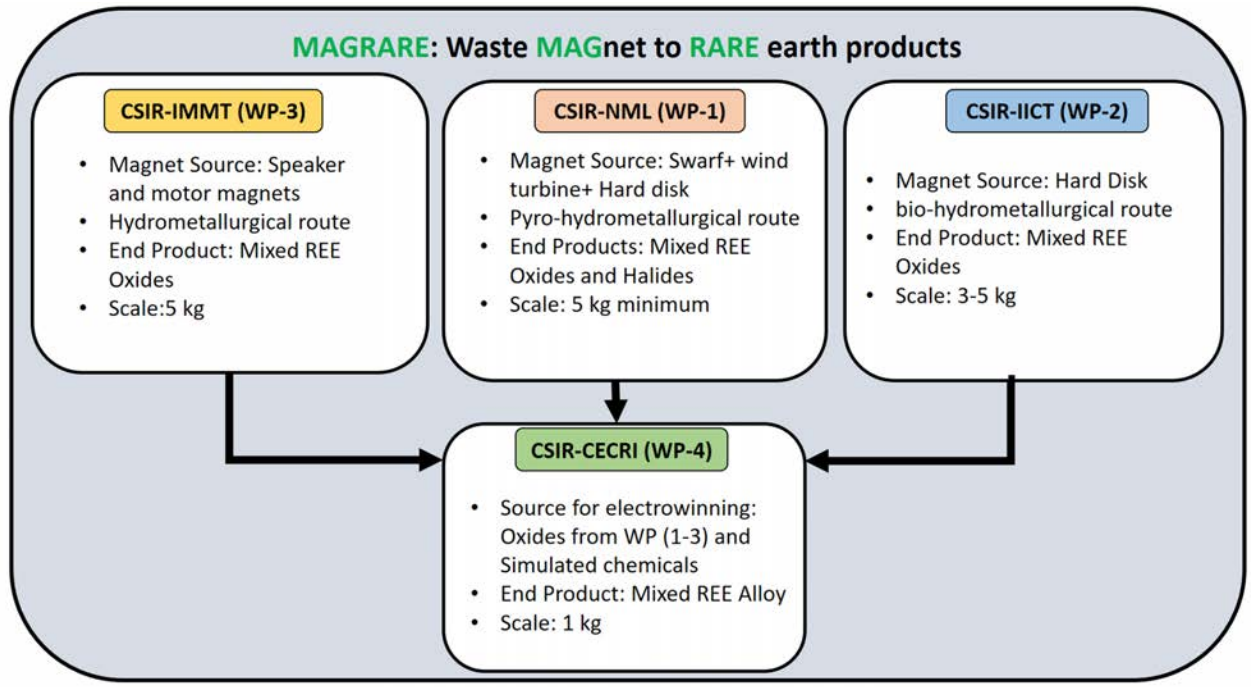


Figure 8: Flow of activities for participating labs under Mag-net and rare-earth (MAGRARE) project

Process Development for Refining Commercial Magnesium Metal through Vacuum Distillation in Semi-Continuous Mode at 5-6 kg Scale

This project aims to scale up the vacuum distillation process at 5-6 kg scale from the developments achieved in earlier activity at 1 kg batch scale. The activities involved are to refine the commercial magnesium (99.80% purity) to ultra-high Magnesium (>99.95% Mg, Fe & Al < 40 ppm) and recovery of pure Mg from Mg alloys/scraps. Several experiments were conducted with commercial magnesium and various Mg scraps like aeronautical scrap (94%Mg), automotive gear grade (91% Mg) and Mg die casting scrap (92% Mg). Images of raw materials/scraps are shown in Figure (9) below. Figure (10) below depicts the various morphologies observed during vacuum distillation tests for Mg refining/recovery along with SEM micrographs of dendritic and spherical droplet deposits during condensation.

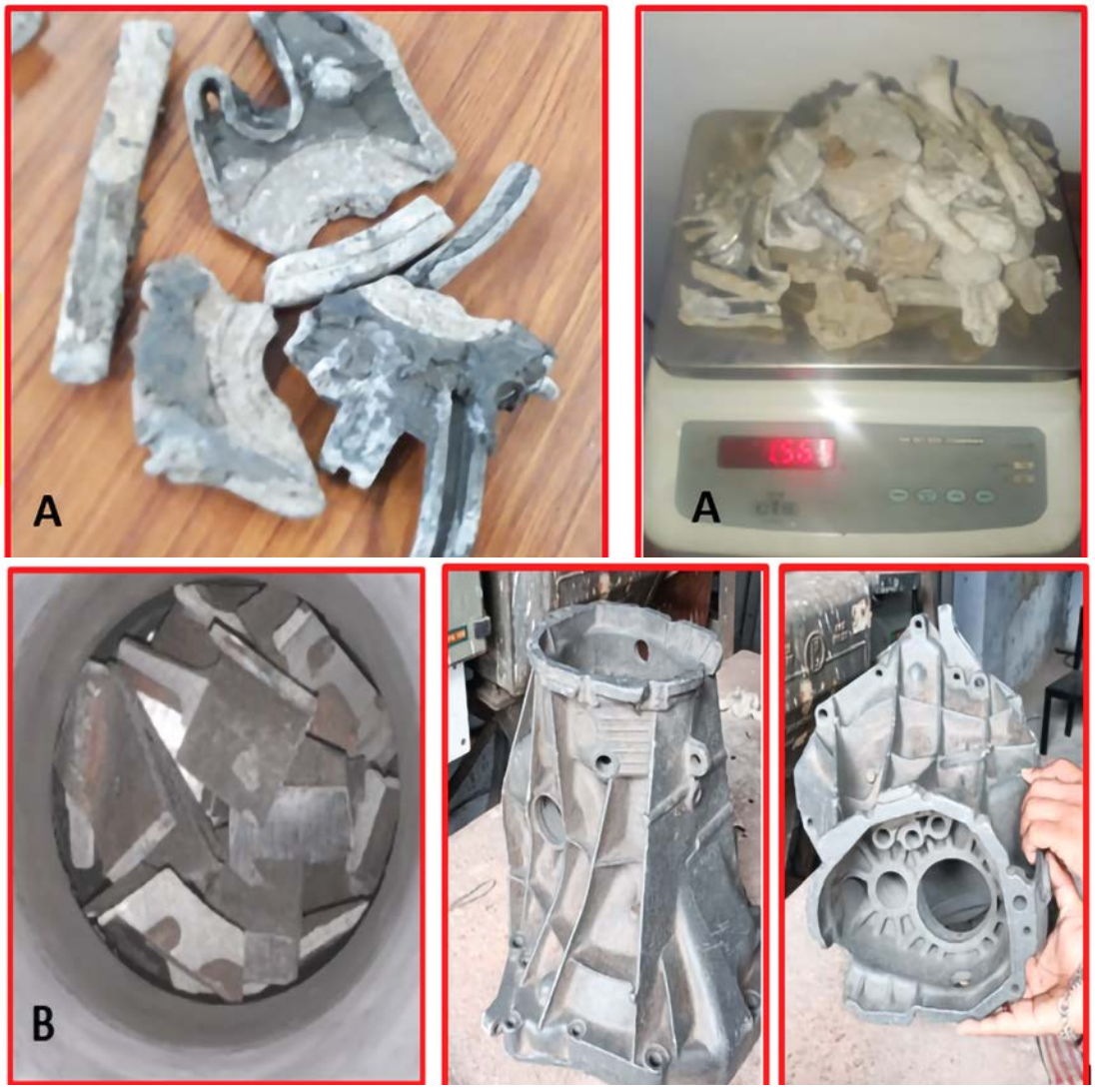


Figure 9. Figures showing, a: Aeronautical grade-Engine component scrap (94% Mg), b: Automotive gear grade Mg alloy scrap containing 90% Mg

Figure 10. Morphologies of Mg distillates in various shapes and sizes with SEM micrographs of dendritic and spherical droplet deposits during condensation

Towards scaling up the process from 1.5 to 5-6 kg scale, an equipment "Semi-Continuous Mg Distillation" is designed with the facility to charge crude magnesium metal intermittently under vacuum, which will be melted in the upper crucible and the liquid magnesium will fall into the bottom vaporization crucible.

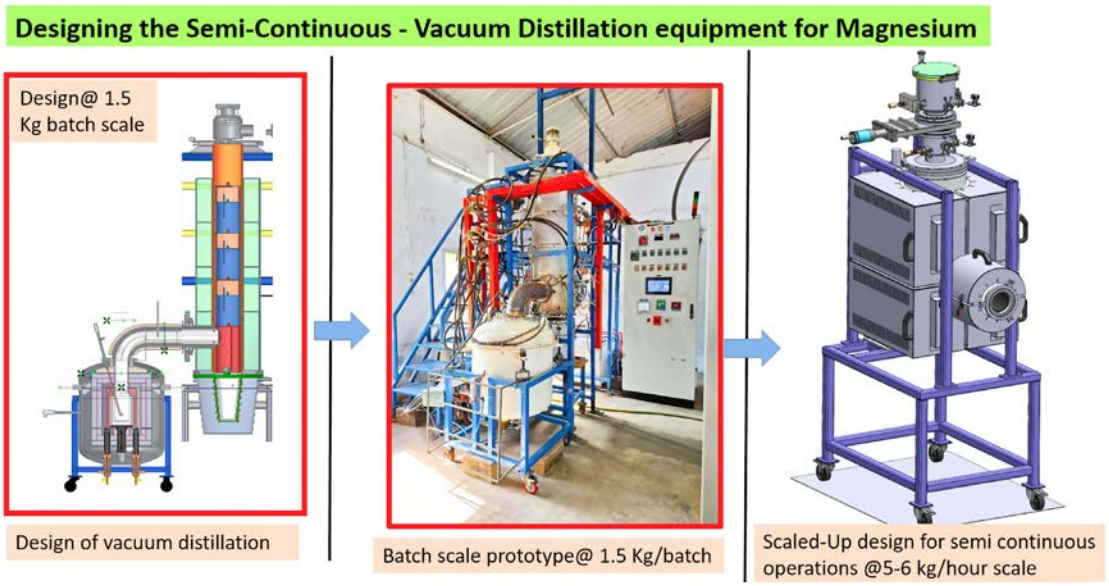


Figure 11 : Semi-continuous-Vaccum Distillation equipment

Purity of refined Mg is achieved up to 99.95% with Fe< 40 ppm and Al<60 ppm, whereas for scrap recycling, recoveries were above 95% with 99.9% purity in single-stage vacuum distillation. Second-stage distillation is initiated to study the aluminium content variation in the final ingot/product. India is the third largest country to import primary magnesium metal and it is 100% dependent on Chinese supply. The outcomes of this project may lead to establishing strategic technologies for high-purity Mg for titanium and zirconium programs for DAE and ISRO. The recycling of Mg scrap would certainly be a greener way for extracting primary and high-purity Mg metal towards strengthening the Indian economy by supporting the various missions of Govt. of India i.e. "Atmanirbhar Bharat", "Make in India", "Viakashit Bharat".

Urban Ore Recycling

Urban ore mining is a process to recover valuables from the waste generated in urban areas e.g. E-waste including batteries, scrap, construction and demolition waste, end-of-life fluorescent bulbs, etc. According to a recent report, India is the 3rd largest e-waste producer in the world, and hence, it holds an economic potential of USD 6 billion. Thus, it can be considered one of the fastest-growing business opportunities. CSIR-NML has foreseen the potential in this area and started working on e-waste in 2005, with a focus on PCB recycling. In the year 2006, CSIR-NML collaborated with Korea Institute of Geoscience and Mineral Resources (KIGAM, Korea) and carried out many successful projects together. The activities in this area continued to grow and resulted in the establishment of the first Urban Ore Recycling Centre of the country, inaugurated by Dr. Shekher C Mande, Former DG, CSIR in 2019. Today it is an internationally recognized center, which has a close loop piloting facility for recycling and has licensed the technologies to 15 entrepreneurs. Another major activity in Urban Ore mining is recycling end-of-life batteries for the extraction of lithium, nickel, cobalt and manganese. Recently CSIR-NML has put up a one ton/ day capacity lithium battery recycling plant. Recently, activities such as extracting critical metals from secondary sources such as LED bulbs/ tubes, spent catalysts, batteries, magnets, Printed Circuit Boards (PCBs), industrial wastes, etc. have been one of the thrust areas at CSIR-NML where outstanding interventions have been made and successfully translated to relevant industries. Plans include recovering high-purity metals from End-of-Life (EOL) solar Photovoltaic(PV) panels, Indium from monitors/screens/LCDs, etc.

Recovery of Metal Values from Spent Lithium Ion Batteries and Fabrication of New Lithium Ion Batteries [A Circular Economy Approach-Battery to Battery (B2B)]

Spent lithium-ion batteries (LIBs) are increasingly being considered as a preferred secondary resource for the recovery of critical battery metals. However, due to variances in battery chemistry vis-à-vis applications and to recover the values from various batteries economically, CSIR-NML in a Bulk Chemicals Mission mode project has developed patented processes for recycling of NMC-Nikel, Manganese, Cobalt, Lithium Cobalt Oxide (LCO), Lithium Iron Phosphate (LFP), Lithium Manganese Oxide (LMO), Nickel, Cobalt, Aluminium (NCA) as individual and mixed lithium batteries to extract and separate all metals. To meet the economic and sustainability challenges that the battery recycling business faces, as well as to create a sustainable and local essential materials supply chain, there is an urgent need for technological advancement in the Indian scenario. The B2B project was created based on the expertise available at CSIR Labs, which focuses on the recovery of metal values from spent lithium-ion batteries and the fabrication of new ion lithium-ion batteries. The project broadly aims for: Sourcing of tonnage volume spent/scrap/ waste LIBs by CSIR-NML and processing at CSIR-NML; Recycling all available chemistries of spent lithium-based batteries (LCO, NMC, NCA, LMO, LNA, LFP), for extraction and separation of high pure (approx. 90%) materials of Li, Mn, Ni, Co as carbonate/sulfate and synthesis of mixed metal oxide precursors. The obtained pure salts shall be upgraded further to the desired levels by CSIR-CECRI to make new batteries.

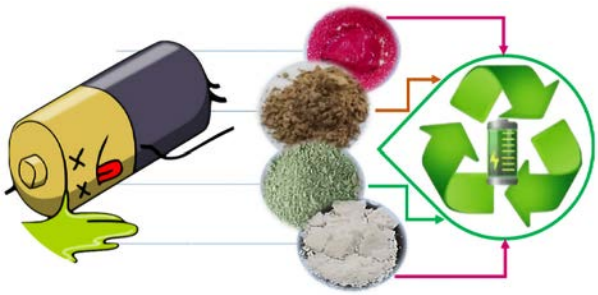


Figure 1: Battery to Battery Recycling

Recycling of graphite from spent lithium-ion batteries for high-energy Li-ion capacitors

This project is funded by the Waste Management Division of DST, and operated in the close knit association of CSIR-NML Jamshedpur, IISER-Tirupati, and Industrial Partner The project aimed for the recovery and purification of graphite from spent Lithium Ion Battery (LIB) followed by the production of high energy and power Lithium Ion Capacitor (LIC) (>150 Wh kg^{-1}). The high pure graphite synthesized at CSIR-NML was submitted to IISER, Tirupati for trials. The graphite analysis showed >95% purity based on a chemical analysis. Herein, recovered graphite (RG) was reported from dead Li-ion batteries as an excellent conductive additive that can improve the electronic conductivity of the electrode material. The surface morphology and structural features of RG were observed by field emission scanning electron microscope (FESEM) and high-resolution transmission electron microscopy (HR-TEM) as displayed. The FE-SEM images of RG exhibited a varying size distribution. The flaky morphology with varying size distribution of RG was very prominent, and the particles were agglomerated, which was visible from the SEM images.

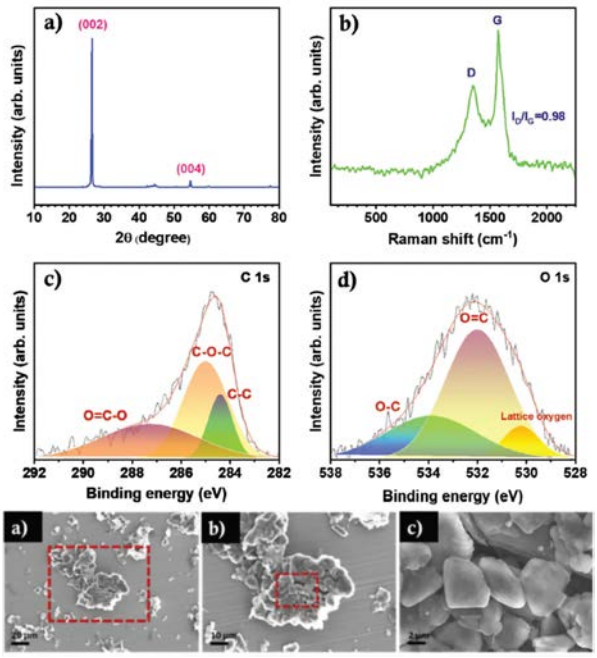


Figure 2: SEM Images

Development of process for synthesis of copper and nickel metal powders from Waste Electrical and Electronic Equipments (WEEES) for additive manufacturing

WEEEs are a rich source of Cu and Ni. Copper accounts for around 35% weight of WEEEs and Ni contents ranges from 5-60 wt%, which can be converted to high quality metal powders of desired shape and size using hydro-cum-electro-metallurgical methods. With India's current vision of indigenous technologies in additive manufacturing by 2030, continuous research and innovation are required. This also contributes to the cost of the metal powders used for 3D printing. Thus, technological intervention is required to reduce this cost by a cheaper process and less costly raw material. A robust technology (TRL-3/4) is aimed at integrated hybrid hydrometallurgical and electrochemical methods for Cu and Ni powder synthesis from WEEEs. This process shall be unique to the remediation of metal wastes in spent batteries as well as integrating solvo-metallurgical methods to convert Cu and Ni fractions to copper and nickel metal powders. The products aimed at

are 99% Cu with particle size 80% below 60 µm and 98-99% Ni with particle size 95% below 60 µm.

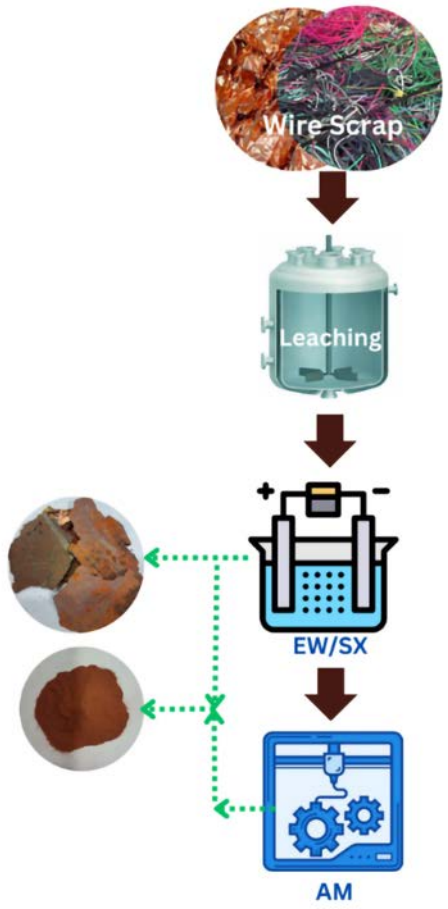


Figure 3: The process

Recycling of lithium-ion batteries (LIBs) to recover valuable metals/ materials

Know-how to recover Co, Li, Cu, Ni and Mn from Lithium-Ion Batteries (LIBs) was developed by CSIR-NML and transferred to Industry. Initially, the spent LIBs were discharged followed by shredding using scutter-cutter. Dry as well as wet gravity separation techniques were used for the separation of black powder, plastics, and metallic fractions. The black powder obtained was processed for leaching of metals using chemical processing in a closed-loop system in a leaching reactor as per the CSIR-NML technological know-how and optimized conditions. The leach liquor generated was filtered using a filter press to separate the solution from the slurry, whereas the leached residue (mainly graphite) was further treated and washed to make saleable graphite. The leach liquor was collected and kept in a storage tank to be further processed using advanced separation techniques. From the leach liquor, the selective separation of Cu and Ni was made using solvent extraction techniques. The obtained purified solution was processed for the recovery of Co, Li, and Mn using precipitation, evaporation and electro winning techniques.

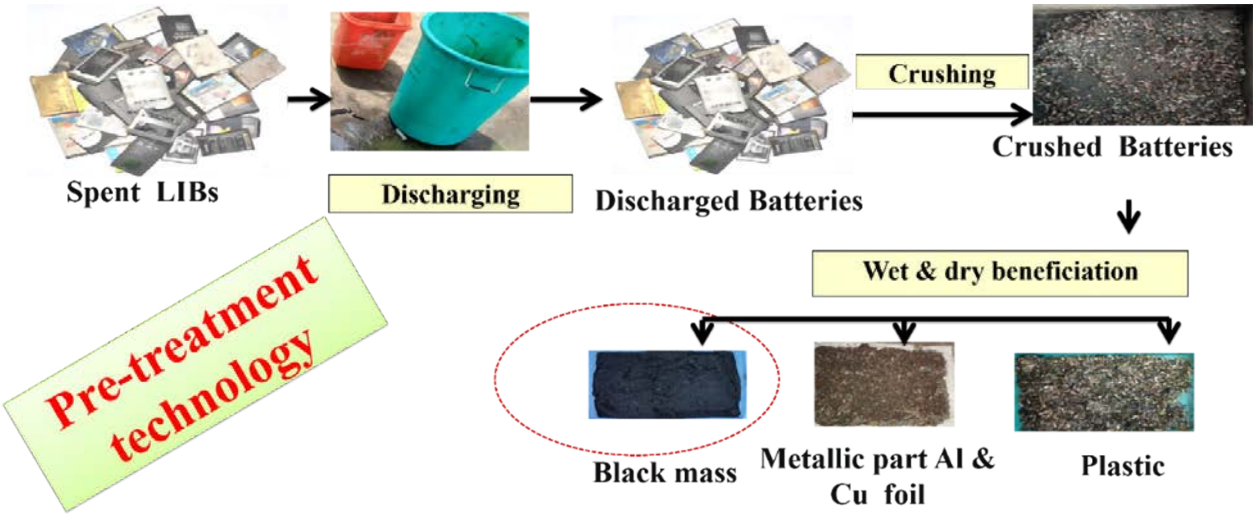


Figure 4: Pre-treatment of spent LIBs to separate black powder, plastics and metallic fractions

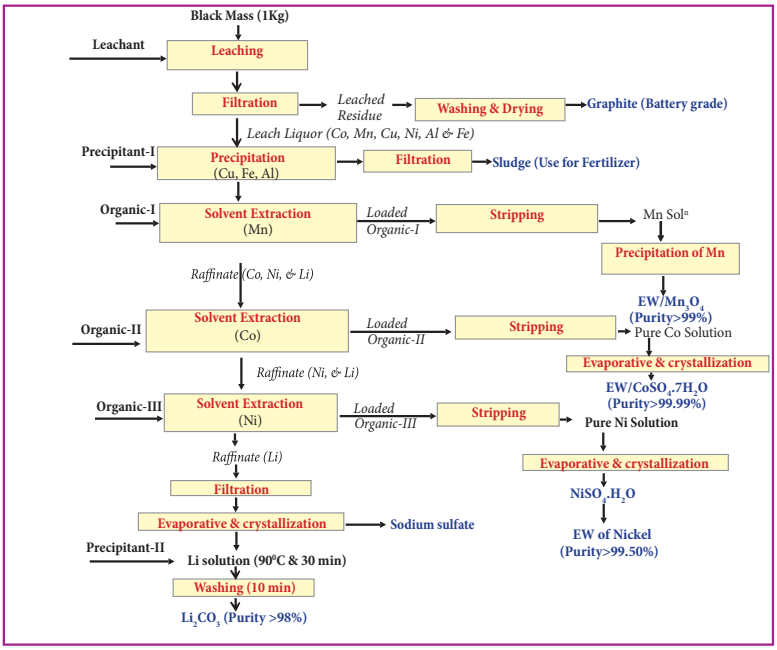


Figure 5: Complete process flow sheet to recover Cu, Ni, Co, Li & Mn from spent lithium-ion batteries (LIBs)

Extraction of Cu, Al and Au from waste PCBs

Know-how for the extraction of Cu, Al and Au from waste PCBs was developed by CSIR-NML and transferred to Industry Initially, the PCBs are dismantled and depopulated. Further, pre-treatment and physical beneficiation of the crushed PCBs was carried out to separate, non-metallic (epoxies) and metallic concentrate (mainly copper). Hydrometallurgical recovery of Cu from metallic concentrate of PCBs was carried out under the optimized condition followed by recovery of gold from the small depopulated components. Aluminum was recovered from the heat exchanger mounted on the PCBs.

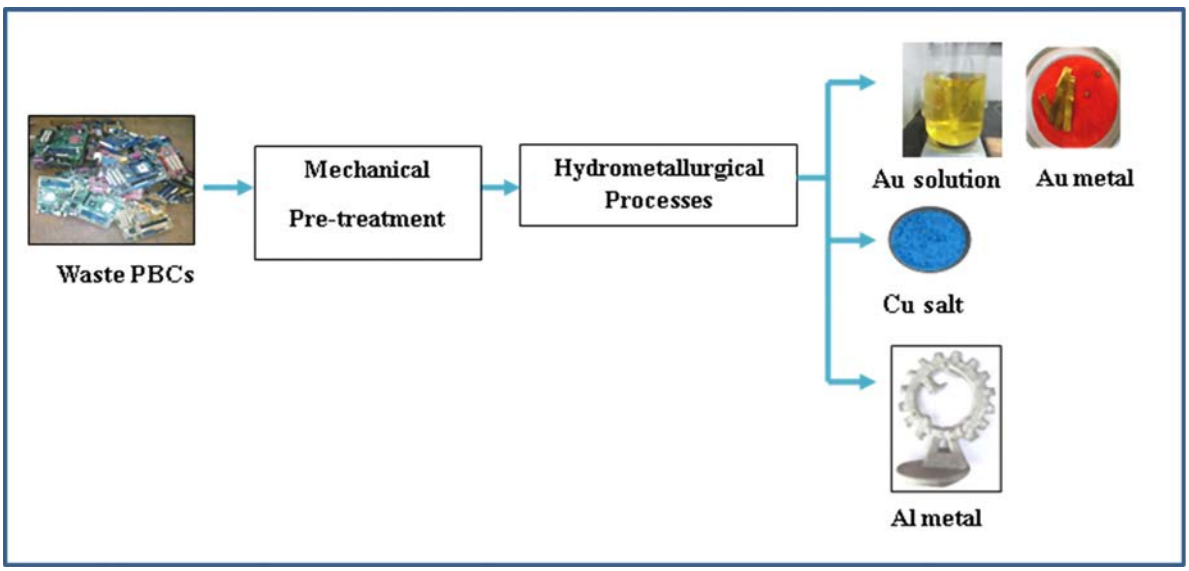


Figure 6: Process flow sheet to recover Cu, Au and Al from waste PCBs

Waste Valorization

In recent years, waste-valorization has gained immense importance not only as a means of pollution mitigation but also due to the huge potential for new entrepreneurship and business opportunities. Waste valorization refers to any process of recycling, reusing, or converting waste materials into value-added products. The Indian government's approach to waste valorization is multi-pronged, focusing on policy support, technological innovation, public-private partnerships, and financial incentives. The goal is to reduce landfill waste, promote resource recovery, and create economic value from waste, aligning with India's sustainability and net-zero commitments. CSIR-NML has done many pioneering works in this area of mineral and metallurgical waste-valorization and many of its processes were adopted by industries. The focus of the research was twofold, value extraction from the waste and value addition to the waste. Some of the important work carried out in recent times includes high volume utilization of granulated blast furnace slag and fly ash in Portland slag cement and Portland pozzolana cement respectively using mechano-chemical activation, sustainable cementitious material from various industrial wastes using geopolymerisation, ceramic and refractory products from industrial wastes, briquetting of iron ore slime, hot stage modification of copper slag, etc. The plan includes the development of a holistic process for the extraction of critical metals from secondary/ by-products and the use of remaining residues in construction materials.

Eco-Friendly Solution with Metal Recovery and Value-Added Products from Stainless Steel Spent Pickle Liquor: A Zero Waste Business Model

The project sponsored by MoS was undertaken in collaboration with BITS Pilani and a steel industry partner to develop a flow-sheet for recovery of Ni, and Cr from spent stainless steel pickling liquor and sludge in the form of value-added products. During the pickling process of stainless steel, the pickling activity decreases with increasing dissolved metal concentration with continuous operation and is rejected as spent pickle liquor (SPL). The liquor contains about 2-10 g/L Ni, 3-15 g/L Cr and 10-50 g/L Fe along with 30-150 g/L free acid. The normal practice of neutralisation and dumping of sludge containing valuable metals is not only hazardous to the environment, but it also incurs huge loss of revenue. Therefore, the project was undertaken to provide an eco-friendly solution for the recovery of metal values as well as fixing toxic components of process residue through the production of value-added products. The SS spent liquor and sludge samples were collected and characterized. Iron in the pickle liquor is about 80% of the total metallic content and creates difficulty during the recovery of the valuable metal. Therefore, both selective precipitation and solvent extraction methods were optimised to separate iron for further recovery of Cr and Ni. By a two-stage selective precipitation approach, a hydroxide/oxide sludge is produced with the higher Cr: Fe ratio which can further be smelted to produce Fe-Cr alloy. Complete iron removal is achieved by solvent extraction without co-extraction and subsequently, Cr and nickel are recovered by selective precipitation. Along with stainless steel pickle liquor, a flowsheet was also developed for recovery of metal values and fixing the toxic components. The sludge was leached in sulphuric acid to selectively dissolve Ni and Cr. Under optimised conditions, a counter current leaching (CCL) method was adopted to maximise Ni and Cr dissolution. A sufficient quantity of Ni-free leached residue was generated and sent to BITS Pilani, for fixing the experiment's toxic component through the production of value added products.

The treated residue was utilized to produce eco-friendly pavement tiles with a strength of up to 30 MPa by mixing it with cement, river sand, and fly ash.

Hot stage engineering of copper smelter slag for recovery of iron and subsequent use of resulting slag in blended cement

India is generating about 1.7 million tons of copper slag annually. A significantly minimal percentage is utilized for low-end applications and the rest is mostly dumped, thus occupying large space for a longer duration. Till date, this slag has been mostly utilized as aggregates in road construction and concrete, mine backfilling, etc. However, its high iron content (~35-60%) and lack of suitable oxide components limit its utilization in blended cement. Therefore, a process that can address both the recovery of high iron value at the molten stage and modify the resulting slag by adjusting chemical composition for subsequent use in blended cement. The carbothermic reduction smelting of the copper slag by using carbonaceous material, metallurgical coke, is carried out to remove Fe from the FeO-SiO_2-(Al_2O_3) slag vis-a-vis modify the liquid slag composition using lime (CaO) to create CaO-SiO_2-(Al_2O_3), which can be a suitable component for blended cement. The raw or pre-calcined limestone is used as a flux. The smelting of the charge mixture is carried out in a 50KVA electric arc furnace at 1500- 1600 ˚C and reduced its FeO into pig iron, which accumulated at the bottom due to inherent high density and finally tapped from the bottom. The chemical composition of the extracted metal was 94-96% Fe, 3.5-5% C, and Si 0.5-2%, which can be used in general usage similar to cast iron. The resulting slag is tapped and water quenched in an indigenously developed granulation tank to get a highly reactive glassy material. This modified slag after granulation is ground and mixed with clinker and tested for Portland slag cement composition. The cement properties of different basicity slags are studied thoroughly. Slag cement using 40% modified slag of 1.0 basicity of both Hindustan Copper Slag and Birla Copper Slag meets the necessary Indian standard (IS) for Portland slag cement (PSC). The Toxicity Characteristics Leaching Procedure test results of the product are satisfactory and meet the obligatory specification. The physical properties of the mortar samples meet the Indian standard IS4031:1988 for Portland slag cement (PSC). A small concrete path is prepared using these slag cement samples for performance monitoring and on-site evaluation purposes.

CO_2 Capture (CC) by Amine Absorption Process with Sequestration by Modified Mineral Carbonation (MC) and Recovery of Marketable Products and Waste Heat (WH)-A Holistic Technology Development Approach

Climate change due to global warming is a worldwide serious concern. Carbon dioxide (CO_2) is a major greenhouse gas responsible for global warming. The rapid growth of atmospheric CO_2 concentration from the pre-industrial era (390ppm) to the present day (422ppm) attracts global concern among the research fraternity. Kyoto Protocol, Copenhagen Accord, and International Energy Agency (IEA) also have urged concerns on the reduction of greenhouse gas emission level by 5.2% and the limitation towards global temperature increase within ±2°C by 2100 and suggested the contribution of CO_2 capture and storage technology up to 19% by 2050. Fossil fuel-based power plants and steel and cement industries are identified as large point sources and primary targets for CO_2 capture and sequestration. In this project, selective CO_2 capture (CC) and mineral carbonation (MC) experiments are performed using aqueous-formulated amine solvents and steel plant slags, respectively, to understand the fundamentals that affect the CC and MC processes. Optimization of factors and load for sequestration of CO_2 in steel slag with valuable product utilization as optimum replacement in OPC with carbonated slag and production of M-35 pavement block for medium traffic application.

Three phases of a trial run of onsite dynamic CO_2 absorption-regeneration using aqueous amine solvents are completed by CSIR-NML at the pilot plant facility at Ram Krishna Dharmarth Foundation (RKDF) University Bhopal under an umbrella MOU with CSIR. A lab-scale mineral CO_2 sequestration study using mineral waste from the steel industry, its application as valuable products, and subsequent testing at the CSIR-NML facility is ongoing.

Holistic utilization of zinc dross for recovery of high value zinc products

Towards the anticipated 300 MTPA target for steel production, India needs to produce/procure Zn proportionally for the production of galvanized steel, and 10-12% of zinc is lost in this galvanizing process in the form of zinc dross. Thus, it can be envisaged that a huge amount of this waste will be generated, resulting in significant loss of zinc values. This loss of zinc in the galvanizing process becomes more important when the increased carbon footprint, depleting primary resources, and huge demands of zinc are limiting factors in primary zinc production. In this background, utilization of zinc dross is a significantly potential step in minimizing zinc loss. This project aims to recover the zinc from zinc dross as high purity metal and zinc sulphate monohydrate via pyrometallurgical and hydrometallurgical routes respectively. This technology is validated at Technology Readiness Level-9 and transferred to a Chemicals Industry at Tohana. Recently, Industrial trials at 2.5 T capacity have been performed to demonstrate and validate the process in an Industrial environment.

Recovery of High grade Zinc sulphate monohydrate and Zinc metal from lean grade zinc dross

- Technology Readiness level : 9
- Transferred to M/s Chandigarh Chemicals
- Validation at 2.5T scale at plant scale facilities at 20 KL and 10 KL Scale
- **Processing :** Pyro and hydrometallurgical

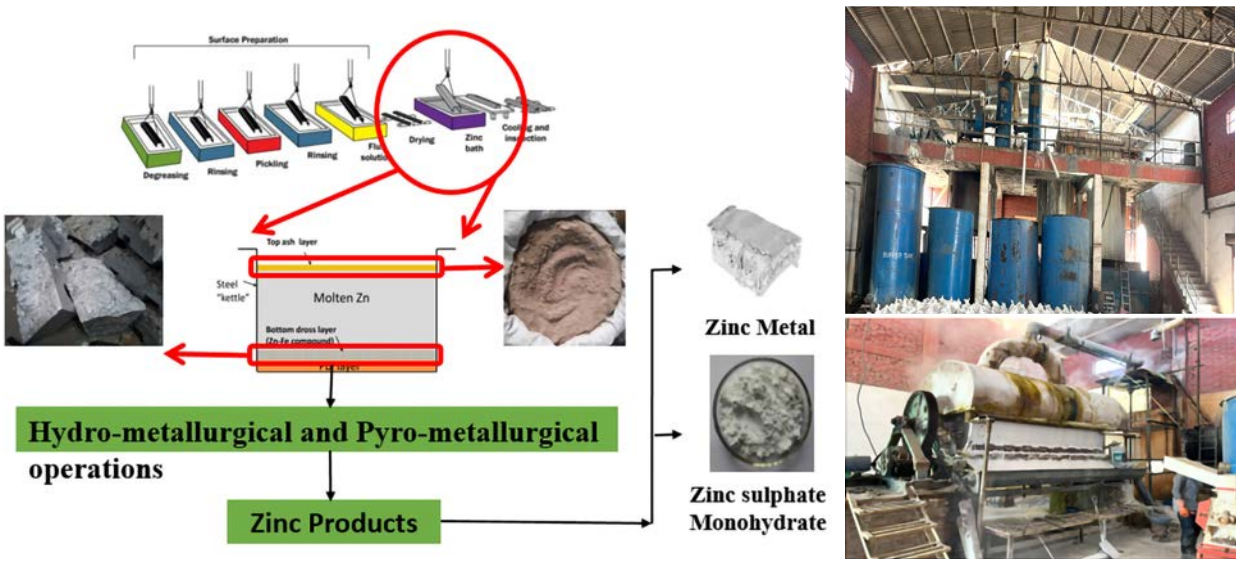
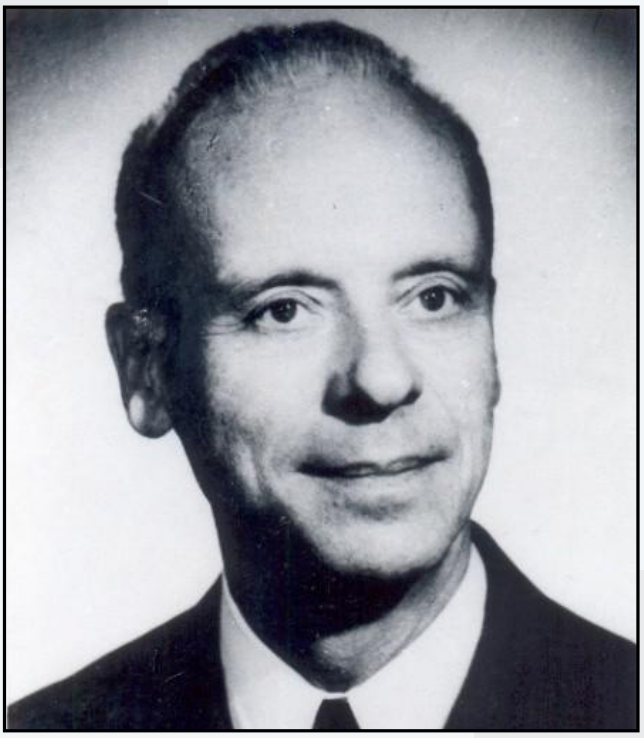


Figure 1: Recovery of high grade zinc sulphate monohydrate and zinc metal from lean grade zinc dross

Directors who led the path on which we walk today...



Prof. Charles Crussard

(1916-2008)

Served as Director of CSIR-National Metallurgical Laboratory from 1950 to 1951.

Prof. Charles Crussard was a renowned French metallurgist who played a pivotal role in establishing the CSIR-NML in Jamshedpur, India, in 1950. Known for his ground breaking work in physical metallurgy, Crussard made major contributions to the understanding of plasticity, phase transformations, and microstructural analysis. His career bridged both academia and industry, and he was widely honored for his scientific achievements.

Alloy Development

The current emphasis on the sustainable development of humankind has given a remarkable fillip to the search for new materials and processes. The stringent requirements for these novel materials are their lightweight, high specific strength, high-temperature strength, excellent corrosion resistance, and better weldability depending upon the envisaged application areas. As all these material properties hinge on their chemical compositions and the microstructure, CSIR-NML has undertaken several challenging tasks related to the development of new or improved alloy compositions and optimizing the process schedule to achieve the desired microstructural characteristics and phase constitution in these materials. Various such alloy development initiatives at CSIR-NML include ultrahigh strength armour steels, structural and functional high entropy alloys, Ni-based superalloys, wear resistant steels for mining and sizing applications, high conductivity and high strength Al-conductor wires, high strength and corrosion resistant Al-alloys, rare earth free hard magnets etc. In addition to alloy and process optimization, development of novel coatings and material joining pathways are also the important research challenges undertaken at CSIR-NML. All these activities on alloy development and processes aim to cater to the "Atma-Nirbhar Bharat" and 'Make in India' initiatives of the government of India.

Pilot upscaling of indigenously developed ultrahigh strength armour steel with excellent toughness

This project aimed for pilot upscaling (clean steel making and processing, preferably 2-3 T capacity) for at least TRL-7 and to produce large size samples (about 500 mm × 500 mm cross-section with 8-20 mm thickness), particularly for ballistic testing. Further, large-scale thermomechanical controlled processing and heat treatment optimization were targeted. Microstructure engineering for assessment and optimization of mechanical behaviour (tensile, Charpy impact, ballistic, etc.), weldability, bendability, etc, will also be conducted. Under the project, the steel compositions are designed with minimal alloy addition and apply novel or recently developed processing scheme to achieve a multiphase microstructure. In addition, the industrial feasibility, i.e., production of these steels with existing facilities, has also been considered in order to avoid difficulties in industrial translation in the future. Over 10 different alloys have been designed based on the theoretical simulations, literature review, and patent search. These alloys were treated through various processing schemes, i.e. through (i) 'continuous cooling' to room temperature at various cooling rates and (ii) 'quenching and non-isothermal partitioning' in the bainite and martensite regions (Figure 1). The above-mentioned processing was applied to eliminate the isothermal holding as required in the tempering and/or conventional quenching and partitioning processes. A comprehensive processing of these alloys, followed by assessment of microstructure and mechanical properties, has helped to identify final chemistry and process technology for pilot upscaling. The mechanical properties achieved for the developed alloys (see Figure 2) suggests the achievement of tensile properties closer to the project target (~ 2 GPa ultimate tensile strength and 7-10% total elongation). Further discussions are ongoing for steel making and hot forging / rolling to produce large size plate for ballistics tests. These plates will be heat treated using a customized muffle and salt bath setup for heat treatment on large size plates (300×300×5-15 mm). All these research activities are expected to provide an optimized alloy composition and process technology for plant trial in the future,

followed by indigenous production of armour grade steel. Thus, advanced high strength steels along with good ductility, impact toughness and fracture toughness have been accomplished, under the project. A further heat treatment optimization is planned on large plate, followed by evaluation and optimization of mechanical properties and fabrication capability (hardness, tensile, charpy impact, ballistic, weldability, bendability, etc.). This will help to arrive at a novel cost-effective steel composition (total alloying < 5%, carbon equivalent <0.6), and industrially feasible energy-efficient process technology for plant trial and indigenous production of ultrahigh strength armour steel with excellent toughness for the production of vehicles.

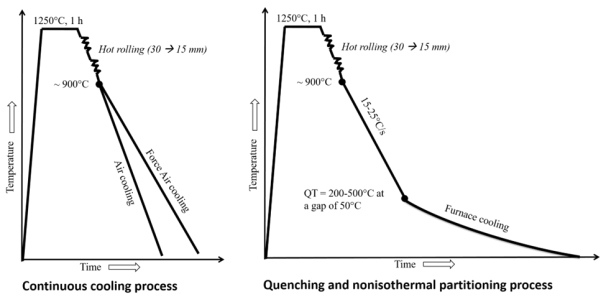


Figure 1: Schematic of the applied processing schedule on designed alloys

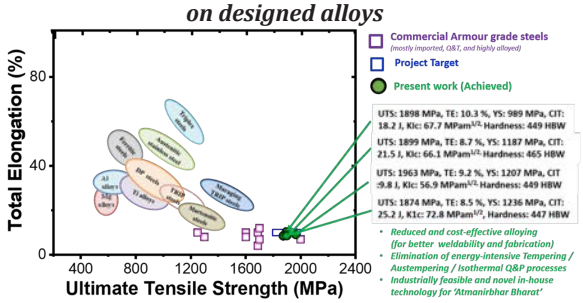


Figure 2: Mechanical properties achieved for the developed alloys compared with literature.

Development of Wear-resistant Steel for Segment of Coal Sizer

The major objectives of this project were: (1) characterization and evaluation of raw materials and existing segment material; (2) establishment of suitable lab scale wear test method to simulate the industrial sizing and crushing operation; (3) design and development of novel and economic alloy composition and its process technology and (4) supervision of modified segment manufacturing, data analysis and suggestion on further areas of improvements. The key findings from the worn-out segment and establishment of suitable lab-scale wear test were: (1) depth of penetration of deformation was 0.8-1.2 mm for completely worn-out teeth whereas the same was 4-7 mm for partially worn-out teeth; (2) a significant presence of Ti-rich particles in teeth surface due to hard-facing operation; (3) partial transformation to body-centered tetragonal (BCT) and hexagonal close-packed(HCP) martensite during partial and after complete worn-out tooth; and (4) wear surface of completely worn-out teeth showed fragmentation and plowing mechanism of wear during sizing operation leading to the selection of dry sand rubber wheel wear test set-up for newly developed alloys performance evaluation at CSIR-NML. Investigation on feedstock raw materials based on megascopic characteristics, coals and overburdens had different mineral composition & structure which affected their strength. Hardness of overburden varied and was higher than coal. The pivot part of used segment tooth became blunt due to the hardness of the raw material. The design of new alloys and their heat-treatment technology followed by a comprehensive experimental investigation was done. Problem specific alloy & process design was done considering low work hardening rate, continuous network of carbides in the grain boundaries, low hardness of the as-received segment, very large grain size, and high wear rate of existing segment. Three new alloys with the appropriate amount of B, Mo, and V addition to the existing segment chemistry & their corresponding heat treatment technology were identified based on comprehensive literature review, numerical simulation, industrial feasibility, etc. A customized steel making (mold, pattern, melting & casting procedures, etc.) and heat treatment practices closely resembling actual segment manufacturing were adopted at the CSIR-NML. A comprehensive experimental analysis in newly developed alloys till date has shown promising results like increase in hardness from about 190 HV to 340 HV due to the

introduction of about 10% second phase particles of Body-centered cubic (BCC) and hexagonal close-packed (HCP) crystal structure along with remaining approximately 90% austenite. Further work is ongoing to assess wear resistance and other mechanical properties for the optimized conditions. This will help to arrive at novel cost-effective steel composition and industrially feasible energy-efficient process technology for making of segments based on CSIR-NML technology and its field trial.

Investigation on Weldability of 8 and 20 mm Thick High Nitrogen Steel (HNS) with Strength of about 800 - 1200 MPa

The project aims at the development of a new filler wire in welding HNS plates using the Shielded Metal Arc Welding process to achieve a minimum 80% base metal strength. Six types of electrodes (D-1 to D-6) with a diameter of 3.2 mm have been developed and coated with commercially available flux. These electrodes are used to weld 8 mm thick HNS plates in butt joint configuration using SMAW process. Dye penetrant and radiography tests are carried out to discover the weldment's flaws. Microstructural investigation has been carried out to examine the characteristics of various zones across the fusion boundary. The Electron Backscatter Diffraction analysis is also conducted over the fusion zone to understand the presence of different phases. Tensile test of the joint assemblies has been performed as per ASTM E8M-16 standard in a 50 kN INSTRON 8800 universal tensile testing machine at a crosshead speed of 0.5 mm/min. The strength of the weld joint of the 8mm plate has increased with the change in the composition of the electrodes. The joint strengths, fabricated using developed duplex stainless steel electrode D-6, are found to be 77.1 ~ 79.6% of the base metal strength. All joints are broken at the fusion zone with the ductile fracture morphology. The fusion zone of the maximum strength sample possesses 56.2% ferrite and 43.8% austenite phases. Indigenously developed electrodes broaden the area of application of HNS plates in the defence sector.

High Entropy Alloys (HEAs) for hydrogen storage application operable at Room temperature (HEART)

Hydrogen storage has inherent difficulty in handling hydrogen because of its low volumetric energy density. A potential solution for a suitable and safe way to store hydrogen is to employ solid-state hydrogen storage systems. However, binary metal hydrides are either very stable (LaH_2, YH_2, ZrH_2, TiH_2, etc.) or very unstable (NiH, FeH etc). The present work focuses on developing an alternate class of materials with excellent reversibility at room temperature and low-pressure storage cycle, free from activation process and enhanced cycling properties. The present study aims to design and develop HEA alloy system comprising predominantly (Ti, Zr) based C14 laves phase as well as BCC refractory HEAs. The objectives of the current work are: (1) designing of HEAs using computational thermodynamic approach (CALPHAD) with a target of hydrogen storage capacity > 2.5wt.%; (2) exploration of appropriate processing strategy for selected HEAs (Arc & Induction melting); (3) detailed microstructural characterization of as cast and heat treated alloys for establishing the phase fractions and respective phase compositions; (4) evaluation of hydrogen storage characteristics in terms of pressure composition isotherms (PCIs) and hydrogenation/ de-hydrogenation kinetics. The following progress and achievements have been made under this project: (i) Design of multicomponent HEAs (07 nos.) adopting CALPHAD approach in conjunction with literature based information, targeting primarily AB_2 Laves phase type and disordered BCC phase type systems has been done; (ii) Arc melting and casting of selected HEAs (07 Nos.): C14 Laves phase (AB_2) type alloy: Two numbers of designed alloys pertain to this category wherein A: Ti, Zr, Nb and B: Fe, Nb, Ni, Cr, Mn. Such alloys basically contain hydrogenating elements (A) on one sublattice, whereas the dehydrogenating elements (B) on another sublattice, which synergistically are expected to render good kinetics of hydrogen

absorption as well as desorption at or near room temperatures. (BCC + Laves phase) type alloy: Five numbers of designed alloys pertain to this category wherein BCC phase is 70-80% and Laves phase is 20-30%. The BCC phase in these alloys (although rich in one/two components) contains both hydrogenating as well as de-hydrogenating components (in lesser fraction) randomly arranged among various available sites of a single sub-lattice which can aid the hydrogenation/de-hydrogenation kinetics; (iii) Detailed microstructural characterization of the selected alloys adopting Scanning Electron Microscopy, X-Ray Diffraction and Energy Dispersive X-Ray Spectroscopy has been done; (iv) evaluation of the hydrogen storage performance of the arc melted alloys (03 alloys) was performed. Alloy reached hydrogen equilibrium within 2-3 minutes depending on the alloy composition. Designed alloys seem to possess good hydrogen absorption kinetics near room temperature; (v) Characterization and comparison of the as-cast and hydrogenated condition of Laves phase-based arc melted alloy has been completed. Moreover, XRD peak shifting and broadening depict lattice expansion and distortion due to hydrogen absorption. (vi) Based on the aforementioned understanding, two heats (Laves phase-based alloys) were prepared using vacuum induction melting (1 kg Capacity) facility. One of the heats with optimum recovery of alloying elements was accomplished. (vii) Detailed characterization of as-cast induction melted alloys are performed. Ingot casting leads to a coarser microstructure compared to arc melted structure. The microstructure reveals presence of $Zr(Cr/Fe)_2$ Laves phase along with the minor presence of Ni_3Ti. (viii) The hydrogen storage performance of the induction-melted alloy is carried out. Hydrogen absorption is more than 1 wt.% within 1-2 min. time at all the studied temperatures. Hydrogen absorption is ~ 3.7 wt.% at 80°C with 40 atm. pressure. Absorption kinetics seems to be fast near ambient temperature.

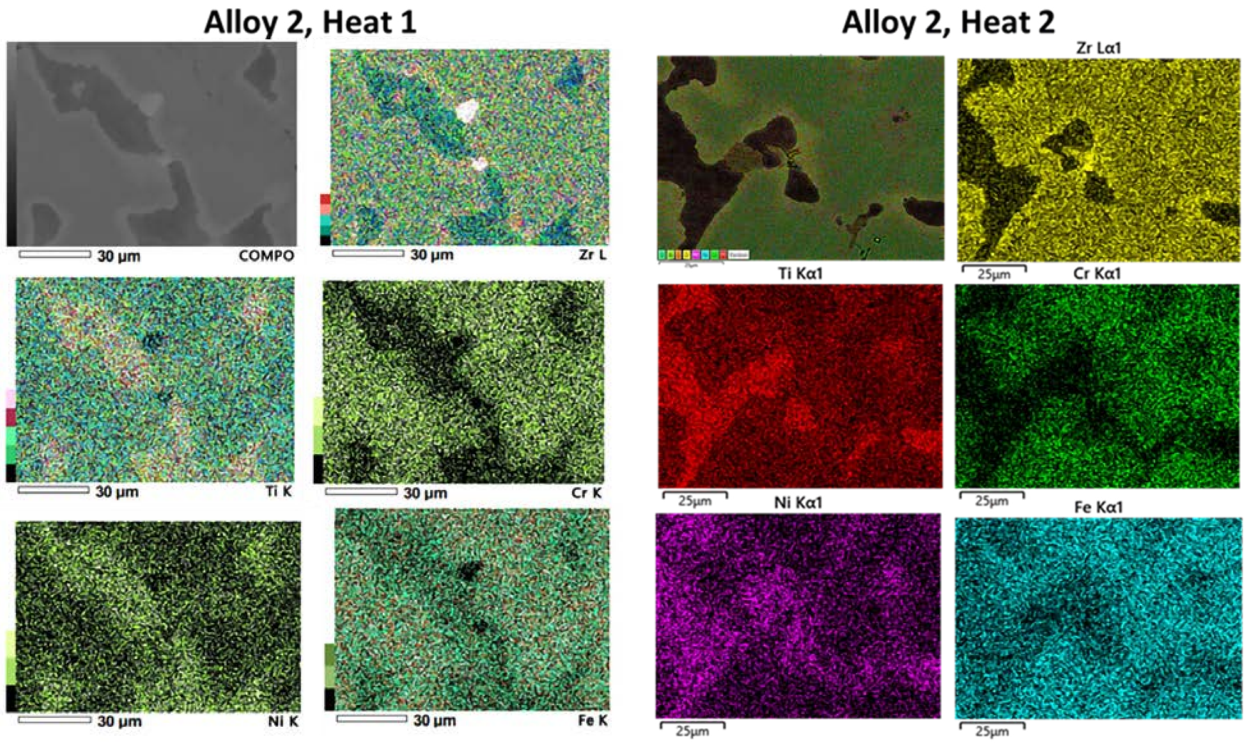


Figure 3: Elemental analysis of Heat 1 and Heat 2 indicates the formation of $Zr(Fe/Cr)_2$ Laves Phase + Interdendritic NiTi type ordered BCC phase.

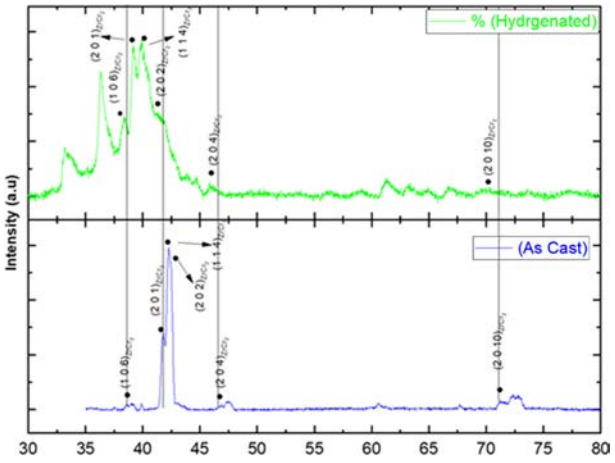


Figure 4: Peak Shifting due to lattice expansion by hydrogen intercalation

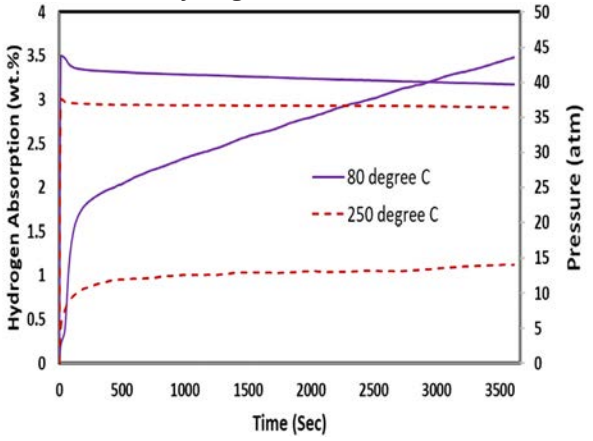


Figure 5: Hydrogen absorption with respect to time in VIM specimen at 40 atm pressure

Development of Ultra High-strength Al-Mg-Sc alloy

The use of Aluminum-based light alloys for different applications such as automotive, marine, and railway sectors, requires high mechanical strength, corrosion resistance, weldability, and fatigue strength. The potential aluminum alloy for such applications is AA2XXX series alloys which show high mechanical strength, having good fatigue properties. However, these alloys suffer from poor corrosion resistance and poor weldability. On the other hand, AA5XXX series alloys exhibit good corrosion resistance and good weldability but show slightly lower strength (~ 275-350 MPa) compared to AA2XXX (~ 400-470 MPa) or less than that required for automotive applications (~ 400 MPa). Therefore, the AA5XXX series aluminum alloys have greater potential to replace the AA2XXX. Hence, the present investigation aims to design a suitable alloy composition by the addition of scandium (Sc) and zirconium (Zr) along with the optimum thermo-mechanical processing schedule for achieving high-strength aluminum alloy with good corrosion resistance and weldability. The developed alloy would be useful for the sponsor to penetrate the automotive, marine and railway sectors. The specific objectives of this project are: (1) alloy design to modify the composition of AA 5083 to take advantage of solid solution and precipitation strengthening; design of suitable thermo-mechanical processing schedule; and (2) evaluation of required properties of the designed and developed alloys. A systematic study was performed to find a suitable composition and process route to produce ultra-high strength Al-Mg-Sc alloys. Five different alloys were prepared utilizing the CALPHAD approach by considering the Mg, Sc and Zr in the range of 3-6 wt.%, 0.06-0.33 wt.% and 0.04-0.1 wt.%, respectively. The thermo-mechanically processed alloy, with Mg 3.87 wt.%, Sc 0.18 wt.% and Zr 0.091 wt.%, exhibits superior combination of properties compared to other studied alloys, when aged at 275°C for 15 mins. The optimized aged specimen reveals YS of 250 MPa, UTS of 362 MPa and total elongation of 16%. The gas-metal arc welding of the optimized aged specimen was performed. The achieved maximum joint strength is around 82% of the base metal strength. The susceptibility of the developed alloy to intergranular corrosion and pitting attack was less compared to AA2024 and AA5083 alloys. In addition, the preliminary fatigue data exhibits that the fatigue property of the alloy is comparable with AA2024. Based on the promising property obtained in the designed alloy, a large-scale melting (14 kg capacity) of the alloy was performed for extrusion of as-cast billet. It is noted that as-extruded rod as well as extruded rod aged at 275 °C for 45 minutes exhibits similar tensile properties. Moreover, as-

extruded rod exhibited slightly better properties compared to aged specimen. The extruded rod exhibits tensile strength close to 400 MPa, YS of 221 MPa and total elongation around 10%. Proper control of important process parameters during plant trial is expected to further enhance the properties of the developed alloy.

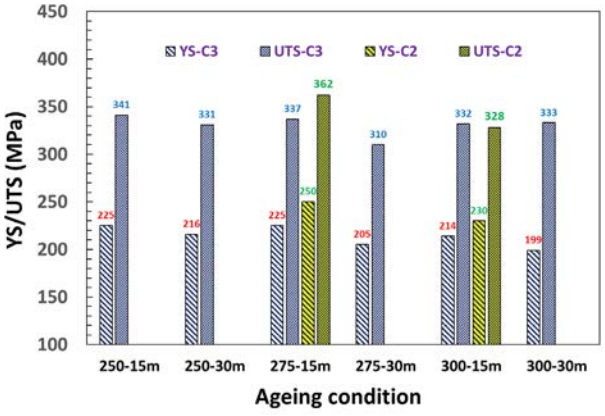


Figure 6: A systematic comparison of tensile properties of developed alloys (C2 and C3) reveals that Alloy C2 possesses superior tensile property compared to alloy C3

Figure 7: Large scale melting of the alloy to obtain as-cast billet with 140 mm diameter and 330 mm length. The final diameter of the extruded rod was 16 mm

Work package to upscale, characterize, and realize the properties in complex concentrated alloys

The scope includes upscaling a medium-Mn steel grade alloy using a Vacuum induction melting furnace, optimizing process parameters through hot/warm rolling, conducting microstructure characterization using SEM, TEM, XRD, EBSD & TKD, and evaluating mechanical properties according to ASTM standards. The project aims to achieve specific mechanical and corrosion properties in 12 mm thick final plate samples and requires the preparation of detailed technical documentation. Project deliverables comprise a comprehensive technical report, sending tested samples to the client, and delivering thermo-mechanically processed plates of approximately 150x100x12 mm dimensions. The specific objectives include upscaling of the alloy belonging to medium-Mn steel (20-40 kg); optimization of the process parameters to produce hot rolled steel plate of 12 mm thickness and properties as UTS ≥ 900 MPa, YS ≥ 600 MPa, %El ≥ 40, Corrosion rate ≤ 5 mpy, Fracture Toughness KJC > 200 MPaVm, and Impact toughness > 80 Joules @ - 40 oC; characterization of the materials to be carried out for the microstructure at various stages using SEM, TEM, XRD, EBSD & TKD with all required consumables; and mechanical properties such as tensile, hardness, fracture toughness, impact, and corrosion to be evaluated as per the ASTM standards for the processed alloy. Currently, the upscaling of the alloy has been carried out and the developed hot rolled plate of ~12 mm thickness has satisfactorily met the targeted properties. The developed hot rolled plate comprised of martensite and retained austenite microstructure as shown in the electron backscattered diffraction (EBSD) phase map (Figure8).

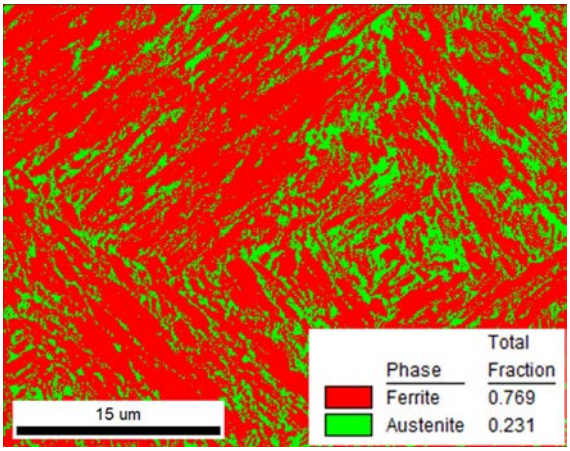


Figure 8: EBSD phase map of the developed HR medium-Mn steel plate showing martensite - retained austenite microstructure.

Integrity assessment of Konarka Iron Beams

The massive iron beams of Konarka have not been systematically studied about their internal structure and integrity, although the broad method of manufacturing iron in ancient India has been established as bloomery process. In this process, a pasty mass of liquid slag and solid reduced iron is hammered to expel the liquid component slag and retain what is known as the wrought iron e.g. Delhi Iron Pillar, Dhar iron pillar and others. Unconfirmed historical records suggest that the Konarka beams have several smaller plates embedded inside, indicating their 'composite' nature. If confirmed, these beams would have possessed good resistance to crack propagation when subjected to high level of stresses in service. The project essentially intends to undertake the following investigations: (i) the exact method of manufacturing including the placement of internal plates if any; (ii) soundness of the interface between the plate and the subsequently poured bloom-matrix composition using ultrasonic non-destructive evaluation technique; (iii) microstructural features in critical portions; (iv) the local and global electro-chemical characteristics of the iron beams contributing to their corrosion behaviour as evidenced over 800 years of exposure to the saline sea- atmosphere at Konarka, and comparison of the same with other bloomery iron structures in India especially, Delhi Iron Pillar. The broad objective of this proposal is to carry out *in-situ* non-destructive characterization and corrosion analysis of iron beams of Konarka, and to correlate the results with the microstructures to understand the technological acumen of our great ancestors. The project has three broad objectives: (i) to review the technology available during that period making beams; (ii) *In-situ* non-destructive characterization of Konarka iron beams and validation with a few microstructural tests of selected samples; and (iii) to characterize the nature of the corrosion occurring in iron beams at the Konarka using portable electrochemical corrosion testing equipment. Currently a team from CSIR-NML and IIT-Bhubaneswar visited Konark Sun temple twice to perform ultrasonic and corrosion measurements and data collected for further analysis. Ultrasonic data infers a composite structure but still more experiments are needed to establish the manufacturing technology of Iron beams. No such slag entrapments are found inside the beam. The slag entrapment in the smaller embedded pieces would be much lower because the manual hammering of smaller cross sections would be more effective in squeezing the slag out and leaving behind a typical low carbon wrought iron.

Mitigation of wettability issues during galvanization of advanced high strength steels in steel industries by adopting a unique sol-gel pre-coat

Thin sheet of AHSS grades for automobile and structural applications are being protected by the corrosion resistant hot dip galvanizing coating. However, the surface selective segregation and oxidation tendency of AHSS grades makes difficult to obtain the good quality of galvanizing coating. The present approaches have their own merits and demerits. Therefore, there is need to develop an alternate cost effective technique to mitigate wettability issue of steel surface in galvanizing bath. CSIR-NML has developed iron-based sol-gel pre layer (200-600 nm) for hot dip galvanizing coating on DP-980 grade of advanced high-strength steel sheet using Hot Dip Process Simulator (HDPS).

The iron-based sol-gel pre-layer mitigate the wettability issue of DP 980 steel sheet and improved galvanizability. The findings are cost effective and feasible to industries continuous hot dip galvanizing Line. They are applicable to all grades of steel sheets and hot dip coating compositions. It is scalable at steel industries having continuous hot dip galvanizing line for GI coated thin sheet of AHSS grades for automobile and structural applications.

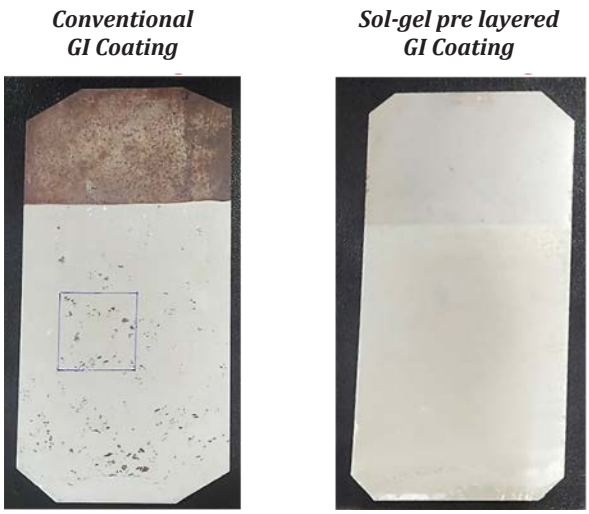


Figure 9: Conventional GI Coating and Sol-gel pre layered GI Coating

Electrodeposition of corrosion resistant Cr-carbide coating on SS 316L for Sink Roll applications in Continuous Galvanizing Lines

The project aims at upscaling the process for electrodeposited corrosion-resistant chromium carbide coating on SS 316L to improve the life of Sink Roll in Continuous Galvanizing Lines (CGL). Currently, the design, fabrication, and procurement of a customized Electrodeposition set up for the prototype of a cylindrical-shaped sink roll (2“diameter and 6“length) at laboratory level has been completed. Technology will be further scaled up at the Indian sink roll manufacturing plant for electrodeposition Cr-C coating on standard-size sink roll (~65 cm diameter and ~135 cm length).

Grain boundary engineering for austenitic stainless steel processed by selective laser melting.

The project aims for developing methods for engineering the microstructure of additive manufactured products from a medical grade austenitic stainless steel so as to ensure enhanced fatigue and anti-corrosion properties. This study evaluates the corrosion performance of SLM-processed 316L, a widely used biomaterial, through electrochemical tests, including open circuit potential (OCP) and potentiodynamic polarization in simulated body fluid. Microstructural analysis revealed distinct features in the build direction (BD) and transverse direction (TD) planes. The BD plane exhibited a characteristic laser-scanning pattern, while the TD plane displayed a semi-columnar melt pool structure resembling a fish-scale pattern. Despite these microstructural differences, the electrochemical behavior of SLM-316L was comparable in both planes, with only marginal variations in pitting potential, indicating the minimal influence of both BD and TD orientations on corrosion performance. SLM-316L exhibited superior passivation and pitting corrosion resistance compared to conventionally manufactured 316L (Refer Figure 10). This enhanced behavior is attributed to the cellular grain structure, residual strain, and the segregation of alloying elements, such as chromium (Cr) and molybdenum (Mo), near cell boundaries, which promote passive film formation. These findings highlight the potential of SLM to improve corrosion properties and its pivotal role in advancing the fabrication of reliable biomedical implants. The project will generate knowledge about the influence of 3-D printing process parameter, and annealing treatment on mechanical properties and corrosion behavior in simulated body fluid environments

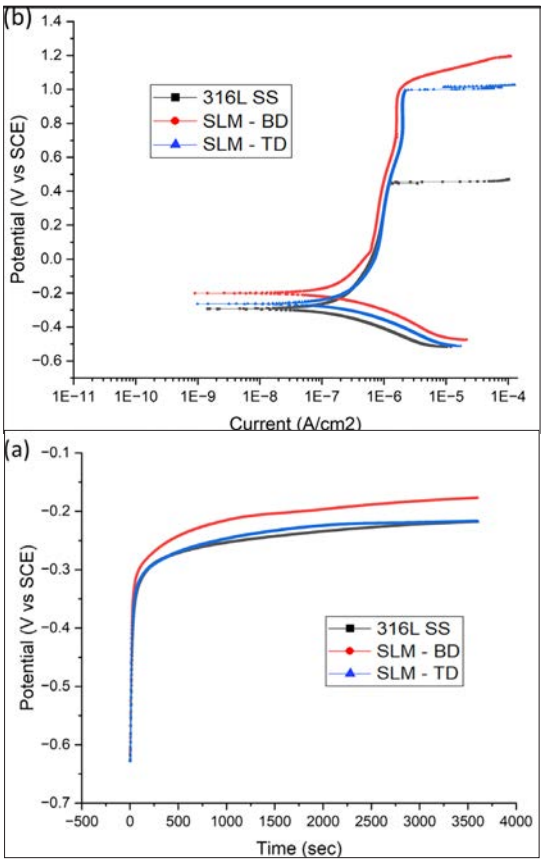


Figure 10: (a) Open circuit potential (OCP) and (b) Potentiodynamic polarization curves of conventional and SLM 316LSS samples in simulated body fluid environment.

Development of Rare-Earth Free Anisotropic α″-Fe16N2 hard Magnetic Material

In search of rare earth free magnets, new magnetic phases like τ-MnAl, MnBi, Zr2Co11, tetragonal FeNi, nano-Co, Co3C, Fe3N, α″-Fe16N2with large magneto-crystal anisotropy were identified . Amongst them, the metastable tetragonal based α″-Fe16N2 and α″-Fe(Co)16N2 phase possessing one of the highest magnetic polarization (~2.1-2.3 T) coupled with large magneto-crystal anisotropy of (Ku ~107 erg/cc or 1 MJ/m3) shows promising material for bulk hard magnet with large BHmax (Figure 11). From a sustainability point of view, absence of rare-earth and comprising of largely abundant Fe and N makes the material very attractive. The various international efforts involving first principle calculations (Materials Project) and adaptive genetic algorithm (AGA) has identified the potential hard magnet based on Iron nitrides and Co-Substituted Iron nitrides. In accordance, nitrogen Ion implantation, co-sputtering based α"-Fe16N2 thins films were successfully employed to establish their magnetic properties. The key challenges for the development of Iron nitrides as permanent magnet lies in developing a bulk synthesis technique addressing the three key issues of phase stabilization, pre-straining of lattice and microstructural tailoring for large coercivity and BH max. In the proposed work, we will be employing preparation of melt-spun Fe or Fe-X or Fe-B X (X =Co, Cr, Cu, Mn, Ni) precursor alloy melt-spun strips (30-100 micron) with nano-structuring. Followed by gas nitriding in austenite (Fe-N) region and quenched rapidly to form dis-ordered martensitic phase. Further the Fe-N martensitic strips will be subjected to tensile strain assisted low temperature tempering to yield anisotropic α″-Fe16N2 hard-magnetic phase. The choice of alloying elements is carefully chosen based on nitride forming elements, theoretical results for large (Ku) and large magnetic mono-domain particle for achieving high coercivity. The anisotropicity will be established during martensite ordering to form a tetragonal crystal structure with noticeable c/a ratio. The work aims to prepare tetragonal α″-Fe16N2 based bulk hard magnetic phase through multi-step gas nitriding route, thorough characterization establishing a viable process route, process optimization and achieving desired hard-magnetic properties.

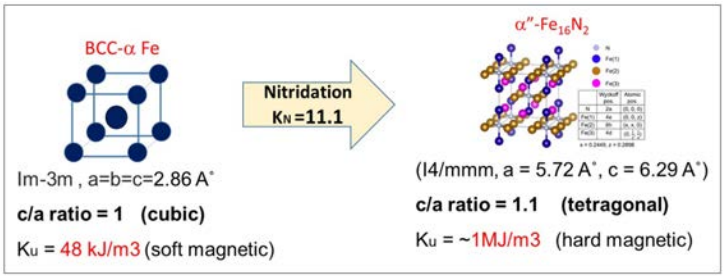


Figure 11: Schematic illustration of hard-magnetic Iron nitride phase formation under controlled nitriding treatment

Directors who led the path on which we walk today...

E.H. Buchnall

Served as Director of CSIR-National Metallurgical Laboratory (CSIR-NML) from 1953 to 1956

He was a researcher engaged in studies on steel hardening and its characteristics. His work included research on the production of ferro-alloys for the alloy steel industry in India, and he also published articles examining the hardening behavior of steels.

Failure Investigation and Structural Integrity Assessment

Understanding and preventing failures and ensuring the structural integrity of engineering components has been one of the thrust areas of CSIR-NML for several decades. Several metallurgical failure investigations, remaining life assessment studies to extend the life of ageing components from diverse industrial sectors and fatigue/fracture assessments for critical engineering components of strategic sectors have regularly been carried out at CSIR-NML. A few of them conducted recently are reported here. With an experienced team of experts, state-of-the-art facilities and professional approach, CSIR- NML is a much sought out organisation among engineering industries for ensuring structural safety of the components and/or remedial measures. CSIR-NML has entered into memorandum of understanding with several industrial/strategic sectors, like Indian Railways, Indian Navy, DRDO laboratories, to name a few. The institute has participated in several National Mission mode programs that demand evaluation of structural integrity assessment. Besides, CSIR-NML also offers structured training to industries on failure investigation and life extension methodologies.

Environmental assisted cracking behavior of RRA and modified RRA treated AA7085 and AA2519 in 3.5%NaCl, humid air, hydrogen environments under cyclic loading

AA7085 and AA2519 are new-generation aerospace structural aluminum alloys with high resistance to environmentally assisted cracking, fracture toughness, and the former alloy has low quench sensitivity. These alloys are also intended for armour and ballistic applications due to their superior resistance to armour piercing and ballistic resistance. One of the major problems of the age hardenable aluminum alloys 7xxx and 2xxx is that they are prone to environmental assisted cracking under static and dynamic loads in chloride and hydrogen containing (humid air) environments. The structural integrity and component life of aluminium alloys are significantly influenced by the synergistic conditions of the environment and cyclic loading. Even these new-generation aluminum alloys are more susceptible to hydrogen environmental assisted cracking in humid air environments than the older alloys. The main objectives of the project are: development of modified RRA (retrogression and re-ageing) heat treatment for AA7085 and AA2519 aluminum alloys of 30 mm and 20 mm thickness respectively to have improved environmental assisted cracking resistance and strength in 3.5% NaCl, humid air/hydrogen environments; Quantify the Threshold Stress Intensity Factor for Environmental Embrittlement –(K1EAC) of these alloys with modified and conventional RRA treatment. The project output will be useful for the country's aerospace and defense sector. Currently, heat treatment of the conventional and modified RRA treatment AA7085 has been established, and further characterization is ongoing.

Development of standard in collaboration with Research Design and Standards Organization(RDSO) for procurement of center buffer coupler (CBC) for Indian Railways; evaluation and assessment of CBC manufactured by Indian vendors (Foundry) for supply to Indian Railways

Centre Buffer Couplers join freight cars of Indian Railways (Figure 1). Before 2009, the CBCs were imported and were expensive. The indigenized CBCs were supplied to Railways after 2009. However, there were many field failures resulting in revenue losses. CSIR-NML undertook R&D project to find the root cause analysis of these CBC failures; preventive measures, and to develop a new standard for supply of healthy CBC to Railways. Indian Railways in collaboration and consultation with CSIR-NML developed a standard WD-70-BD (define full form) with the following

objectives: Indigenization of Grade E castings used for manufacturing of Center Buffer Couplers (CBC); Safety in rail transport; and Revenue saving. The standard WD-70-BD envisages that the CBC manufactured by the foundry needs to be evaluated at CSIR-NML for soundness of casting, mechanical properties, microstructure, etc. Presently, several manufacturers in India have started manufacturing and supplying CBC to Railways and some vendors are at the developmental stage. The contribution *led* to Indigenous vendor development for Indian railways; saving in revenue losses resulting from parting of wagons; safety in rail transport; spin-off projects led to a value of about 700 Lakhs INR.

Figure 1: ***(a) Centre Buffer Coupler (CBC) joining two rolling stocks; (b) Different parts of CBC (Yoke, Body, Knuckle)***

Development of an AI-based smart alarm system for predicting the critical temperature zone of a large industrial structure

The objectives of this project are: (i) complete simulation and thermal modelling of the structure followed by validation using thermal imaging data from the plant; (ii) an AI-based real-time temperature prediction system using data from a model for known number of embedded Fiber Bragg Grating (FBG) sensors and; (iii) an IOT based alarm generation protocols before occurrence of critical situation of the structure. Currently, an AI-based real-time temperature prediction system for one of the industrial structures, i.e. for the Blowpipe of the Blast Furnace in a steel plant, has been completed using an optimum number of embedded FBG sensors. Sensor layout for downcomer in the Pellet plant of the steel industry has been completed after receiving the engineering drawing of the burner of the downcomer. Three arrays each with ten FBG sensors along with a locking arrangement have been fabricated and installed in three locations as per the suggestion of the user industry at one of the down-comers. Complete cabling up to the control room was completed and real-time temperature data from the sensors is getting saved in the computer. Along with the temperature data from the sensors, temperature data from the thermal images of the accessible areas are also collected for developing the model for generating the thermal profile from only the sensor data. Demonstration of retraining with real-time data has shown improvement in temperature prediction variation from ±20 °C to ±4 °C for Blowpipe in the Steel Industry has been completed. Collection of real-time data through the sensors is going on. It is planned to generate a thermal profile of the entire zone of the downcomer and to detect the critical zone from the profile.

Design and fabrication of electronic packages for flow rate measurement of the Propellant of spacecraft

The objectives of this project are: to design and fabricate electronics packages for propellant gauging of spacecraft, fabrication of a master calibrator for ground-based studies, calibration, optimization, and design validation. The calibrator shall be capable of variation and adjustment of critical performance parameters like frequency, delay, first negative peak amplitude, signal logic etc. Fabrication of three electronics packages with space-qualified electronics components and to test them in the space environment at Indian Space Research Organization (ISRO). The master calibrator system has been fabricated, delivered to Liquid Propulsion Systems Centre (LPSC), and successful trials using continuous and pulsating flow have been completed. Space qualified systems fabrication is in progress, currently.

Ultra-precise on-machine metrology (OMM) system for optical fabrication of freeform optics

The objectives of this project are to develop a snapshot dual-mode multi-wavelength interferrometric method based on a polarization technique for high-speed and high-performance metrology; and phase unwrapping, stitching, and noise reduction using the deep-learning image-processing algorithm. Currently, design & optimization of the concave or convex rotationally symmetric or non-symmetric optical surface is completed. Engineering schematic drawing for the proposed configuration setup of the OMM interferometric system during machining is finalized. Power spectral density and surface roughness (Ra) value correlation study is being carried out on profilometer data provided by the collaborator. Power spectral density for mid-spatial frequency is being developed for the analysis of the surface roughness of different optical and infrared glass materials. Algorithm development for power spectral density and surface roughness Ra value correlation study on profilometer data is completed. Fabrication of designed optics by ultra-precision machining to achieve desired accuracies in terms of form & finish and measurement of the optics by standard interferometric techniques are planned.

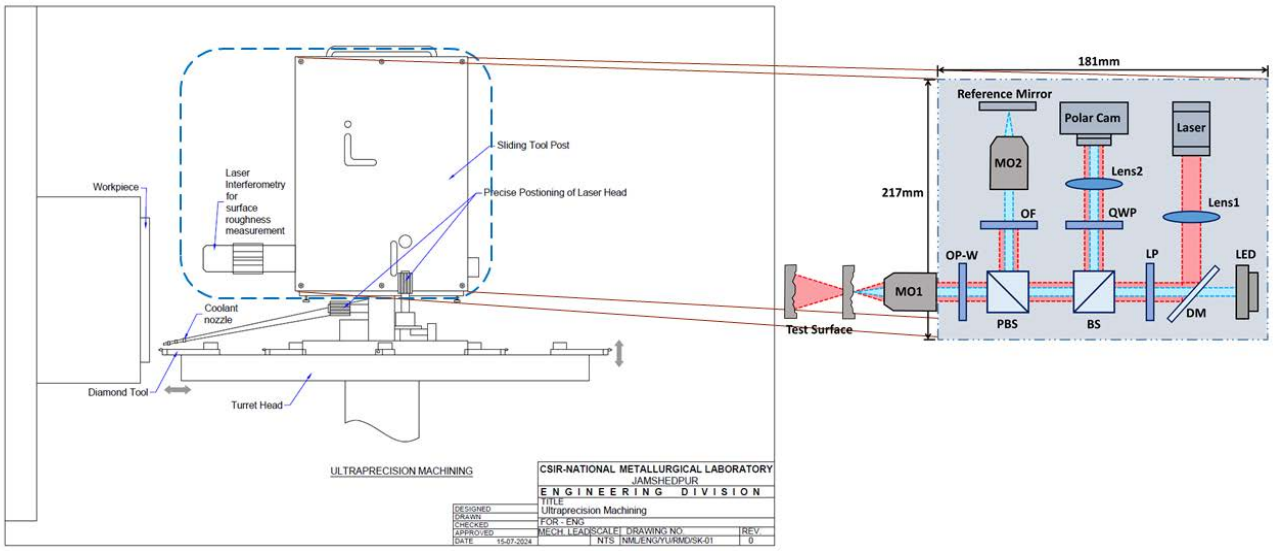


Figure 2: Proposed Configuration setup OMM interferometric system during machining

Metallurgical investigation of fractured rails involved in derailment of train

This project was undertaken to understand the metallurgical aspects of rail track failure and the subsequent measures that can be implemented to mitigate such failures in the future. Under this project, metallurgical failure investigation of fractured rails, involved in derailment of train was carried out. It was reported by the sponsor that the derailment of rail coaches initiated from the 1st coach behind the loco and followed by the subsequent other coaches. During the event, an approximately 3-meter-long rail piece was found to be detached from the left rail side of the main track. The 3-meter-long rail piece was cut into four pieces and sent to CSIR-NML for investigation. The fractured rail pieces were thoroughly investigated through visual observation, chemical composition analysis, hardness tests, tensile test, microstructure analysis, fractography, inclusion analysis and ultrasonic inspection. Visual observation of the fracture surfaces of the rail did not reveal any signature of progressive deformation such as beach marks, rather the entire surface showed chevron pattern indicating brittle failure. The chemical composition, tensile strength and hardness of the rail conformed to the IRS-T-12-2009 standard. Microstructure of the investigated rails consisted of fully pearlitic structure and therefore, was at par with the designated standard. Albeit at some location, specifically close to neural axis in the web region, small fraction of grain boundary ferrite was observed. Presence of inclusion, primarily the MnS type stringers was also found. However, the inclusion rating as per IS 4163 standard confirmed that the extent of inclusion was within the permissible limits defined in the IRS-T-12-2009 standard. Scanning Electron Microscope (SEM) fractography exhibited cleavage and quasi-cleavage nature, which indicated brittle fracture of rails. The signature of fatigue deformation such as striations / crack propagation steps / beach marks were absent. Therefore, it was concluded that the rail was failed due to overload in a brittle manner.

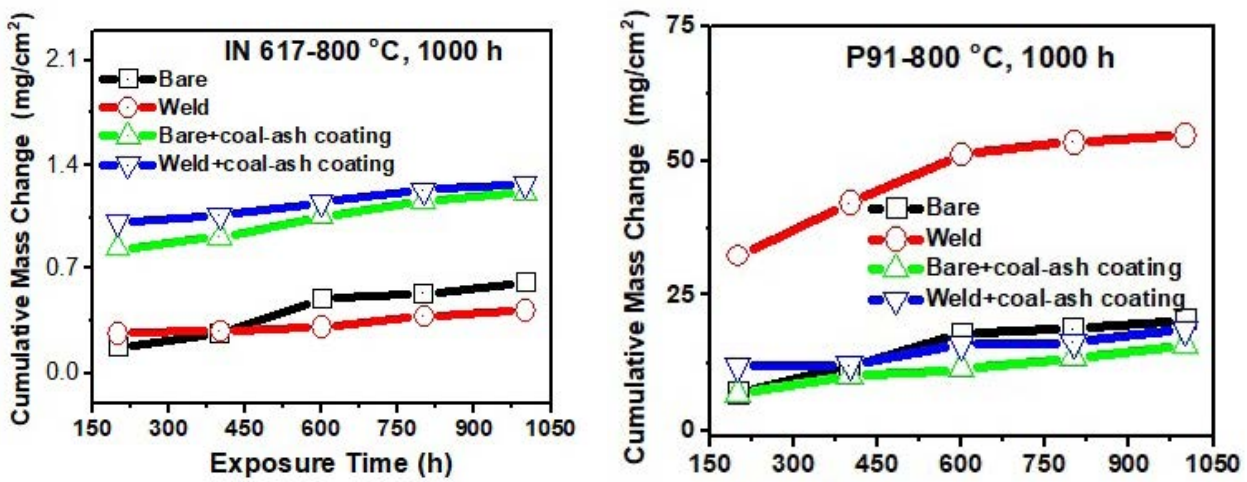


Figure 3: SEM Fractography

Sensor & Devices

At CSIR-National Metallurgical Laboratory (NML), the development of sensors, devices, and technologies tailored to the specific needs of the industries has been a key focus of our R&D efforts. Our work spans the entire innovation cycle—from conceptualizing ideas to the fabrication of sensors and devices, culminating in real-world application at the customer's end. We have successfully designed and developed a range of sensing devices and technologies, addressing critical industrial challenges. The most notables are the "ZincoMeter, FlawGuard, Ultra-ß, UFM, MagStar, MagSys, MagStrics" to name a few. Most of these technologies have been successfully transferred and several devices have already been supplied to user industries.

For instance, the *ZincoMeter* device has been operational at a multinational steel industry since 2023. Furthermore, the MagStar technology has been successfully transferred and currently being commercially produced by M/s Technofour, Pune, India. Most significantly, the '*Fiber optics based BreakOut Prevention technology for continuous Billet Caster'* developed by the CSIR-NML is now operational at a multinational steel industry. Our recent initiatives include developing a sensor/ device for in-situ SHM of critical engineering components exposed to high temperature and stress.

Low Temperature Co-fired Ceramic (LTCC) based eddy current sensor for real-time health monitoring of power plant components

Real-time health assessment of power plant components will help to prevent any catastrophic failure by taking preventive measures well in advance. A failure of any component causes a huge production loss and it may also be responsible for the loss of humans. No commercial solution is available for real-time structural health assessment of power plant components due to the limitations of available sensors (not sustainable to high temperatures) used in various non-invasive techniques. This project aims to bridge the gap using the eddy current sensor fabricated through Low Temperature Co-fired Ceramic (LTCC) technology for real-time health assessment of engineering components through plant trials at the user industry premises. To evaluate the performance of the sensor and the sensing system at the plant in real-time, the objectives of the research work were: (1) fabrication of a specific sensor for real-time creep damage monitoring in the material used presently in power plant components; (2) generation of a calibration curve through creep tests in 4-5 number of samples at the same temperature and pressure condition; (3) evaluation of the performance of the sensing system at the plant in real-time; and (4) monitoring of the real-time condition of the power plant components and data visualization from remote through the Internet of Things (IOT). Currently, the interrupted creep experiments using already fabricated sensors are in progress in the modified P91 samples to generate the strain% vs. sensor output voltage calibration curve. Generation of a calibration curve (strain % vs sensor output voltage) performing tests on 4-5 samples in the same creep condition is conducted (presented in Figure 1). A visit to the power plant is completed to check the feasibility of sensor deployment in the plant component. Fabrication of the Printed Circuit Board (PCB) is initiated and impact studies of wire length in the performance of the sensor are initiated. Real-time creep damage monitoring using an embedded sensor in P91 materials (used in the header) at the laboratory is initiated. The project is aimed at developing the technology for real-time creep damage evaluation by fabricating and embedding a sensor on the real component of the power plant.

Achievements

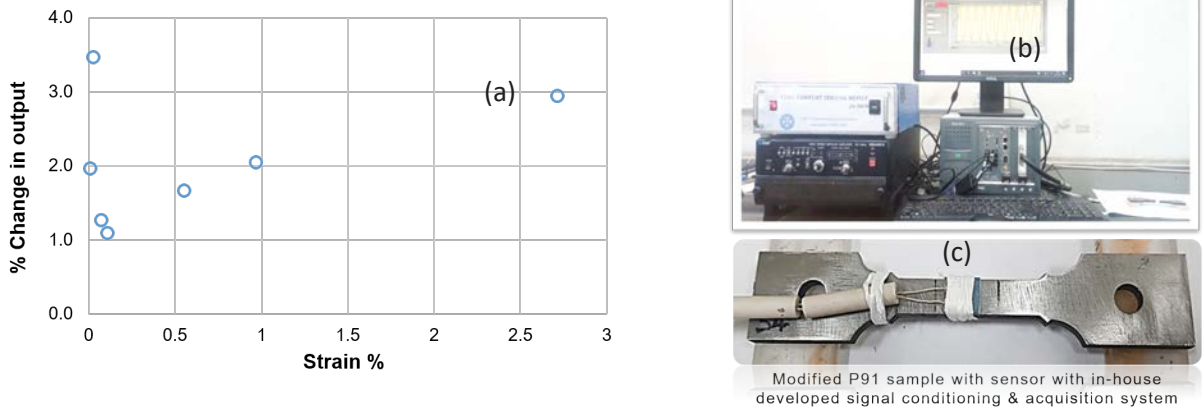


Figure 1: (a) % change of the LTCC eddy sensor as a function of applied % strain (b) measurement setup (c) modified P91

Establishment of a centre of innovation & manufacturing eco-system for sensors (CIMES) in industry IOT

The objective of the project is to explore the commercialization of sensor technologies in the area of structural and geo-technical instrumentation and industrial process control monitoring. and to establish a centre of innovation & a manufacturing eco-system for sensors (CIMES) for Industrial IoT (IIoT) in Kolkata, West Bengal. The project will be carried out with the support of West Bengal Electronics Industry Development Corporation Limited (WBEIDCL), a nodal agency of the Department of Information Technology & Electronics, Government of West Bengal along with other industry partners and stakeholders. The centre will be developed by pooling complementary competencies of five CSIR laboratories having excellence in sensor development and field application in the areas of geotechnical and structural health monitoring and industrial process control instrumentation with well-defined application domains as demanded by the stakeholders and industry partners. The broader aims of the proposed centre are: (1) enabling a start-up and innovation ecosystem in the country as a solution provider in the sensor and instrumentation for industrial IOT; (2) creation of a knowledge and resource centre for Indian industries; and (3) placing India in the global market of sensors and instrumentation in the domain of geotechnical and structural health monitoring and industrial process control instrumentation. To this end, CIMES is a consortium of five CSIR Labs (CSIR-CGCRI, CSIR-NML, CSIR-SERC, CSIR-CRRI, CSIR-CIMFR) where CSIR-CGCRI is the nodal laboratory. For the establishment of the centre, procurement is underway. Discussions with various MSME companies for technology transfer is in progress.

Development of Gas Atomized Iron Alloy Powders for Soft Magnetic Core Applications

High Si steels are superior materials as soft magnetic core components of electrical machines. However, the increasing Si percentage in Fe alloys makes the alloys more brittle, causing more difficulties in processing thin alloy sheets by conventional casting and rolling techniques. The alternative approach is the rapid solidification of liquid melts in the form of thin ribbons and powders. From this viewpoint, the present research is focused on developing fine micron-range powders by gas atomization technique. The developed 6.5wt% Si powders are examined with their high spheroidicity and good flowability, enhancing their possibility for additive manufacturing applications. At present, there are

no reported documents of similar alloy powders by any Indian companies. Therefore, the research outcomes of the present project will help process gas-atomized powders of other new alloys.

The broader objectives of this project are: the development of gas-atomized iron-based alloy powders with low core loss and high induction behaviours and a feasibility study of alloy powders for additive manufactured soft magnetic core components. Currently, the High Si steel alloy powders have been developed possessing high spheroidicity and good flowability.

Instrumentation of billet mould with sensor and installation at caster CC3 for breakout prevention

Breakout is the most catastrophic phenomenon associated with a continuous casting process. This is the major contributor to the loss of productivity and equipment life. The best way to do breakout detection is to have temperature sensors installed on the wall of the continuous casting mould. In this project, Fiber Bragg Grating (FBG) based temperature sensor array needs to be embedded in 10 no. of moulds supplied by the steel industry partner. Six moulds were instrumented by fixing packaged FBG sensors and the temperatures of the mould were recorded. For two moulds, breakout was prevented at the caster CC3. Peak temperature detection and time calculations have been completed for the programmable logic controller (PLC)-based mechanism to avoid breakout. The project mainly aims for the sensor array fabrication, packaging and instrumentation of the Mould by embedding the sensor array. Further work includes the installation of the instrumented mould in the caster and temperature-capturing and decision-making based on the temperature profile in the control room. Currently, the system can log temperature variations into the centralized data acquisition system for preventive actions. Software logic for the PLC-based breakout prevention mechanism has been completed. Real-time breakout prevention with a PLC-based mechanism is to be demonstrated.

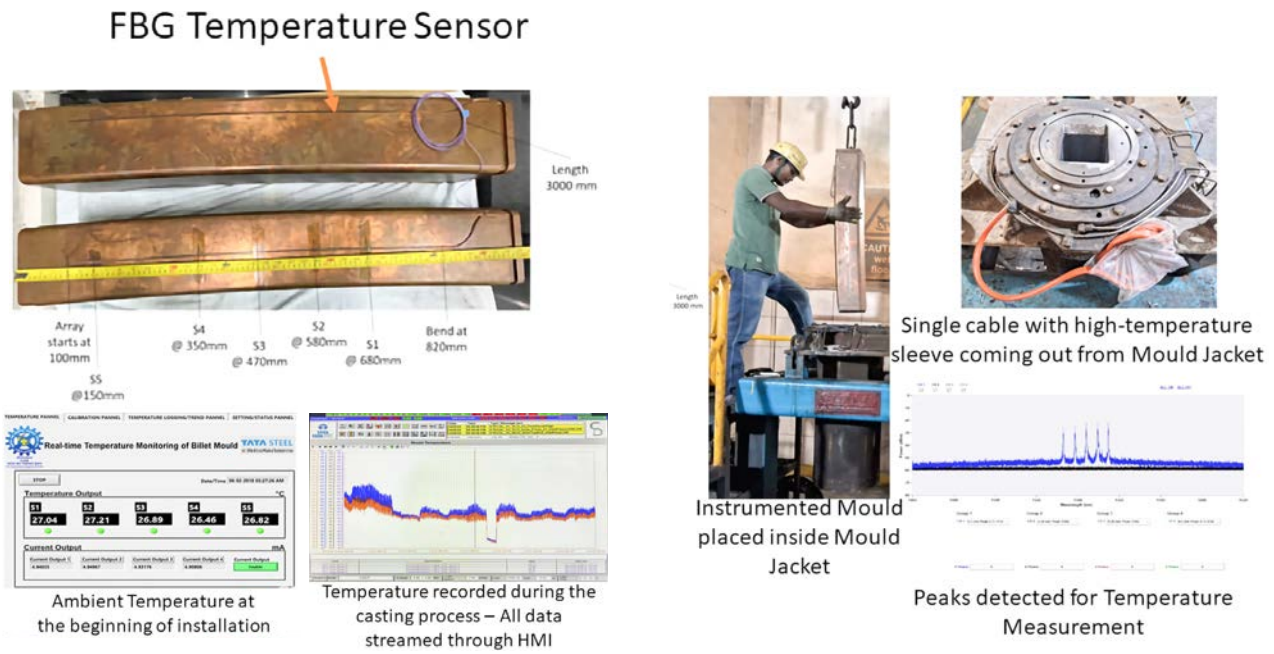


Figure 2: Installation and commissioning of instrumented mould at the Caster and temperature recording

Development of Advanced NDE based Diagnosis and Prognosis Protocols for Advanced-Ultra Super Critical (A-USC) Power Plants

This project is one of the modules of the consortium project entitled "National Centre for Development of Advanced Materials and Manufacturing Processes for Clean Coal Technologies for Power Applications". The present module aims to address the following:

- NDE for the advanced manufacturing processes like laser and hybrid laser weld quality assessment of Ni-based super alloy.
- Comprehensive database creation of various non-destructive evaluation (NDE) parameters to spot onset of damage (Fatigue, Creep Fatigue, etc).
- Development of sensor for *in-situ* structural health monitoring of engineering components exposed to high temperature and stress.

This module addressed the development of non-destructive techniques for advanced manufacturing processes like laser and hybrid laser weld quality assessment of Ni-based superalloy. Another important objective of this project is multi-parameter NDE measurements of futuristic materials like Oxide dispersion strengthened (ODS) material. The goal is to develop an appropriate NDT technique for damage evaluation of such a kind of component. The other important aspect of this module is to develop a sensor susceptible to high temperature > 600°C for real-time integrity assessment of power plant components. Assessing and monitoring of such degradation during operation in a harsh industrial environment is hindered by the non-availability of high-temperature (HT) sensors. In this module, a sensor based on Low-Temperature Co-fired Ceramic (LTCC) technology was fabricated and used for real-time creep damage evaluation at 650 °C/305 MPa till the sample rupture (Figure 3). This will help to overcome the current limitation for real-time integrity assessment of components operating at a temperature beyond a certain limit and assessment of the extent of damage.

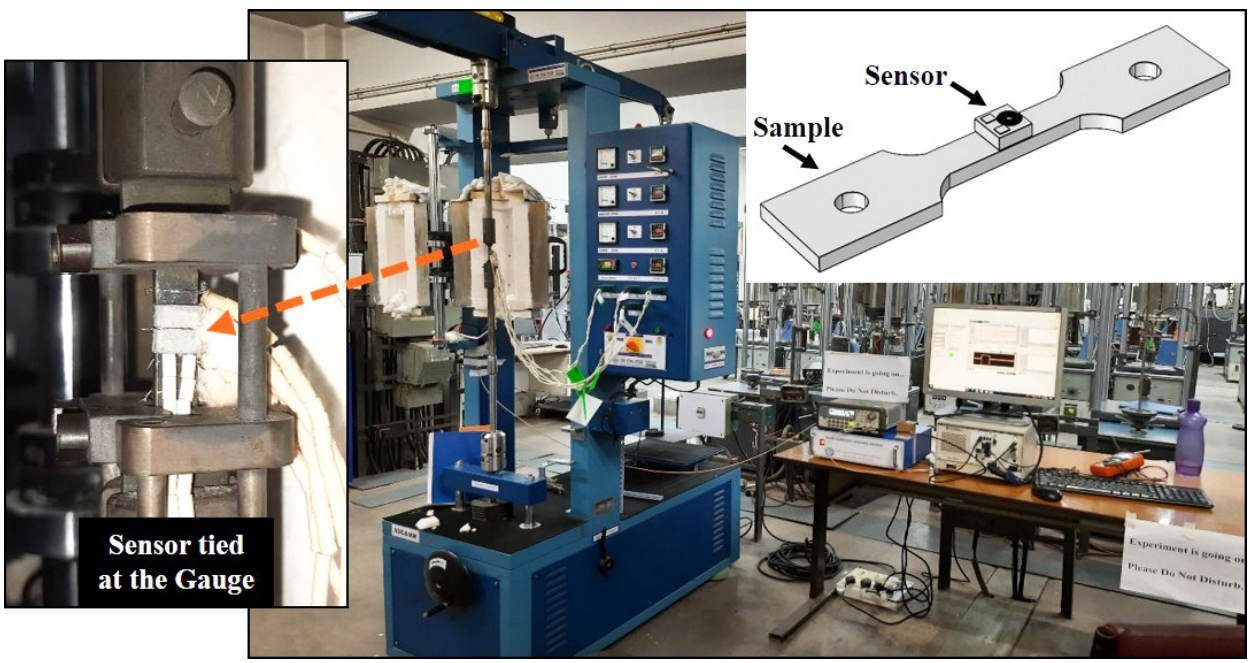


Figure 3: Real-time Creep damage monitoring at 650°C/305 MPa using fabricated LTCC-EC sensor

Mineral Processing

CSIR-NML's seven-decade legacy in mineral processing is built on transformative research and development, converting challenging low-grade ores, and minerals into viable industrial feedstock. With advanced laboratory infrastructure, CSIR-NML excels in mineral characterization and scalable beneficiation, contributing to the establishment of numerous commercial processing plants. Over 900 diverse projects, encompassing ferrous, non-ferrous, and strategic minerals, underscores comprehensive expertise. Research initiatives concentrate on pivotal areas like detailed mineralogical characterization, tailored bench, and pilot-scale flowsheet development, innovative dry beneficiation techniques, effective fine particle processing, sophisticated mathematical modeling, and sustainable waste recycling strategies, and optimized agglomeration processes. The goal is to provide industries with cutting-edge, sustainable resource utilization solutions.

Pilot Scale flotation of coal fines using a synthesized collector reagent

The research work was undertaken in collaboration with industry for carrying out the pilot scale flotation of coal using a synthesized reagent to analyze the performance of flotation of coal in terms of ash reduction and yield with the application of a synthetically developed collector. Coal fines (−0.5 mm) samples having an ash content of ~29% ash content were used for pilot scale trials. Experimental trials were carried out with varied parameters such as collector dosage, frother dosage, feed flow rate, and airflow rate on the flotation of coal fines at a pilot scale of 60-80 kg dry solids per hour feed rate. The optimized results from the pilot-scale flotation showed an ash content of 14.35% in the clean coal, with a yield of 43.77% for seam 7 coal. These results were achieved under the following operating conditions: pulp density of 10%, frother dosage of 8 ml, collector dosage of 30 ml, and synthetic collector of 2.52 g, volumetric flow rate of 900 l/h, and an air flow rate of 15 lpm.

Figure1: Froth collection during pilot scale flotation trials

Development of a process for beneficiation of lean grade iron ores with less than 45% Fe content

The processing and utilization of lean-grade iron ore face several constraints, including compositional characteristics, its soft nature, and typically high alumina content. With the Indian Bureau of Mines setting a 45% Fe cut-off, it is crucial to effectively beneficiate lean-grade iron ore to meet the demands of iron and steel production. A process flowsheet is being developed for lean-grade iron ore with 39.01% Fe (T), 26.86% SiO_2, 7.54% Al_2O_3, and 3.35% Loss on Ignition, aimed at generating a pellet-grade concentrate with optimal recovery. The work is in progress.

Beneficiation study of quarzitic sand to produce a sand glass grade

Developing a laboratory-scale beneficiation flowsheet to produce glass-grade silica sand. Around 700 kg of silica sand sample with a particle size of −3 mm was received, with a target SiO2 content ≥ 99.5%, Al2O3 ≤ 0.3%, Fe2O3 ≤ 0.03%, and TiO2 ≤ 0.05%. The desired size range for the sand was −0.6 + 0.106 mm.

The beneficiation study involved comminution, scrubbing, magnetic separation, and gravity separation. The as-received sample analysiswas analysed, by Saint-Gobain India Pvt. Ltd. showed SiO_2: 98.23%, Al_2O_3: 0.61%, Fe_2O_3: 0.34%, TiO_2: 0.061%, and CaO: 0.049%. Key observations listed below.

- 10 Wt.% of the material was below 0.106 mm.
- 62 Wt.% of the material was above 0.6 mm, requiring further grinding
- Single-stage grinding for 13 minutes yielded d80 of 0.6 mm, generating 7% fine material below 0.106 mm, while 27 minutes of grinding, most of the material below 0.6 mm, and 17% of fines generated.
- Multi-stage grinding in a closed circuit produced 9% additional fines, with 47% of material above 0.35 mm.
- Simulation studies indicated a 0.40 mm cyclone diameter was needed to remove −0.106 mm material from cyclone underflow.
- Wet-high intensity magnetic separation reduced iron content from 3000 ppm to 800 ppm, with minimal variation above 1.0 Tesla. It was found that around 97% of material is received in Non-magnetic fraction.
- Scrubbing showed no significant improvement in alumina content.
- Spiralling reduced ironcontent from 800 to 400 ppm but lowered silica recovery compared to magnetic separation.
- A magnetic separation cleaning step is recommended to reduce iron content to below 500 ppm.

Sustainable technology for the production of high-grade synthetic rutile (TiO_2) from Orissa ilmenite

Studies were conducted to isolate iron oxide through an environmentally friendly method. Initially, the mineral was directly reduced at 1050° C for 4 hours, and aeration leaching was carried out by suspending the reduced limonite in 1.5% (w/v) Ammonium Chloride and adding a few drops of carbonyl compounds to make sure the pH of the mixture was maintained at 4.0. It is already known from the Eh-pH diagram that iron dissolution takes place only at pH 4.0. Aeration leaching was carried out for five hours, and the analysis indicated a decrease in the iron values, which was about 25% total iron remaining and 75% TiO_2. Further, the Odisha ilmenite was reduced at 1100°C for four hours, and aeration leaching was performed. The iron value was 15% after five hours of leaching, and the TiO_2 enhancement was 83%. Currently, investigation studies are underway to reduce the ilmenite at 1150° C. In the meantime, as critical minerals are finding traction globally, the leach liquor and the iron oxide obtained from aeration leaching were subjected to solvent extraction, and it was found that several lanthanide series of rare earths are available and can be recovered. The by-product iron oxide was treated and separated, and the iron oxide was found to be 87% pure with chemically bound water molecules, and the rest of the oxides are in ppm level. Further studies are in progress.

Reduction of surface contamination of Teri heavy mineral sand and dewatering studies on slimes

Teri heavy mineral sand from Manavalakurichi, Tamil Nadu, is characterized by clay that appears in different shades on the surfaces of heavy mineral grains and was reported as slime during processing. If the surface coatings of the fine clays on mineral grains are not reduced/removed effectively without the loss of heavy minerals, the efficiency of separation of heavy minerals would be sub-optimal, resulting in loss of values and productivity. To address the heavy mineral beach sand surface clay contamination issue, the investigation involves developing an eco-friendly process for reducing surface contamination of Teri sand containing heavy

minerals of Manavalakurichi. In this study, attrition scrubbing was improved by adding scrubbing aids, which are natural reagents and are environmentally friendly and biodegradable, and ultrasonication tests based on the surface morphology/nature of the Teri sand. The sand sample was subjected to laboratory scale (batch) attrition scrubbing using the eco-friendly surfactantreagent to study its effect on surface contamination reduction. Optimization of process parameters for scrubbing and desliming was studied. Laboratory scale ultrasonication tests conducted with a 500-watt sonication system, utilizing 5-minute iterations, demonstrated an effective removal of slime coatings from the sand surface. The heavy mineral surface cleaning process was followed by further studies on desliming and clarifying the slimes for recycling the recovered water and appropriate utilization of the thickened or filtered slimes. The studies extend to identifying suitable industrial applications for the filtered slimes generated and developing a process scheme for desliming and clarifying slimes for water recycling. This would enable the reuse and recycling of water within the plant premises and better handling of slimes, mitigating the related environmental issues.

Evaluation of performance of newly developed flotation reagents

The project is a comprehensive evaluation of new flotation reagents developed by the sponsor. The assessment encompasses laboratory-scale testing and, potentially, pilot/commercial plant-scale feasibility studies. The objective is to determine the reagents' efficacy in achieving targeted mineral separation metrics (grade and recovery) through laboratory flotation experiments and to ascertain their suitability for their intended industrial application. The silica collectors developed were evaluated for their effectiveness through laboratory tests on BHQ samples from the steel industryin Karnataka. At laboratory scale studies, the newly developed coal collector and frother yielded about 67% clean coal with 9% ash content from coal of 27% ash. Another coal sample from West Bokaro with 26% ash content yielded 57% clean coal with 14% ash using these new coal collectors and frothers. Based on the laboratory studies, commercial plant trials were undertaken to study their performance at 58 tonnes/hr capacity flotation circuit of Coal Washery of the steel industry at Jharkhand (with total reagent consumption of 1850 litres and 250 litres of frother during the trial period) which yielded a positive and promising performance at plant scale evaluation. These successful trials at West Bokaro Coal Washery validate a new collector-frother system for coal flotation and plant scale commercialization via partnerships with coal washeries, promising process improvement and industry-wide adoption.

Exploratory studies on beneficiation of low-grade quartzite

Quartzite, a naturally occurring mineral primarily composed of silica, often contains impurities such as ferruginous surface clay and iron oxides, which hinder its direct industrial applications. The study was conducted using laboratory-scale exploratory investigations to enhance the quality of quartzite and reduce ferruginous surface clay contamination and magnetic impurities (iron oxides) in quartzite samples through beneficiation techniques. The study explored processing methods like scrubbing and washing to remove ferruginous surface clay, magnetic separation to reduce iron oxide impurities, and selective flotation to achieve a better grade of quartzite in the beneficiation process. A series of physical (attrition scrubbing), magnetic (dry and wet magnetic separation), physicochemical (flotation), and hydrometallurgical (leaching) beneficiation methods were attempted to enhance the silica content and reduce the associated gangue. Flotation of quartzite with customized reagents was carried out to upgrade the quality of quartzite for specific industrial uses. Acid leaching was also studied to remove iron oxide, which could be detrimental, especially in producing high-purity

silica for industries like glassmaking.A combination of scrubbing, washing, magnetic separation, selective flotation, and acid leaching proved effective in enriching silica content and achieving the desired grade for industrial applications. The findings highlight the potential of customized reagent-based flotation and leaching methods in producing high-purity quartzite, ensuring improved material quality.

Beneficiation of coking coal by hybrid mode: dry and wet processing to reduce the ash-forming impurities.

India has vast coal reserves but still imports low-ash coking and non-coking coal to meet industrial demand, impacting the country's foreign exchange reserves. As the quality of raw coking coal is depleting, it is essential to improve the quality of raw coal before wet beneficiation. Dry deshaling presents an alternative route for beneficiation of high-ash, difficult-to-wash coking coal, enhancing the raw coal feed quality before wet processing. Dry processing has certain advantages as no process water is required, it prevents the generation of slime water producing clean, environment-friendly,and cost-effective products with higher heat value. Hybrid beneficiation (dry and wet methods) is effective in reducing the ash content to desired levels while lowering water consumption.This investigation aims to develop a process flowsheet for high-ash coking coal beneficiation using a hybrid approach, targeting metallurgical coal grades of 14-17% ash with maximum yield. Dry deshaling to improve the quality of the feed material for wet processing and the feasibility study of dry beneficiation of coking coal, reducing ash content of the ROM coal, and water consumption were also undertaken in the project. The techno-economic feasibility of the developed process flowsheet is also being studied. Deshaling and washing of coking coal will lead to the reduction of energy consumption increasing the thermal efficiencies, along with an accompanying reduction in erosion rates and equipment maintenance costs. Hybrid mode (dry and wet) processing of the high ash raw coal could help improve the feed quality and productivity. The developed process is expected to positively impact Indian coking coal washeries and steel-making industries, holding promise for water-scarce regions.

Effective utilization of middlings and fines of coking coal washery for recovery of carbon values

An R&D project was undertaken for the recovery of carbon values from the middling's and fines of coking coal washeries in India, where coking coal is scarce, representing only 9.7% of the country's total reserves. The demand for coking coal in the steel sector is increasing, but India's indigenous supply meets only 15% of its requirements. As a result, India imported 57.16 million tonnes of coking coal in FY 22-23. The quality of domestic coking coal is deteriorating due to the depletion of high-grade reserves. Typically, Indian coking coal washeries produce clean coal, middling's, and rejects. However, as high-grade coal reserves decrease, the yield of clean coal drops, and the generation of middling's increases. These middling's, which contain recoverable carbon values, are currently used in power plants.

In collaboration with Coal India Ltd., the project aimed to develop a process for utilizing these middling's to increase carbon recovery for coke making. Two middling samples of different characteristics were collected from the CIL, called washed power coal as they are used for thermal power plants. Beneficiation studies included washability, gravity separation using a Wilfley Shaking table, and column flotation with diesel oil as a collector. Flotation tests using two frothers (MIBC and Nalco) revealed that MIBC performed better in terms of yield and ash content. The flotation concentrate obtained 10.5% by weight had 17.48% ash, while the tailing contained 38.43% ash. Simple process flowsheets were developed, with the first

middling sample yielding 22.2% washed product with 18.46% ash and a calorific value of 6989.5 kcal/kg (Figure 2). The second sample yielded 12.1% with 18.57% ash and a calorific value of 6386.6 kcal/kg (Figure 3).

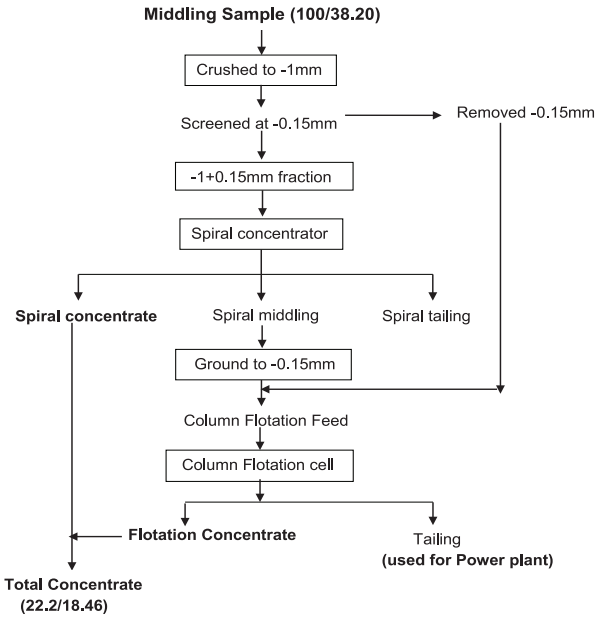


Figure 2: Process flowsheet developed using Spiral concentrator and column flotation cell.

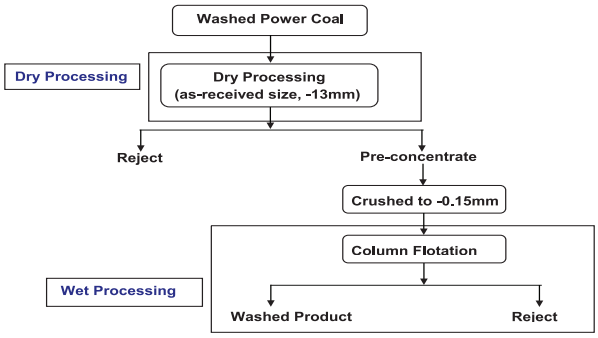


Figure 3: Process flowsheet using dry and wet processing of Coking coal middling sample.

Development of a process for the production of chromic oxide from chromite beneficiation plant tailing

The aim of the project is value addition to waste generated by Mining and Mineral Industries and the objective of the project is to develop a process for the synthesis of chromic oxide from the chromite beneficiation plant tailings. A large amount of chrome ore is discarded as a reject during the beneficiation of low-grade chromite ore. The tailing is fine-grained and poses difficulties in producing a high-grade concentrate by conventional gravity separation techniques. Non-utilization of tailing causes loss of chromite value, and it also has an adverse impact on the environment. In the present study, an attempt will be made to develop a process for the production of a chromium-based chemical compound from chromite beneficiation plant tailing leading to its rational utilization. It is proposed to develop a process for the synthesis of chromic oxide from the chromite beneficiation plant tailings. The tailings sample was pre-concentrated using advanced physical beneficiation techniques, around 90% of chromite mineral was recovered through advanced gravity concentration experimentation at CSIR-NML. Study on Oxidative roasting of concentrated product was carried out. Optimization studies for the production of chromate was done. Additionally, crystallization of dichromate compound and reduction roasting of dichromate will be conducted in the next stages of the project.

Directors who led the path on which we walk today...

Bal Raj Nijhawan

(1915-2014)

Served as Director of CSIR-National Metallurgical Laboratory (CSIR-NML) from 1956 to 1966

Dr. Bal Raj Nijhawan was a renowned Indian metallurgist and the first Indian-origin Director of the laboratory. He made significant contributions to steel and alloy research, holding over 55 patents and publishing 500+ papers. Dr. Nijhawan was awarded the Padma Shri (1958) and the Shanti Swarup Bhatnagar Prize (1964). He also worked with UNIDO and received international recognition for his work in metallurgy. He is remembered as a key figure in the development of India's metallurgical research and international collaboration in the field.

Advanced & Functional Materials

In this area, CSIR-NML mainly focuses on developing advanced materials and processes to improve the performance of various engineering components. Key research areas include (i) Surface engineering : To develop eco-friendly coatings for wear resistance, corrosion protection, and high-temperature applications (ii) Functional materials: To evaluate & improve the optical, magnetic, electrical, and thermal properties of metals, ceramics, and composites, (iii) 2D Materials: To develop advanced 2D materials like graphene and MXene through optimized synthesis techniques for energy generation, storage, and conversion applications,; (iv) Non-Destructive-Evaluation: NDE evaluation of materials, focusing on structural health monitoring, industrial damage assessment, and (v) Magnetic Materials: To Develop advanced magnetic materials/ alloys for aerospace, defence, power sector applications etc.

Development of self-healing geopolymer composites

Global attention on geopolymer research is increasing day-by-day because it is considered a green alternative and an eco-friendly product compared to conventional cement. The durability of cementitious composite, both conventional and geopolymer, is impaired by the cracks formation and damage, which leads to serious concern when massive infrastructures such as high-rise, highways, bridge, tunnels, etc. are in continuous service. Often, their repairing becomes difficult, and is also associated with higher maintenance & repair costs.

Therefore, self-healing building materials are among the most sought-after composites. The research on self-healing building material started a decade ago. The various approaches are: microcapsules containing mineral healing agents, bacterial healing, use of a shape memory polymer (SMP). However, most of the above efforts are focused on conventional cementitious material. To date, no such efforts for geopolymer composite have been reported. In the present work, hydroxyapatite is used as a self-healing agent in metakaolin-basedgeopolymer, where graphene or other fibre material is used to develop the geopolymer composite. Hydroxyapatite, a calcium phosphate-bearing compound from which calcium oxide is leached out and can be deposited as $CaCO_3$ on the crack area, and can help to repair the crack. Graphene or other fibre material, is used to strengthen the geopolymer matrix and to improve the mechanical properties, particularly its tensile strength. These fibres also restrict the propagation of the crack under load. Therefore, in this approach, propagation of the crack can be stopped and the crack can be healed.

Development of efficient bi-functional electrocatalyst of transition metal for anion exchange membrane (AEM) based alkaline water electrolyser, scale-up and prototype fabrication of membrane electrode assembly (MEA)

Development of transition metal based bi-functional electro catalyst for water electrolysis having superior activity and long term stability is highly necessary to overcome the adverse environmental effect of non-renewable energy sources. In the present study, developed an arrayed γ-FeOOH nanosheet and CeO_2 nanoparticle loaded Mn_3O_4 nano-cube as efficient electrocatalyst. It is a simple one-pot aqueous solution based cost effective and scalable synthetic strategy performed in atmospheric conditions. The Mn_3O_4@CeO_2/γ-FeOOH exhibited excellent bifunctional activity, both for Oxygen Evoluation Reaction (OER) and Hydrogen Evoluation Reaction (HER), in low as well as elevated current density (η_{10}: 190 mV and η_{1000}: 300 mV for OER, and η_{10}: 180 mV and η_{1000}: 420 mV for HER), also showed long term stability. For overall water electrolysis in a two-electrode

electrolyser having Mn_3O_4@CeO_2/γ-FeOOH in both anode and cathode achieved a current density of 10 mA cm^{-2} and 1A cm^{-2} at an applied potential of 1.55 V and 2.06V. In a 4 cm^2 prototype Anion Exchange Membrane Alkaline Water Electrolyzer (AEMAWE) having Mn_3O_4@CeO_2/γ-FeOOH in both anode and cathode side, it attains current density of 366 mA cm^{-2} at room temperature and an applied potential of 2 V, also showed stability for 50 h. Thus, the simple and scalable catalyst synthetic strategy, and its superior and stable electrocatalytic activity, particularly in AEM electrolyser, suggest that the developed catalyst Mn_3O_4@CeO_2/γ-FeOOH might be the alternative to the Platinum Group Metal (PGM) based catalyst for large scale hydrogen production through AEM electrolyser.

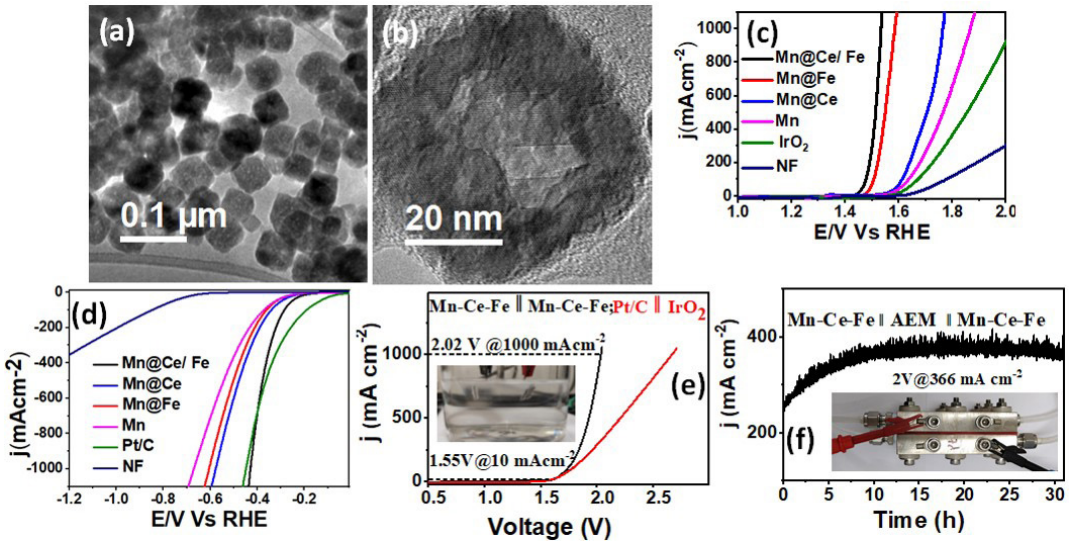


Figure 1:TEM images (a, b), LSV curves for OER (c), HER (d) and two-electrode electrolyser for overall water splitting (e), and plot of cell voltage vs current density of 4 cm^2 AEM electrolyser of synthesized electrocatalyst Mn_3O_4@CeO_2/γ-FeOOH.

Development of large-scale synthesis process for transition metal nano-composite based efficient and stable bifunctional electrocatalyst for anionic membrane alkaline water electrolyser.

Developed nickel and iron based bimetallic metal-organic gel as an efficient and stable electrocatalyst, alternative to respective PGM based catalyst. The gel was loaded on nickel foam (NF) without using any binder. The corresponding dried gel loaded NF exhibits excellent bifunctional, both HER and OER, activity for water electrolysis in both low as well as high current density and showed low ovepotential of 110 mV and 260 mV for OER and 88 mV and 324 mV for HER at a current densities of 10 and 1000 $mAcm^{-2}$, respectively. It also showed a small Tafel slope of 29 $mVdec^{-1}$ for OER and 72 $mVdec^{-1}$ for HER. For overall water splitting, it required a low potential of 1.49 V and 1.89 V to attain current density of 10 and 1000 $mAcm^{-2}$, respectively. It also showed outstanding stability for at least 100 h at 1000 $mAcm^{-2}$. It is most important to mention that in a fabricated 4 cm^2 prototype anion exchange membrane (AEM) electrolyser, the NiFe-gel loaded NF could attain current density of 588 $mAcm^{-2}$ and 1082 $mAcm^{-2}$ at the temperature of 25 and 50 ^oC, respectively, at an applied potential of 2V and a very nominal performance reduction was observed on scale-up of electrolyzer from 4 cm^2 to 9 cm^2. The excellent performance is attributed to the synergistic effect of accessible individual metal ions in the metal organic gel as active sites, and electronic interaction between the Fe^{3+} and Ni^{2+}. This developed efficient and scalable

synthetic strategy, and its superior electrocatalytic activity and stability in prototype AEM electrolyser demands as a potential PGM-free electrocatalyst for industrial scale hydrogen production through water electrolysis.

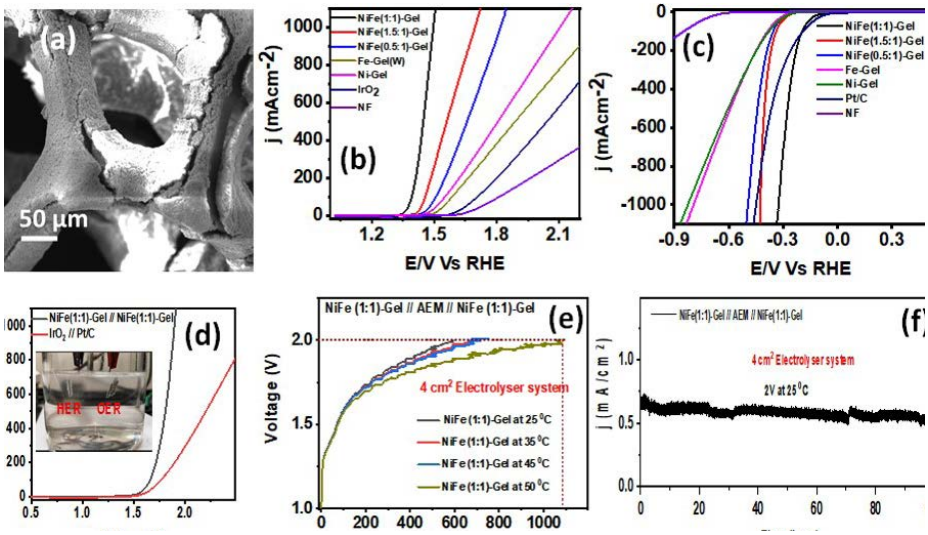


Figure 2:SEM images (a), LSV curves for OER (b), HER (c) and two-electrode electrolyser for overall water splitting (d), and plot of cell voltage vs current density (e) and corresponding stability (f) of 4 cm² AEM electrolyser of synthesized electrocatalyst Ni-Fe-Organogel.

Large-scale production of M_2AX (M=Ti/V, A=Al, & X= C) type MAX and corresponding MXenes based electrodes for developing aqueous electrolyte based coin and cylindrical supercapacitors

The scarcity of fossil fuels, rising pollution, and increasing demand for energy drive the necessity of extensive utilization of clean energy storage systems like supercapacitors (SCs) for practical applications. In India, two major issues that prevent the successful commercialization of SCs are i) the unavailability of suitable electrode materials and ii) the lack of expertise in handling volatile and moisture-sensitive electrolytes during cell designing. Thus, the current project is on addressing the development of highly capacitive layered transition metal carbides (known as MXenes) based SCs with aqueous electrolytes to enable the manufacturing of efficient SCs, in ambient conditions. Among the various types of MXenes, M_2X type shows ~50% higher gravimetric capacitance than other types because exposure of their M surface to the electrolyte remains maximum, which means better electrode/electrolyte interaction than others. Therefore, currently, this project aims to develop Ti_2AlC MAX through a simple and optimized pressureless sintering method to create Ti_2C MXene based aqueous SCs. We already developed the Ti_2AlC MAX and Ti_2C MXene, but to control the purity, optimizations of the process are going on. Through this project, we have prepared and submitted a book chapter entitled "MXene Based Functional 2D Nanostructures for Energy Application" which will be published by Bentham Science, Singapore publisher.

Development of simple, cost-effective and scalable spray drying based synthetic strategy for inorganic nanostructured materials

A generalized spray drying based synthetic strategy for inorganic nano-structured materials has been developed. Synthetic strategy is simple and continuous, and thus scalable to Kg scale. Use of aqueous solution of simple metal salts, like

metal nitrate, acetate, and ammonium carbonate solution, makes the developed procedure green and cost effective. The developed strategy provides the opportunity to vary the morphology of solid sphere, hollow sphere, and sheet just by varying the amount of ammonium carbonate in the precursor solution. Most importantly, for varying the morphology no organic/inorganic structure directing agent or any costly metal precursor is utilized. Using the developed strategy, different bi-, tri-, quaternary- metal, metal oxides, sulphides, selenides and carbides, with varying morphology, have been synthesized. Corresponding reduced graphene oxide incorporated materials have also been synthesized. After successful synthesis, the material is utilized for varying important applications, which include inorganic pigments, organo-, photo-, electro-catalyst, polymer nanocomposites, and membranes etc.

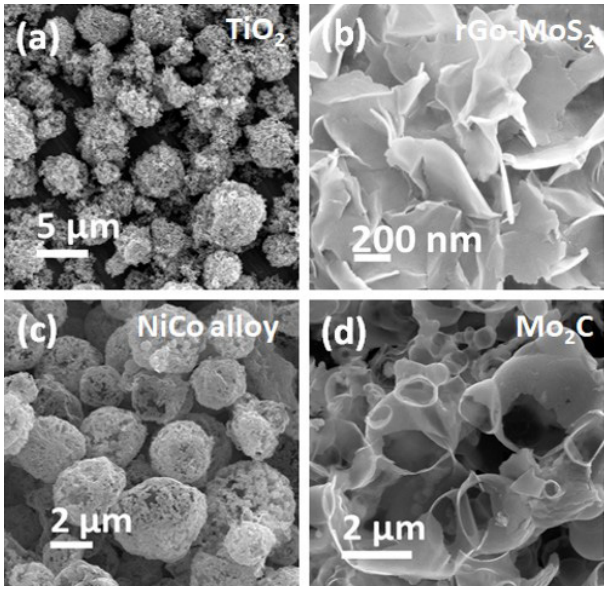


Figure 3: SEM images of some of the synthesized materials.

Replacement of Toxic Cadmium Coatings by Electrodeposited Al/Zn-Mn Coatings on High Strength Steels

Replacing toxic cadmium coatings aims to reduce environmental & health hazards by using safer, more sustainable alternatives, such as electroplated environmentally friendly coating materials. They enhance corrosion resistance, durability, and performance. Under the "Aerospace Materials and Technologies" theme, CSIR-NML has developed Zn-based alloy coatings on high-strength steel for aerospace applications. The objectives of the project were as follows:

- Development of Binary (Zn-Mn) and Ternary Al/Zn-Mn Alloy Coatings from Deep Eutectic Solvent (DES) and Aqueous Electrolytic Baths
- The Coating Performance Should Be Comparable To Cadmium Plating

The proposed objective has been achieved by developing two technologies: (1) a process for binary ZnMn alloy coating from a DES electrolytic bath and (2) a process for ternary Al-ZnMn alloy coating from an aqueous plating bath.The coatings developed from both types of electrolytic baths have passed all essential tests, such as salt-spray, hydrogen embrittlement, tensile, fatigue, wear, and others, according to ASTM standards.We are the first in the world to have developed an Al-based coating from an aqueous electroplating bath.In the first type of coating, we achieved a composition of wt% Mn: 46.12 and wt% Zn: 53.88. In the second process, the coating composition consists of wt% Al: 25.50, wt% Mn: 20.60, and wt% Zn: 53.90.

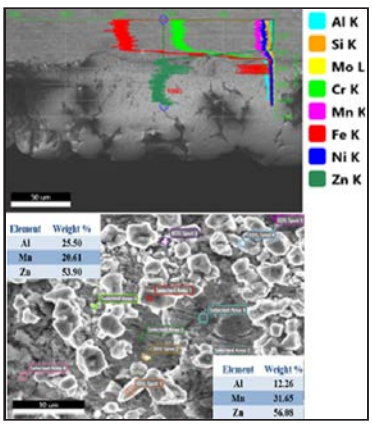


Figure 4. (a)Cross-sectional SEM, and (b) EDSbinary Zn-Mn alloy coatings from DES electrolytic bath, (c) salt-spray and Hydrogen Embrittlement (HE)tests for ternary Al-Zn-Mn alloy coatings from an aqueous plating bath, and (d) Zn-based alloy-coated landing gear prototype showcased at CSIR-NAL Bangalore on 25th November 2024

Corrosion and Powdering Resistant Coatings on High Strength Steel (HSS) as an Alternate to GA Products: Application in Automobile Industry

This project aims for the development of cost-effective Corrosion and Powdering Resistant Coatings through the electro-deposition process on High Strength Steel for automobile applications. This study evaluated the feasibility of the Zn-Fe (Zinc-Iron) alloy electroplating on HSS steel, which could be seen as a potential substitute for galvanized(GI) and galvannealed (GA) coatings, depending on the specific application requirements. The monolithic ZnFe alloy coating were successfully developed using both pulse current and direct current electrodeposition methods. The desired phases and the required Fe composition in the coatings were successfully achieved, similar to that of GA-coatings (as shown in Figure 5). The coatings deposited by pulse electrodeposition successfully passed the Erichsen Cupping and 180° Bend tests without any powdering and flaking. Further, the corrosion, adhesion, and powering properties evaluation of the coatings deposited by direct current electrodeposition is partially completed. One process (Zn-Fe coatings by pulse electrodeposition) patent has been submitted for filing, and another is currently under preparation. The present invention aims to produce alloy electroplated duplex steels similar to GA products at a low cost and suitable for automotive panels, aerospace, and other applications. The developed process is scalable at Steel Industries, facing issues during Hot Dip Galvanizing/Galvannealing of thin sheets of HSS grades for automobile and structural applications.

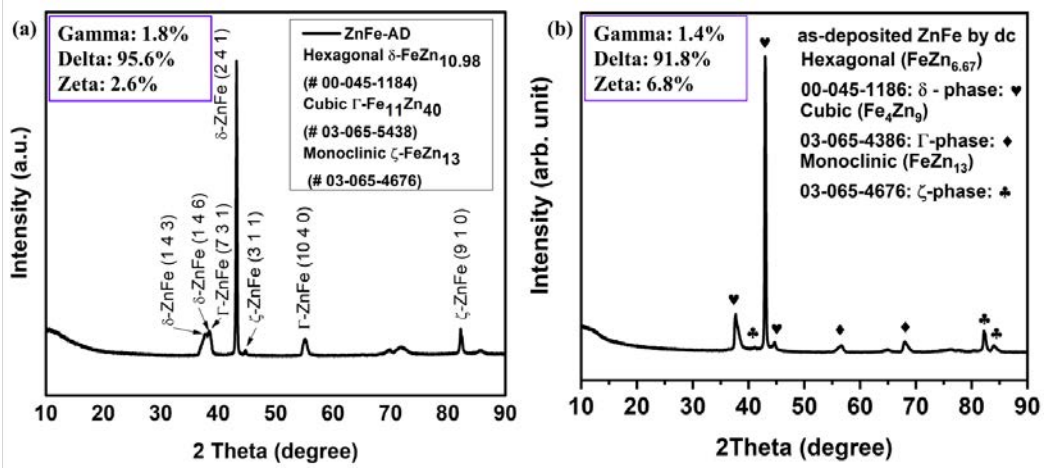


Figure 5: XRD patterns obtained for Zn-Fe Coatings developed through (a) pulse & (b) direct current electrodeposition process; blue border inserts presents the fraction of different phases in respective coatings.

Polymer Based Conversion Coating for Production of Ready to Paint Steel

This project aimed for the development of polymer based conversion coating for production of ready to paint Steel. This study evaluated the feasibility of the phosphating on different steel substrate at room temperature, which could be used as a rust preventer during the storage/transportation of various components. The coating method utilized the magnesium phosphate-tannic acid hybrid phosphating technique and successfully applied to rebar specimens by dipping (for 3s) method at room temperature. This coating was transparent and having thickness less than 1µm. The coating rebar specimens didn't corrode even after 90 days of outdoor exposures as compared to un-treated rebar specimens which found to covered fully with rust just after 7 days (Figure No. 6). Further,

the developed coating passed the 72 hours of salt spray exposures (ASTM B117). Also, the developed coating found to perform effectively after 180° bending, where bended rebar didn't corrode after 30 days of outdoor exposure. Currently, optimization of the phosphating process for cold rolled steel sheets and casted components is going on. Also, the detailed investigation of the anti-corrosion performance of the coating using salt spray, electrochemical and outdoor exposure tests is yet to be completed. A cost effective room temperature phosphating process is developed. It is scalable at industrial level as the coated surface just after production can be directly used for further aesthetic and anti-corrosion top paints/polymeric coatings. Additionally, the requirement of rust preventive oils during storage/transportation and post caustic wash and phosphating prior to applying top aesthetic/anti-corrosion coat, will be eliminated.

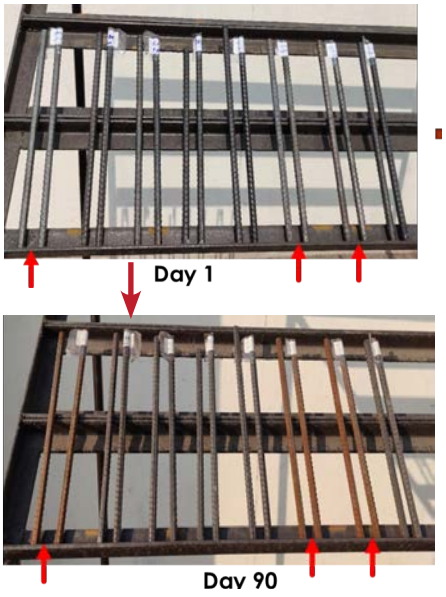


Figure 6 Photographs showing the appearance of non-treated/as produced and coated rebar specimens during outdoor exposure at CSIR-NML Jamshedpur; red arrows indicate the non-treated/as produced rebars.

Self-healing Polymeric Coating for Corrosion Protection of Steel

This project aimed for the development of a self-healing polymeric coating to prevent the corrosion and failure of structural steels. A novel self-healing coating incorporating polymeric resin and inorganic additives was developed and evaluated for the self-healing properties through immersion and electrochemical methods in water and 3.5% NaCl solution, respectively. This could be an effective replacement for the commercially applied barrier coatings (paints) which often fail miserably in presence of any cracks or scratches. The self-healing ability of coatings were evaluated by dipping the fresh cut specimens into 3.5% NaCl solutions and monitoring the impedance of the coating with time. The impedance of the coated specimens was found to increase by multi-folds with increasing the dipping time. Further, the fresh cut specimens were immersed in water for 24 hr to visualize the mechanism involved in the corrosion protection. The cut area was found to fully covered with an inert ceramic material after 24 hr which healed the coatings with time (Figure 7). This formation of ceramic is attributed to the reaction between the acid and base part of the inorganic mixture in presence of water. Also, the coating has adhesion strength > 10 MPa and passed successfully the salt spray exposures of 1000 hr after break in the coating. Further, the coating meets all the requirements mentioned for a self-healing coating in the standard IS 101. Initially, the proof of concept for self-healing coating established with coating formulation in 100 ml/batch scale. Currently, the coating production has been scaled up to 200 liter/batch scale using the pilot scale facility. Also, the performance of the self-healing coating has been evaluated in real environments through outdoor exposure at Delhi, Mumbai, Kolkata, Chennai, Jamshedpur, and Digha along with the market available epoxy paints. Which confirmed the maintenance-free corrosion protection ability of the developed coating. An organic/inorganic composite self-healing anticorrosion coating was developed and patent has been filed (Indian patent 202111002151). The self-healing coating production process has been scaled up to 200 liter/

batch scale. The coating meets all the requirements of IS 101 standards. The technology has been transferred to industry for commercial production. The developed self-healing coating has a bright future to be deployed in various industrial sectors including infrastructure, transport and others. This coating is easily applicable (by brushing or spraying) and curable in atmospheric conditions which makes them a perfect solution for onsite applications.

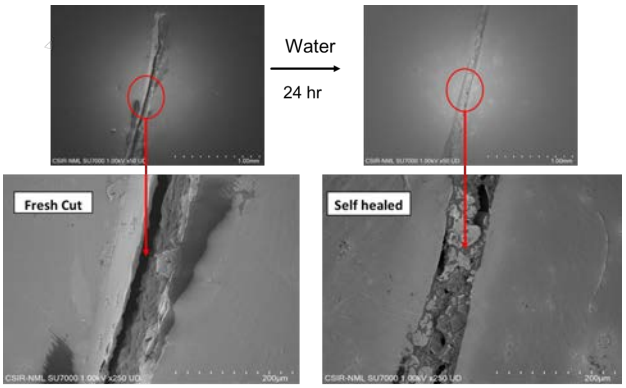


Figure 7: SEM micrographs showing the appearance of cut/crack before and after healing in presence of water.

Ceramic Coatings for Corrosion Protection of Steel in Highly Corrosive Environments

This project aimed for the development of a sustainable and cost-effective ceramic-assisted polymeric coating for corrosion protection of steel in aggressive environments. A novel polymeric coating incorporating ceramic was developed and evaluated for the corrosion and adhesion properties through immersion, electrochemical, salt spray, and 180° bend test methods, respectively. These coatings could be an effective replacement for the commercially applied paints, which often fail miserably in 6-12 months in open environments. Additionally, these paints required a lot of surface preparation before application, but the developed coatings can be applied directly to the rusted surfaces. The developed coatings mainly contain iron, magnesium phosphate, and adhere well to the substrate. The coatings passed 180° bend test without any cracking and delamination. Also, passed the salt spray exposures of 1500 hrs without any corrosion, whereas the commercially available primer failed only in 72 hr exposure. The developed CERA-PRIME provides much better corrosion protection as compared to the commercially available Red Oxide primer, as shown by salt spray and immersion in 3.5% NaCl solutions with and without a cut. and monitoring the impedance of the coating with time. The impedance of the coated specimens was found to increase by multi-folds with increasing dipping time. Further, the fresh-cut specimens were immersed in water for 24 hr to visualize the mechanism involved in the corrosion protection. Further, the developed coatings passed the acid fumes exposure of 4000 hrs, which makes them suitable for application in acid pickling areas. These coatings are cured at ambient conditions and temperature resistant upto 300° C. These coatings have also passed the field exposures of more than 1 year (Figure 8). A ceramic incorporating polymeric anticorrosion coating was developed and successfully applied for field exposures. The coating production process has been scaled up to a 200-liter/batch scale. Currently, interactions with various industries are going on for the feasibility of industrial applications.

The developed coating has a bright future to be deployed in various industrial sectors that face harsh environments such as acid fumes, high temperatures, and alkali exposures. This coating is easily applicable (by brushing or spraying) and curable in atmospheric conditions, which makes it a perfect solution for onsite applications.

Figure 8: Ceramic coating applied at CSIR-NML pilot plant area.

Advanced Colorized Hot Dip Galvanising Zn-X (X- Mn, Ti, Co) Alloy Coating with Excellent Powdering and Corrosion Resistance

This project aimed for the development of an advanced colorized hot dip galvanising Zn-X (X- Mn, Ti, Co) alloy Coating with Excellent Powdering and Corrosion Resistance. The hot dip galvanized coated products are often applied with secondary organic coatings (~250 µm) like paints for decorative purposes which are severely prone to filiform type of corrosion. The conventional hot dip galvanizing coatings exhibits the typical silvery-white shade from the surface. Therefore, in this investigation, attempts have been made to develop an advanced Hot Dip Galvanizing Coating which will show the colorized surface. The novel colorized galvanizing coatings (~50 µm) were developed at industrial process parameters using Hot Dip Process Simulator (HDPS) at CSIR-NML (Figure 9). Hot Dip Colorized Galvanizing Coating provides different colorized shades with an ease process feasible to the batch type as well as continuous type hot dip galvanizing steel industries with an alternate change in bath composition and bath temperature. The property of the cathodic corrosion protection and the resistance to change in surface chromaticity remains intact in the colorized GI coating. The coating possessed very good Powdering Resistance as successfully passed V-60 Bend test as per the standard ASTM E290. Also, the coating possessed very good corrosion resistance as found to exhibit overall impedance value >1200 $\Omega.cm^2$. Further, the coating passed the requirements of salt spray exposure for the appearance of red rust, is more than 500 hours. The coating optimized compositions has been patented (IN). The different colors of coatings are achieved by varying the bath temperature between 460 °C-575 °C. The coating meets all the requirements of various ASTM standards, including ASTMA123/G90, E1164, E290, G106 & B117. The developed colored coatings have a bright future to be deployed in various industrial sectors, including construction, agriculture, automobile, and wire fencing for aesthetic and decorative purposes. This coating can be easily applied on large components like towers, pillars, pipes, rods, roof sheets, bridge angles, gates etc. as well as small components like solar panel liners, steel handles, cap-covers etc.

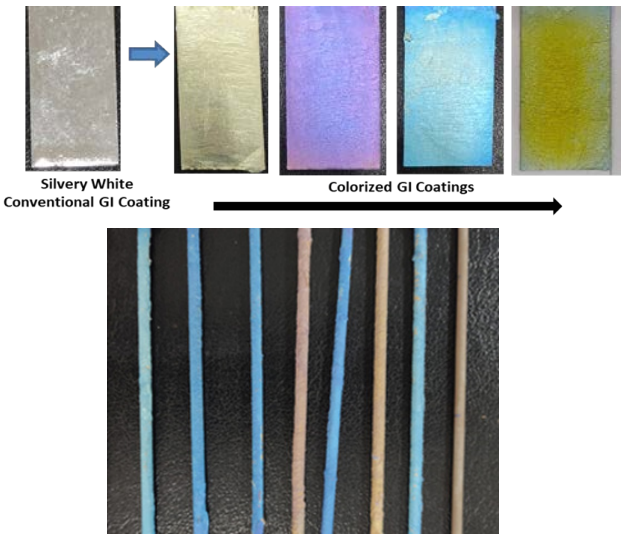


Figure 8: ***The developed advanced colorized hot dip galvanising Zn-X (X- Mn, Ti, Co) alloy coatings on steel sheets and wires.***

Mitigation of the Erosion Damages and Span the Operational Life of the Hydro Turbine Components in Cost-effective Manner

This project aimed for the development of a cost-effective hard, tough erosive resistive coating with improved structural properties to mitigate the mitigate the erosion damages and increase the operational life of hydro turbine components. The designed and prepared Fe-based amorphous alloy ribbons exhibit the high glass-forming abilities (Trg ~ 0.6), and comparable mechanical and corrosion properties with WC-10Co-4Cr coating. The following compositions were designed, prepared (ribbons), and examined:

- $Fe_{50}Cr_{15}Mo_{10}B_{12}C_{10}Si_3$ (Base Alloy)
- Base Alloy + 3Wt% FeP
- Base Alloy + 3Wt% Al
- Base Alloy + 3Wt% Cu
- Base Alloy + 3Wt% Nb

Various structural and mechanical properties of these ribbons were analyzed by respective methods as shown in Figure 9.

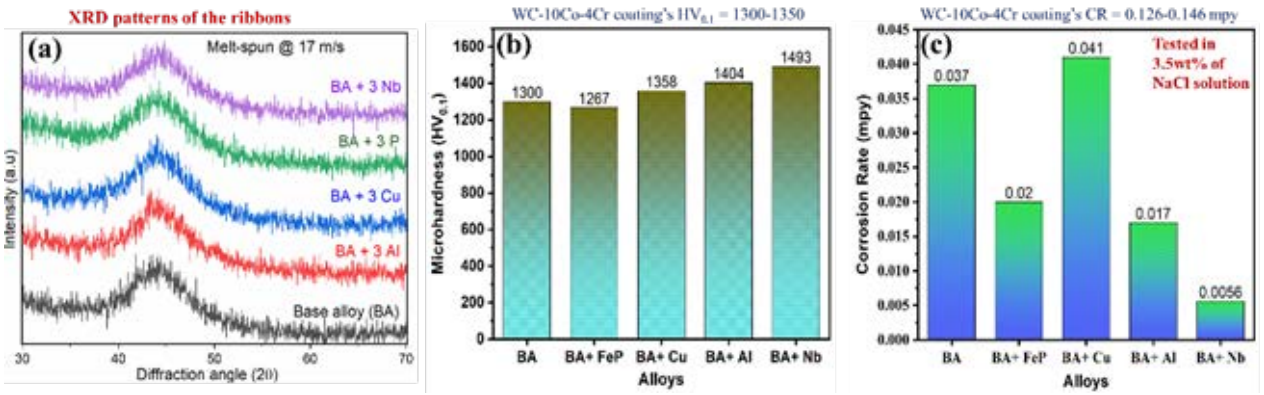


Figure 9: (a) XRD patterns, (b) Microhardness, and (c) corrosion rate of the designed and prepared Fe-based amorphous alloy ribbons.

Further the $Fe_{50}Cr_{15}Mo_{10}B_{12}C_{10}Si_3$ amorphous alloy (BA) coating represents the superior mechanical and corrosion properties over the mild steel. The coatings strongly adhered to the substrate and possessed very less defects. Also, the coatings were amorphous in nature and had around 4 times lower corrosion currents than the bare substrate (Figure 10). The coatings had around 6 times higher hardness than the mild steel substrate. Also, the specific wear rates were found to be reduced by 5.5 times with the application of the coatings. optimized compositions have been patented (IN). Further, optimization of the compositions is in progress to achieve much superior properties, and attempts are being made for the IP rights. The hydro-turbine components often suffer from erosion damage, due to which the service life of the components is reduced drastically. With the application of such cost-effective coatings, the service life of the turbine components will be increased, and shut-downs will be reduced.

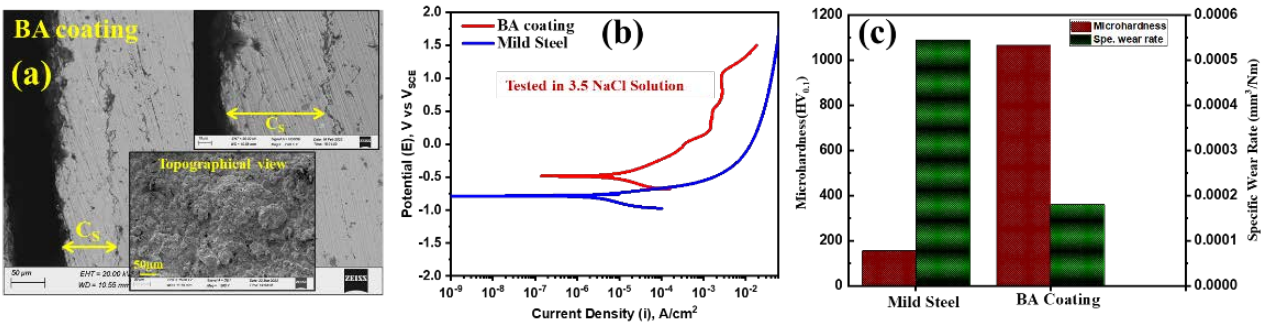


Figure 10: (a) SEM micrographs, (b) potentiodaynamic polarization curves, and (c) wear rate of the BA coating and mild steel.

Surface Modification by Ultrasonic Shot Peening to Mitigate Stress Corrosion Cracking of 304L and 304LN

The project aimed to investigate the effect of ultrasonic shot peening(USP) technique in mitigation of the stress corrosion cracking of austenitic stainless steels, viz-a-viz modification of the surface grain structure and nature of stress state. The degree of sensitization (DOS) can be correlated well with the susceptibility to intergranular stress corrosion cracking (IG-SCC) in stainless steels, i.e. higher the DOS, the higher the susceptibility to IG-SCC. Initially, the highly sensitized specimens were prepared through cold working and sensitization treatment (at 600°C for 20hrs). With increasing cold working compression or thickness reduction, the degree of sensitization was found to be increased.

The highest DOS (around 78%)is determined for the 50% cold-worked specimens. Later on, these cold-worked/sensitized specimens were subjected to ultrasonic shot peening for 1 and 3 min. The strain-induced martensite fraction was found to increase with an increase in both shot peening time and the degree of cold working. The degree of sensitization was found to be reduced in shot-pinned specimens for 1 min, whereas the DOS was found to be higher in 3 min shot-pinned specimens for both 20% and 50% cold-worked specimens (Figure 11). Further, the study on the effect of USP on DOS and IG-SCC in welded specimens is in progress. The USP was successfully carried out on all the cold-worked specimens. The USP for 1 min was found to decrease the degree of sensitization for both 20% and 50% cold-worked specimens. Further, an increase in USP time was found to increase the degree of sensitization. A novel USP technique is being utilized for decreasing the degree of sensitization and IG-SCC. This could find a lot of applications in nuclear and thermal power plants, where tensile stresses play an important role in deteriorating the component life by SCC.

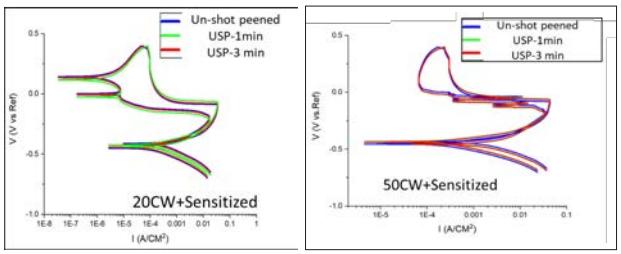
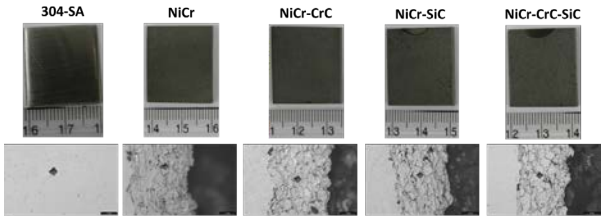


Figure 11: The double loop electro-potentio kinetics reactivation (DLEPR) curve for 20% and 50% cold-worked 304L steels.

Development of Wear and Corrosion Resistant Metallic Coatings for Boiler Components in Coal-Fired Thermal Power Plants

This project aimed to develop wear and corrosion-resistant metallic coatings with good thermal conductivity for boiler components in coal-fired thermal power plants. The present study investigates the erosion behavior of HVOF-sprayed coatings (NiCr, NiCr-CrC, NiCr-SiC, NiCr-CrC-SiC) on Type 304 stainless steel substrates. The phase composition, cross-sectional microstructure, micro hardness, and erosion resistance of the coatings were analyzed using optical microscopy, SEM-EDS, 3D optical profilometry and erosion test rig. Micro-hardness results show that the micro-hardness of the HVOF-sprayed coatings is significantly higher than that of the substrate, due to the presence of embedded carbides in the coatings. However, the coatings exhibit lower erosion resistance compared to the substrate, which is attributed to improper melting of the feedstock and the presence of a high volume fraction of pores. Various coatings with different compositions were successfully deployed on SS 304 substrate through High Velocity Oxy-Fuel (HVOF) process. To increase the coating efficiency and erosion properties, further optimization of compositions and process parameters is required. The erosion and high temperature corrosion are serious issues in existing thermal power plants. These coatings could find lot of applications in nuclear and thermal power plants where reduction in shut-downs and increase in component life is the need of the day.



Sample	304-SA	NiCr	NiCr-CrC	NiCr-SiC	NiCr-CrC-SiC
Hardness (Hv)	185 ± 8	218 ± 31	333 ± 120	273 ± 29	237 ± 37

Figure 12: The substrate and various coatings deployed by the HVOF process; top surface & cross-section photographs and micro-hardness values are determined for respective coatings.

Development of Surface Modification Techniques to Combat Molten Chloride Salt Corrosion in Concentrated Solar Power Plant

The project aims to develop methods for engineering the microstructure of additive-manufactured products from austenitic stainless steel to ensure enhanced fatigue and anti-corrosion properties. This study explores the impact of grain boundary engineering (GBE) on the corrosion behavior of

Type 316L austenitic stainless steel when exposed to molten chloride salts. The GBE microstructure was achieved by optimizing the grain boundary character distribution through a single-step thermo-mechanical process involving small-strain annealing treatment. Hot corrosion tests were conducted in a molten salt mixture of KCl/$MgCl_2$/NaCl at 923 K for 72 hours in an air atmosphere. Microstructural analysis of the corroded samples using SEM-EDS revealed that chromium was preferentially depleted along the grain boundaries, leading to the formation of a porous corrosion layer. Compared to the As-received condition, the GBE-treated samples demonstrated significantly better resistance to molten chloride salt corrosion. This enhanced resistance is attributed to the minimal penetration of molten salts in the GBE samples, which is due to the disruption of random high-angle grain boundary connectivity (Figure 13). This disruption was confirmed by the higher fraction of low Σ-coincident site lattice boundaries in the GBE samples. Various specimens were surface modified for grain boundary engineering through thermomechanical processing (pre-straining, annealing temperature, and time variation). The GBE specimens show much less weight loss and depth of penetration as compared to unmodified specimens in the molten salt mixture. Further optimization of GBE characters is underway to improve the corrosion resistance of the steel. In recent years, CO2 emission-free large-scale power generation techniques like concentrated solar power (CSP) plants have become progressively more attractive. However, corrosion by the molten salts is now a major concern for the structural integrity of the TES materials (specifically, Ni and Fe-based super alloys) that directly deteriorate the overall performance of the systems. Such advancement in surface modification will be in very much demand to increase the service life of the components in CSP.

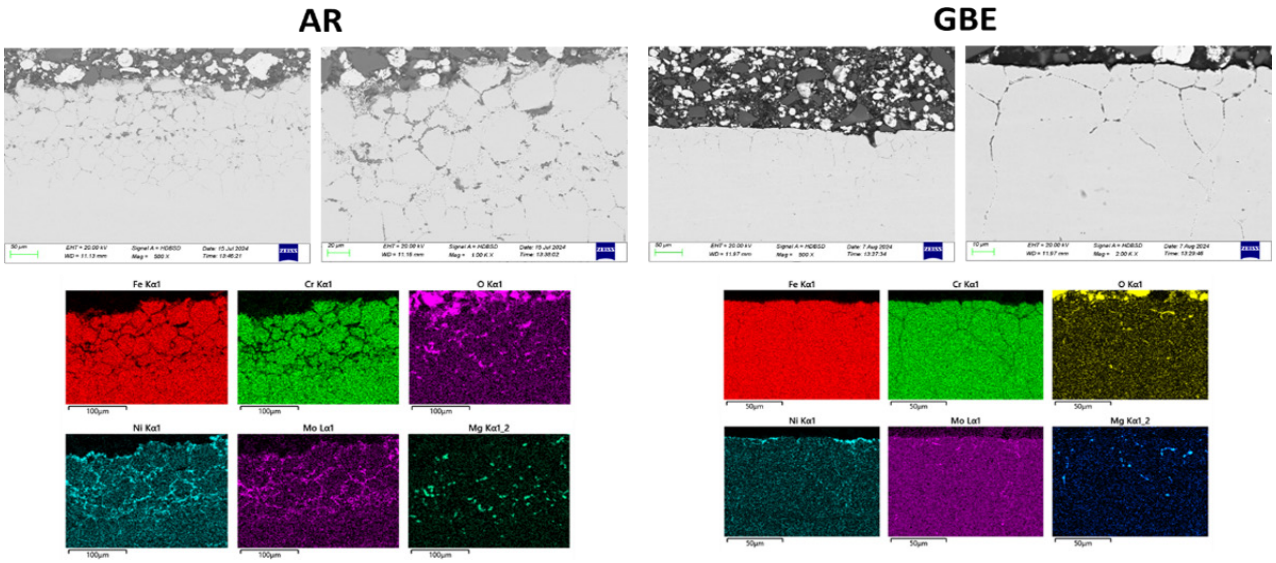


Figure 13: Electron probe micro-analyzer (EMPA) micrographs showing the depth of penetration and compositional distribution in corroded as-received and GBE specimens.

Oxidation and Hot Corrosion Behaviour Studies of Micro-Arc Oxidation (MAO) Coated Ti2AlNb Alloy

The project aimed to develop micro-arc oxidation (MAO) coating on Ti2AlNb-based alloy and to study the oxidation and hot corrosion behaviour of coated and uncoated alloy in temperature ranges 600-1000 °C for durations of 100-1000 hours. This study aimed to explore the effect of MAO coatings on oxidation and high-temperature corrosion

behavior of the Ti2AlNb alloy suitable for turbine blade making. The alloy Ti70Al24Nb6 (at%) was successfully developed through a vacuum arc melting procedure at CSIR-NML. The alloy was found to consist of Ti, Al and Ti_3Al phases in the matrix as revealed through XRD analysis. Further, the as-cast alloy was studied for high temperature oxidation behavior at temperatures 600, 700 & 800 °C for 100 hr. The weight gain was found to increase with both the exposure time and temperature, as shown in Figure 14. All the exposed specimens were found to be covered with the oxide composed of TiO_2, Nb_2O_5, Al_2O_3 and Ti_3Al phases, where Ti3Al might have come from the base matrix. Further, the thickness of the oxide was fond to increase with the increase in exposure temperature. Other, alloys with different chemical compositions are being prepared to determine the best composition w.r.t. the high temperature oxidation and corrosion performance. Ti-24Al-6Nb alloy was prepared at CSIR-NML Jamshedpur. Oxidation studies on prepared Ti-24Al-6Nb alloy at 600- 800 °C in air for 100 hours are completed. Post oxidation characterizations of Ti-24Al-6Nb alloy, using XRD, SEM, and Raman spectroscopy for 600-800° C for 100h exposures have been completed. Preparation of Ti-50Al-6Nb alloy at CSIR-NML Jamshedpur is in progress. Oxidation & Hot corrosion behavior of Ti-24Al-6Nb & Ti-50Al-6Nb alloys are in progress. Oxidation behavior investigations of Ti-24Al-6Nb alloy at 600-800 °C for 100 hours suggest that these materials are suitable for aerospace applications. This will reduce low-pressure turbine blades failures caused by oxidation/hot corrosion, enhance fuel efficiency, and contribute to India's aim of self-reliance in the aerospace sector.

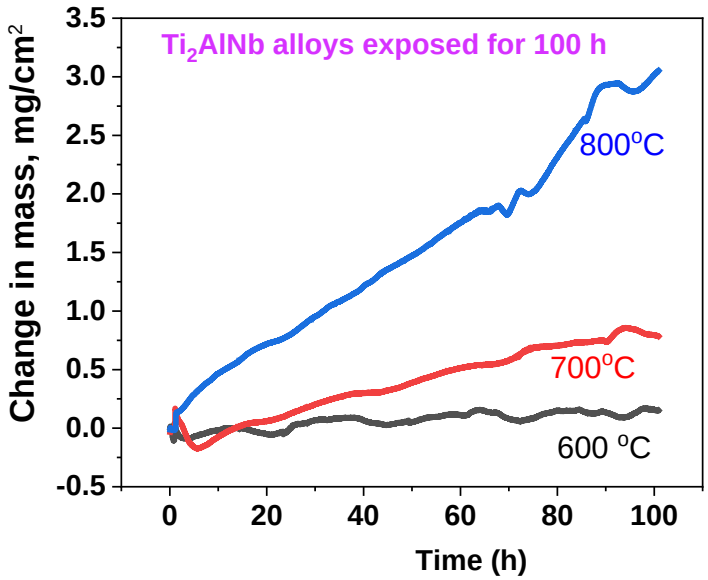


Figure 14: ***Weight change per unit area of the Ti-24Al-6Nb alloys oxidized at 600-800 °C for 100 h:***

Development of Cost-Effective Corrosion-Resistant Coating for Railway Tracks Through Optimization of the Alloying Elements

To develop a cost-effective and corrosion-resistant zinc coating for rail track steels through a thermal spray process such as High Velocity Oxy Fuel (HVOF). Also, the type of alloying elements (aluminium, magnesium, silicon and rare earths) and their composition optimization will also be a focus in order to achieve superior mechanical and corrosion characteristics of the system. Initially, the railway specification recommended Zn coating (85Zn-15 Al, wt%) was prepared in the laboratory to check

the feasibility of the HVOF process to deploy such coatings. Later on, the various coatings with varying Al and Mg content were prepared through the HVOF process at an equipment company, Jodhpur. All the coatings were deployed successfully on the rail steel substrate without any powdering or flaking. Further, the coatings were found to exhibit very low oxygen contents as revealed through SEM-EDS and EPMA analysis, suggesting very low or minimal oxidation during coating deposition. The average surface roughness was found to decrease with an increase in Al content in Zn-Al coatings. Further, the contact angle was found to increase with the increase in Al content in the coating. Similarly, an increment was observed for the corrosion properties, where corrosion resistance was found to be highest for the highest Al contents. The HVOF coating was also compared with the commercial hot dip Zn-0.2Al and Zn-5Al coatings. The corrosion properties were found to be comparable for the Zn-5Al coating deposited with both the processes but the corrosion rates were found to decrease to lower values with an increase in Al content in HVOF coatings (**Figure 15**). The long-term exposure for scribed specimens suggested that the HVOF Zn-Al coating can protect the underlying substrate effectively up to 6 days. The long-term exposures of Zn-Al coatings and corrosion investigation of Zn-Al-Mg coatings are in progress. Zn-Al and Zn-Al-Mg coatings were successfully developed on rail steel specimens through the HVOF process without any flaking or powdering. The increase in Al content from 5 to 15% decreases the corrosion rates by more than 50%. This increased corrosion resistance might be attributed to the increased contact angle and decreased surface energy of the specimens with an increase in the Al contact. Further, optimization is required to get the reduced corrosion rates. The corrosion causes huge losses in the railway sector, including replacement of railway tracks without completion of their intended service life. An improved coating process will help in reducing the replacement of railway tracks due to corrosion.

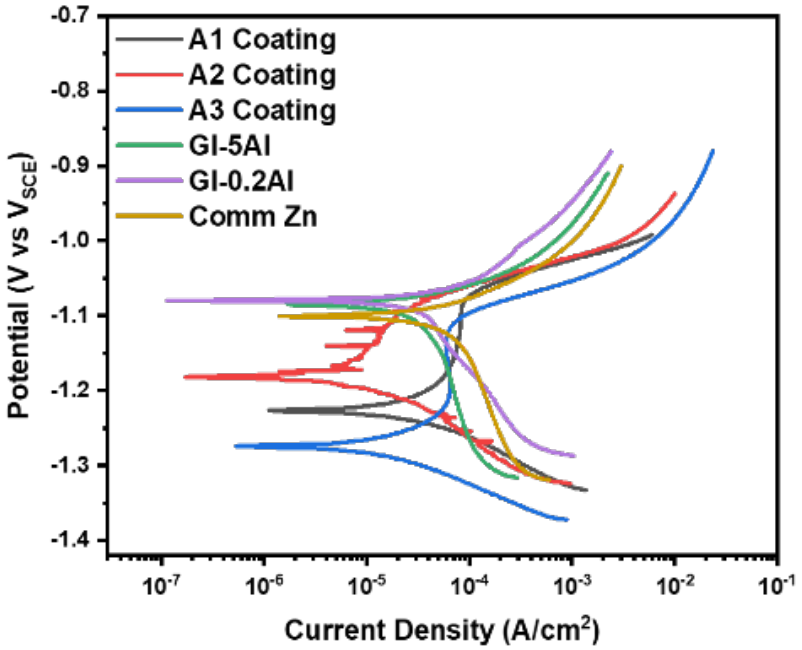
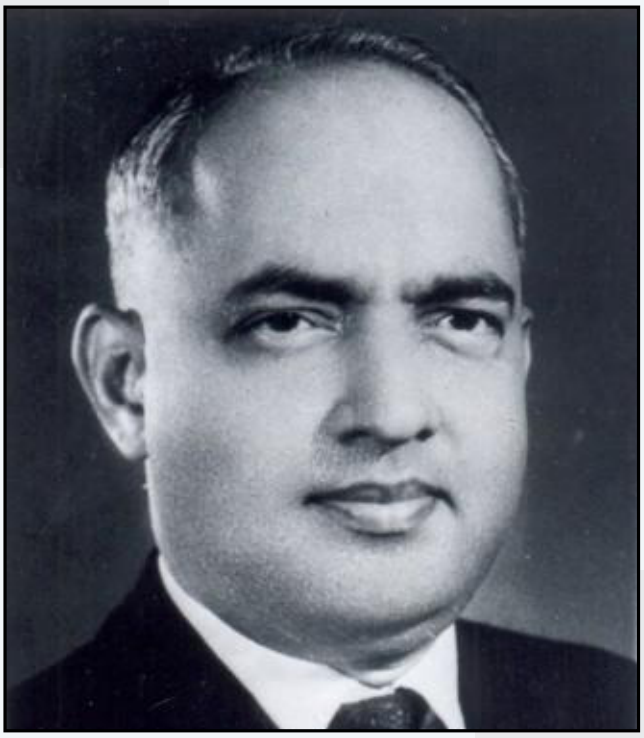


Figure 15: Potentiodynamic polarization curves showing the corrosion performance of various HVOF (ZN-Al) coatings, viz-a-viz GI (Zn-0.2Al & Zn-5Al) coatings and commercial Zn block.

Directors who led the path on which we walk today...



Prof. V. A. Altekar

Served as Director of CSIR-National Metallurgical Laboratory (CSIR-NML) from 1967 to 1984

Prof. V.A. Altekar was a distinguished metallurgist He completed Metallurgical Engineering from Banaras Hindu University in 1946. Prof. Altekar's research on the utilization of lead-zinc ores from Zawar earned him a scholarship for postgraduate studies at the Colorado School of Mines, USA. His academic and industrial experiences included assignments with the U.S. Bureau of Mines and a private copper mining and milling company in Arizona.

CSIR-NML Madras Centre

CSIR-National Metallurgical Laboratory, Madras Centre had its roots in the NML Foundry Station, established in 1965 at Guindy Industrial Estate, Chennai (Figure 1). The idea of establishing foundry stations across the country was first proposed by Sir Jehangir Ghandy, the then Chairman of the Executive Council of the National Metallurgical Laboratory. The intention was to provide technical assistance and testing facilities to the foundry industry. Since then, for long years, the station extended its services related to analysis of both ferrous and non-ferrous metals, testing of molding sands etc.

Later on, the idea of setting up the CSIR Madras Complex, in close proximity to many other technological institutions, was conceived by Dr. S. Husain Zaheer and Dr. Atma Ram, former Director Generals of CSIR. The objectives were two-fold: (i) To provide scientific services in the interest of economy and (ii) To allow the interplay of scientists working in different disciplines, offering a unique opportunity for developing a multi-disciplinary culture. NML Foundry Station was shifted to the present campus of CSIR Madras Complex in 1973 and renamed as NML Madras Centre. An ore dressing laboratory and a refractory unit were also added.

In the middles of 1980s, the centre shifted its focus towards ore dressing/mineral processing activities. Over the years, the center was instrumental in developing column flotation technology, which was one of the flag ship technologies of CSIR-NML in the area of mineral processing. The centre made its mark at the National level for the indigenization of 'Column flotation technology' for processing lean and fine-grained ores. The laboratory scale (74 mm diameter) and pilot plant scale (500 mm diameter) flotation columns were designed, fabricated, and field tested at various private and public sector mineral processing plants located across the country. Development of column flotation technology achieved Technology Readiness Level - 9, implying that it is ready for successful deployment at a commercial scale. The unique selling point (USP) of the NML Madras Centre is providing a one-stop solution for installing commercial scale flotation columns by collaborating and partnering with an engineering, procurement and construction (EPC) company, M/s Tega McNally Minerals Limited, Bengaluru, and Reagents manufacturers and suppliers, M/s Sudarshan Chemical Industries Limited, Pune. The important National level recognitions include (i) National Mineral Awards, awarded by Ministry of Mines, Government of India to both inventors of the column flotation technology, i.e. Dr. G. Bhaskara Raju and Dr. S. Prabhakar (ii) Technology Award for most significant CSIR technology of the five year plan period – 2014.

In 1998, the center embarked on a major restructuring, to accommodate the demands from the industry and stakeholders, a new metallurgy section was started. Altogether, a new state-of-the-art metallurgy lab was setup with a range of sophisticated equipment, including optical microscope(s), micro-hardness tester, image analyzer, stereo microscope, metallographic sample preparation facilities etc. New facilities were also added to chemical analysis lab. Gaining strength from advanced facilities and qualified manpower, the centre expanded its activities to include (i) Failure analysis of metallurgical components, classification and (ii) Classification of import/export metallic consignments to cater to the demanding needs of various government agencies including Customs, Directorate of Revenue Intelligence, and other statutory bodies of Government of India. The metallurgical team of the center provided the consultancy services to the above agencies across the country including offices of Commissioner of Customs, located at Chennai, Mumbai, Jaipur, Viskhapatnam, Tuticoring, Cochin etc. These

activities not only made the center financially self sustaining with significant amount of external cash flow (ECF) but, also gained a wide-spread of appreciation from the agencies for the timely delivery of the expert services in an efficient and transparent manner.

The Center's leading role in column flotation technology continues till date, and successfully implemented at several mineral process industries across India. Some of the recent beneficiaries include M/s Hinduja Foundries, Chennai, M/s Hindustan Zinc Limited, Udaipur, M/s The Ramco Cements Limited, Chennai, M/s Rajshree Sugars & Fertilizers, Tamil Nadu and M/s Tamil Nadu Electricity Board, Chennai among several others. So far, 5 laboratory scale, 2 pilot plant scale, and 7 commercial scale flotation columns have been commissioned across India (Figure 2).

The Centre also embarked on a program for developing biodegradable and eco-friendly flotation reagents for sillimanite, coal, graphite, limestone, and iron ore fines in collaboration with M/s Sudarshan Chemical Industries Limited. Another flagship program currently being pursued is 'Sustainable technology for the production of high-grade synthetic rutile from Odisha ilmenite' sponsored by the Department of Science and Technology. The Centre is also actively engaged in finding industrially viable solution for the 'Reduction of surface contamination of Teri heavy mineral sand and dewatering studies' in the Mineral Separation Plant of M/s IREL at Manavalakurichi, Tamil Nadu.

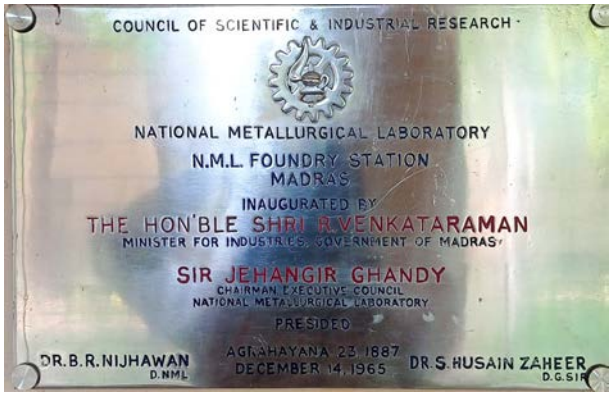


Figure 1 : Commemorative plaque of NML Foundry Station at Madras (Chennai)

Figure 2 : The Centre

Figure 3 : Commercial scale flotation columns for barite (1000 tpd) at M/s Oren Hydrocarbons (P) Ltd., Chennai

In-house Project Support Group (i-PSG)

In-house Project Support Group (*i*-PSG) at CSIR-National Metallurgical Laboratory strives to achieve excellence in in-house research by enabling the researchers and supporting their aspirations. The group supports the research in pre-identified thematic areas, on technology development initiatives, researches of scholastic nature leading to masters / doctoral degrees as well as infrastructural development activities. The aim of these projects is directed towards improvement in performance, new developments in emerging research areas of relevance and initiation new research in minerals, metals and materials at CSIR-NML. A total of thirty-six i-PSG supported projects were in progress during the year 2023-24. Some of the significant outcomes/ achievements of these projects are as follows:

- As End of Life (EOL) solar PV panels may become a source of hazardous waste during landfilling, the valuable content of these panels like glass, silicon, aluminium, silver etc. make them attractive secondary resources. A research into recovery of metal values led to metallurgical grade Si with 98% purity as well as Ag and Al have been recovered with 95% purity. The glass content (~70% of panel mass) was processed to develop glass ceramic with 150 MPa compressive strength which may find application in construction and architecture replacing the natural marble and granite.

- A 5-10 kg scale planar flow casting system was developed integrating in-house designed sub-assemblies such as tundish, nozzle, air separator, melting unit, pneumatic height adjustment, RF induction coil suitable for both the ferrous and non-ferrous materials. Trials on Al-12.5Si, Pure Zn and Fe-based alloys led to strips of up to 25 mm width and 150 m length. The strip thickness varied in the range 100-250 mm.

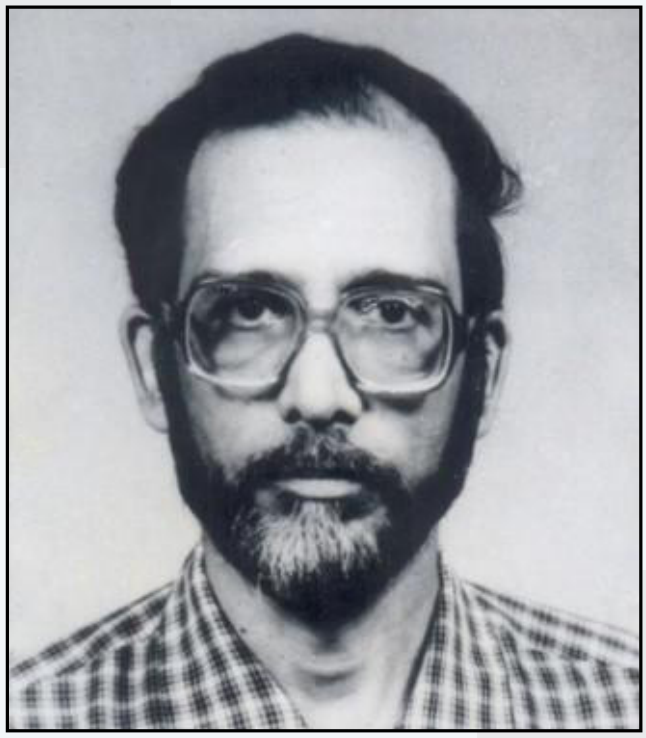
- Hard tungsten-copper (W-Cu) composite scraps, generated during the production of heavy electrical contacts and/or at their end-of-life, were processed to recover valuable materials. Tungsten and copper powders were successfully extracted from the scrap using selective electrodeposition and oxidation processes, respectively. The recovered copper powder and tungsten, as tungsten oxide, were of high purity.

- Lean iron ore pre-concentrates, using conventional beneficiation techniques, contain 15-17% silica which cannot be used directly in a blast furnace. The column floatation route was adopted to beneficiate these pre-concentrates so as to achieve silica content to less than 5%. Based on the appropriate design of experiments and employing statistical empirical models and process optimization the silica content of around 3.6% along with an iron recovery of 67.8%.

- As there is a limited R&D scope for developing new alloy feedstock powders applicable in additive manufacturing (AM), recently installed inert gas atomizer was used to produce Fe-based amorphous alloy powders with high sphericity and smooth surface finish. The good flowability of powders (50-80 mm size) thereof led to successful preparation of partially amorphous products (22x22x8 mm^3) by direct-energy-deposition (DED). This demonstrated the possibility to develop newly designed high-performance alloy powders for AM and other applications.

Dr. Krishna Kumar and his team received '*Prof. Shilowbhadra Banerjee award 2024*' for the best in-house project completed in 2022 entitled "Investigations on the NML's retort technology for magnesium metal production" from Dr. N. Kalaiselvi, Director General CSIR and Secretary DSIR, during Platinum Jubilee Foundation Day function held on November 26, 2024, at CSIR-NML Jamshedpur.

Directors who led the path on which we walk today...



Prof. Shilowbhadra Banerjee

Served as Director of CSIR-National Metallurgical Laboratory from 1985 to 1992.

Dr. Shilowbhadra Banerjee is a renowned metallurgical engineer. A prolific contributor to the field, Dr. Banerjee has authored 51 international publications, holds 17 patents, and has received nine national and international awards. He is also a fellow of seven esteemed academies. Beyond his academic and research achievements, he has played influential roles as a consultant and board member across both public and private sectors, actively participating in numerous technical committees and academic bodies.

Academy of Scientific & Industrial Research (AcSIR)

The Academy of Scientific and Innovative Research (AcSIR) was established as an 'Institution of National Importance' by an Act of Parliament in 2011. It is the largest Academic institution for doctoral research in India, having more than 8000 students currently registered for PhD. AcSIR is ranked 11th by "Scimago Institutions Rankings", 12th by "Nature Index", and 11th by "NIRF" in the Research Category, among the academic institutions in India.

AcSIR-NML offers an Integrated Dual Degree (M.Tech + Ph.D) Program (IDDP) as well as a Ph.D in Engineering Sciences. A total of 10 students have been admitted in the year 2024. Out of the 6 students enrolled in the IDDP program, 2 students have been awarded the CSIR-GATE-JRF. By the end of December 2024, total 34 students were enrolled with AcSIR-NML. In addition to the PhD program in Engineering Sciences, admissions in both Chemical Sciences and Physical Sciences disciplines have also been approved to further improve student enrolments. A total of 5 young scientists have been inducted as faculty members at AcSIR-NML in 2024.

Following are a few achievements of AcSIR-NML students in the year 2024:

1. Mr. P S Manoranjan Jena, IDDP student of August 2018 session working under the supervision of Dr.-Ing Jitendra Kumar Sahu, received Acta student award for publication of a paper entitled "Discrepancy in low cycle fatigue and creep-fatigue life of 720Li alloy tested at 720 °C: Role of crystallographic texture evolution" in Materelia in the year 2024.
2. Mr. Sukalpan Nandi, IDDP student of January 2021 session working under the supervision of Dr. V. Rajnikanth was awarded second prize for the oral presentation in BTTD 2024 for the presentation titled "Effect of inter-pass temperature on microstructure of Wire Arc Additively Manufactured Inconel 625".
3. Mr. Vaibhav Gaur, PhD student of August 2019 session working under the supervision of Dr. B. Ravikumar has been deputed to RMIT University, Melbourne, for the Joint AcSIR- RMIT PhD Program.

In the year 2024, the following students of AcSIR-NML were awarded their PhD degree:

Name of the PhD Scholar	Enrolment No.	Thesis Title
Dr. Gaurav Kumar Bansal	32EE16A31003	Phase Transformations and mechanical behaviour of quench and partitioned steel
Dr. Rashmi Singla	32EE16A31005	Study of structure-property correlations of inorganic-organic hybrid geopolymers
Dr. Ajit Kumar Thakur	20EE16A31005	Optimization of the continuous annealing cycle for improvement of the mechanical property and microstructure of dual phase (dp 590)
Dr. Komal Singh	20EE18A31001	Development of tin selenide based thermoelectric materials and thin films for energy harvesting applications

Directors who led the path on which we walk today...

Prof. Pacha Ramachandra Rao

(1942-2010)

Served as Director of CSIR-National Metallurgical Laboratory from 1992 to 2002.

He was a distinguished metallurgist and administrator, uniquely recognized as the only individual to have served as Vice-Chancellor of Banaras Hindu University (BHU) from 2002 to 2005, while also having been both a student (1963–1968) and a faculty member (1964–1992) at the same institution.

1976-85

R&D Facilitation/Support

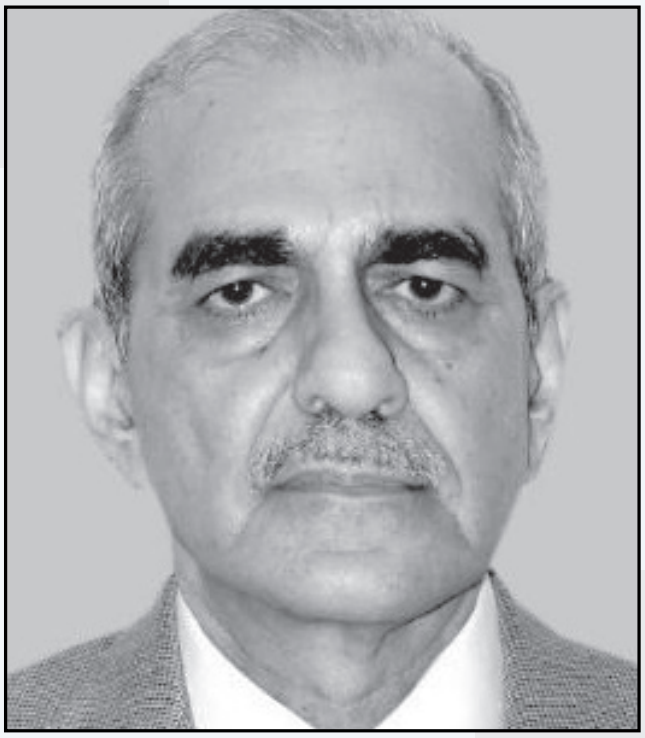
Prof. Altekar handing over the Monogram to Smt. Indira Gandhi, Hon'ble Prime Minister

Beneficiation of coal fines for reduction of ash content

Cast with NML Filter

Inauguration of Tunnel Kiln, Carbon Pilot Plant

Directors who led the path on which we walk today...



Prof. Surya Pratap Mehrotra

Served as Director of CSIR-National Metallurgical Laboratory from 2002 to 2009.

Prof. S.P. Mehrotra, a distinguished authority in metallurgy and materials science, had an extensive academic tenure at IIT Kanpur, where he led both the Department of Metallurgical Engineering and the Advanced Centre for Materials Science. A prolific researcher, he has published numerous papers and authored a book on the history of IIT Kanpur. His contributions have been recognized with several prestigious awards, including the Tata Gold Medal (2007) and the SAIL Gold Medal (2002) from the Indian Institute of Metals.

Research Planning and Business Development

The Research Planning and Business Development (RPBD) division is engaged in the management of research and several other key functions, which ensure the smooth execution of research in the laboratory. The division also interacts and acts as a bridge between the researchers and the potential stakeholders. Its major activities are: (a) Research management, including Project management and IP Services, and (b) Business Development, including Client Interfacing, Negotiations & contracts, and Technology Marketing. Apart from these, the division also develops and manages Information Systems and Databases, and is involved in Tender Management & Annual Procurement Plans and Documentation and Reporting.

Figure 1 : Key Functions of RPBD

Research Management

RPBD is engaged in the research management of the institute, which includes mainly project management and IP services. The division plays an important role in the planning and execution of various projects as per the CSIR guidelines. RPBD has the central role in project approvals and funds allocations. RPBD also manages the manpower involvement in projects. In the year 2024-25, 56 new projects were initiated in varying fields of Minerals, Materials, and Metals. 868 Nos. of Tax Invoices were sent to various customers, and Corresponding E-Invoices were created in the GST Portal by the division. 122 numbers of Proforma Invoices for the advance payments were also facilitated by the division.

Further, the department provides Intellectual property-related services such as prior art search and analysis, White Space Mapping, and assistance in patent filing through CSIR-IPU for the researchers to ensure maximum research output. In the year 2024-25, six patent applications and one industrial design were processed and filed by the group.

Business Development

The RPBD group serves as the pivot between the potential sponsors for projects, industrial partners for technology transfers, and other collaborations in Research and Development. A total of twenty-seven MoUs/agreements were signed between national and international industry and academic partners for collaborative work and other technology-related areas. Indian Rare Earths Limited Technology Development Council, Odisha; Geovale, Kolkata; Vossloh Cogifer, New Delhi; University of Calcutta, Kolkata; Accelor Microsystems, Chandigarh; Shree Mahabir Refractories, Ranchi; Midhani; RDSO, Lucknow; RDCIS SAIL, Ranchi; BHEL, Hyderabad; Alleima India Private Limited, Mumbai; and

Eyantram Waste Management Pvt. Ltd., Bangalore are a few to name. Multiple drafts are in the pipeline, which will be executed in the next fiscal. RPBD facilitated collaboration with two foreign institutions named CSIRO, Australia, and Lyten, USA. RPBD also participates in e-Tendering Processes of Government Bodies, PSUs and Industries requiring specialized services in the field of Minerals, Materials, and Metals. In the reporting year, CSIR-NML participated in nearly to hundred tendering processes and was awarded eighty-six out of those. The division also ensures that customer feedbacks are sought to understand the impact of the CSIR-NML technologies and services, which further allows us to fine-tune them.

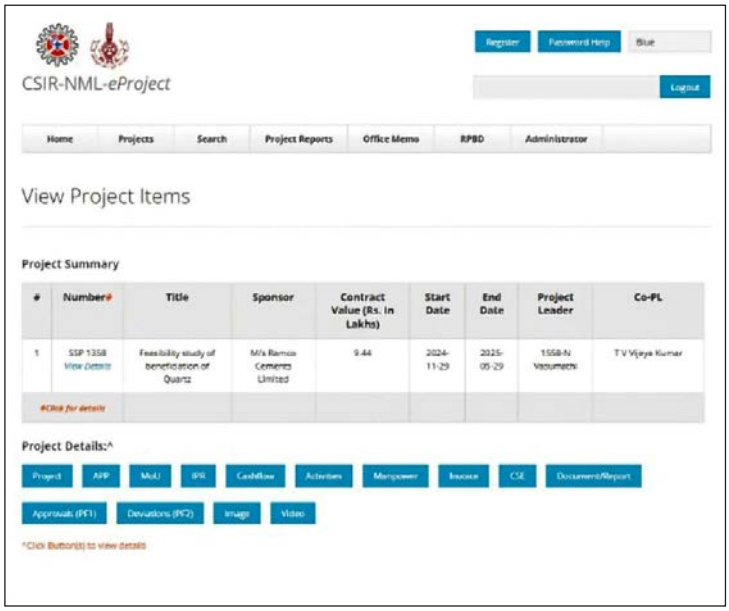
Information Systems & Databases

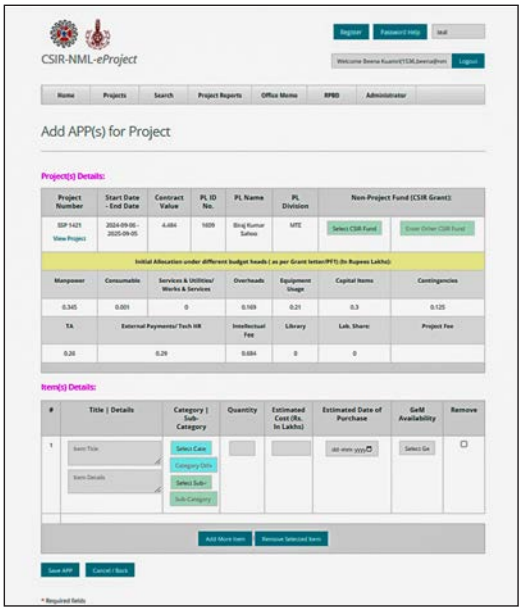
The division has developed several in-house web-based information systems and databases for smooth dissemination of information to the research fraternity. These ensure the larger goals of transparency, digital inclusion, and enhancing the overall efficiency of the laboratory. Some of these Information system also act as the decision support systems for the managemen. RPBD is involved in preparation of reports for various government bodies, these systems assist for timely submission of various data. Some of the significant documents are the Key Performance Indicator (KPI) Document, the PMO Portal Data, the Research Utilization Data, the Monthly Reports, the Quarterly Reports, the Annual Procurement Plan Document, and the Replies to PMO & Parliament Queries, among others. In the reporting year more than eighty such reports were prepared and sent to various stakeholders of the laboratory by the division.

Figure 2 : Information Systems & Databases

CSIR-NML-EProject: A web-based information system for one-window access to varied project information, project annual procurement plan, and project report management system

The web-based information system caters to varied purposes like Project Report Management, Annual Procurement Plan (APP) Management, Single window access to all project-related information viz. *Genesis, Proposal, Report, Payments, Manpower, Agreements, IPR, and others*. Several Legacy systems provided scattered information about projects via separate data repositories and websites. The new system brings all under one point of access and creates a comprehensive, unified view. The Annual Procurement Plan Management System enables the planning, prioritization, and utilization of Funds for procurement in an optimal way.





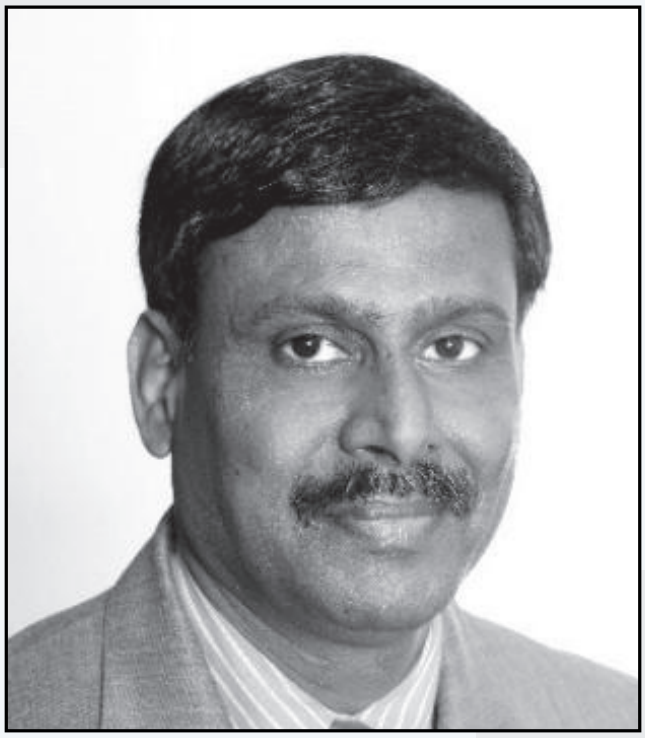
Documentation and Reporting

CSIR-NML disseminates monthly newsletters via RPBD, which highlight the significant activities & achievements of the organization. The division is responsible for coordinating the preparation of the Annual Report of the laboratory. In addition, the division also publishes the RC Agenda, Technology Handbook, Director's Desk, and Equipment Brochure.

Other Activities

Apart from the above, the division is also involved in maintaining the Annual Procurement Plans and procuring intangible services for R&D. RPBD coordinates the provision of S&T Services to customers. Testing as per standards is carried out for various organizations every year. Last year, over 55 customers were provided testing services. The division also coordinates the summer/ winter student trainings. In the last fiscal, 158 students pursuing undergraduate and post-graduate courses like B. Tech and M. Tech. from 34 institutes all over India viz. IIT Kharagpur; IIT Jammu; IIT Indore; IIT BHU IIT (ISM) Dhanbad; IIT Patna; NIT Rourkela; NIT Durgapur; NIT Andhra; NIT Hamirpur; NIT Jamshedpur; NIT Raipur; NIT Surathkal; NIT Tiruchirappalli; IIEST Shibpur; BIT Mesra; MGIT Hyderabad; MANIT Bhopal; MNIT Jaipur; Indus University, Ahmedabad; NIAMT Hatia; BITS Pilani; BITS Hyderabad; BITS Goa; VIT Andhra Pradesh; were provided training at CSIR-NML.

Directors who led the path on which we walk today...



Dr. Srikanth Srinivasan

Served as Director of CSIR-National Metallurgical Laboratory from 2010 to 2016.

Dr. Srikanth Srinivasan is a distinguished metallurgist. During his tenure, Dr. Srinivasan made significant contributions to extractive metallurgy, thermodynamics, and failure analysis, authoring 63 research publications. He held several prestigious fellowships, including those from the Indian Academy of Engineering (2010) and the National Academy of Sciences, India (2005). Notably, he received the Materials Research Society of India Medal in 2006 and the Metallurgist of the Year Award from the Ministry of Steel and Mines in 2004 . Dr. Srinivasan's leadership at NML was instrumental in advancing the laboratory's research and technological initiatives.

Information Management and Dissemination Centre

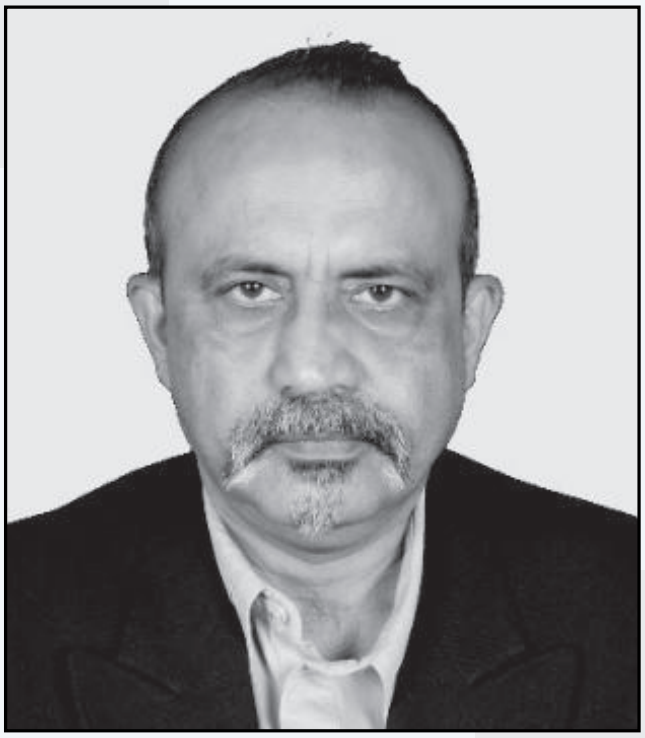
The Information Management and Dissemination Centre (IMDC) serves as a key hub for the efficient collection, organization, and distribution of information. Through resource accessibility and organized storage, these centres aim to promote research, instruction, and knowledge exchange. The key objectives of IMDC include:

- **Collection and Organization:** Accumulating relevant data and resources such as books, research papers, reports, and digital content, and systematic cataloguing for easy access.
- **Storage and Conservation:** Protection of valuable information in both physical and digital formats to ensure longevity and protection against data loss.
- **Access and Dissemination:** Providing access to resources for researchers, students, and professionals through different means such as digital platforms, physical libraries, and document-sharing systems.
- **Information Sharing:** Sharing of information through offline or online modes.

At CSIR-NML, IMDC works in different verticals, viz. Library management, managing the Museum and Archive, organizing the Skill Development Program, and Jigyasa activities for the school students.

- Library management: CSIR-NML has a vast library consisting of approximately 55000 documents in the form of reference books, technical reports, manuals, conference proceedings, standards, thesis, etc. Approximately 21000 bound volumes of journals since 1950. Full text reprints of research publications of S&T members of CSIR-NML. This is maintained through an in-house developed software, e-prints, which is accessible even from outside the organisation.
- NML-journal publication: IMDC ensures publication of the Journal of Metallurgy and Materials Science (JMMS), a CSIR-NML publication. JMMS publishes original articles, review reports, and short communications in the areas of minerals, metals, and materials, tracing the overall life cycle of structural as well as functional materials. The journal lays special emphasis on fundamental sciences related to metallic materials and their applications.
- Museum and Archive: The Museum and Archive is an integral part of IMDC. It maintains old records, demonstration items, and other documents of importance.
- Skill Development program: CSIR-NML organizes a Skill Development program for the youths and employed professionals in the field of Materials, Metallurgy, and Mineral engineering. Since FY 21-22, CSIR-NML has trained approximately 3578 participants under the Skill Development Program.
- Jigyasa program: CSIR-NML, under its Scientific Social Responsibility, organizes a school interaction program for the school students of classes VIII-XII. Under this program, school students often visited NML and saw the research facilities available in the lab. It helps to ignite the younger minds in the field of science and technology.

Directors who led the path on which we walk today...



Dr. Indranil Chattoraj

Served as Director of CSIR-National Metallurgical Laboratory from 2017 to 2022.

Dr. Indranil Chattoraj is a distinguished metallurgist. He holds a B.Tech. in Metallurgical Engineering from IIT Kanpur. During his tenure at NML, Dr. Chattoraj led significant advancements in materials research, particularly in areas such as hydrogen embrittlement and localized corrosion. He has authored numerous publications and contributed to various scientific His leadership and research have had a lasting impact on the development of metallurgical sciences in India.

Information Communication Technology Unit (ICTU)

The Information Communication Technology Unit [ICTU] caters and coordinates the lab-wide needs for IT resources and management in terms of creation of IT infrastructure, its services & maintenance. The group is mainly looking after the development and services of IT facilities & infrastructure at CSIR-NML from basic to advanced needs.

The group is well equipped with computational facilities in terms of hardware and software. The IT-Team, consisting of scientists and technologists, is actively involved in supporting the R&D-activities of the laboratory by providing a reliable and efficient IT infrastructure with uninterrupted Internet service.

At CSIR-NML IT infrastructure is used primarily for data transfer, communication, exchange of manuscripts and data with authors and referees, generation of a knowledge base through the internet, Email communication, HR activities, project & planning meetings around the globe, through video-conferencing facilities.

Besides day to day routine activities, the following are some of the major milestones achieved while equipping the multiple office & residential campuses of CSIR-NML and two dispensaries located in the residential campuses, with quality IT infrastructure during the reporting year:

(a) Planning, estimation & installation of an IT facility for the specific needs of the renovated location.

(b) Coordination and management of lab wide maintenance services for IT assets.

(c) Preventive maintenance of the IT infrastructure installed across campuses.

(d) Provisioning of IT facilities in terms of network connections and utility services to new entrants.

(e) Development and maintenance of several in-house utility web applications.

(f) IT support to Human Resource Group (HRG) for performing various HR activities like interviews/ assessment/ DPC etc.

(g) Conducting Video Conferencing sessions for project meetings, project review activities, and other events.

(h) Lab-wide CCTV surveillance services and hardware maintenance by resolving various technical issues.

(i) Providing telephone facility, its maintenance, and teleconferencing in multiple campuses of CSIR-NML in Jamshedpur.

(j) Upgradation of audio-visual facilities at common places.

(k) IT support for the conduct of seminars, workshops & conferences at CSIR-NML.

(l) Upkeep of turnstile based attendance system at CSIR-NML for employees and pensioners.

(m) Verification of data and printing of the employee identity card.

(n) Technical maintenance and upkeep of Aadhaar Enabled Biometric Attendance System (AEBAS).

(o) RTI-related activities.

Illumination during Diamond Jubilee (2010) & One Week One Lab @CSIR-NML (2023)

Engineering

The Engineering Division caters and co-ordinates the engineering needs, both R&D and infrastructural, of the laboratory, Large Scale Testing Facilities & Residential Complexes. Majority of the needs are non-repetitive in nature, though some are of routine type. The division has two groups called Works Services and Maintenance (WSM) group and Project Planning and Engineering (PPE) Group. WSM group include Civil Engineering Unit, Electrical Engineering Unit and Air-Conditioning Unit, while PPE group consists, central workshop and new projects unit. The type of activities performed by the Division include: Design and Development of prototypes, Project Engineering, Engineering Consultancy, Infrastructural Development, R & D activities of the core areas of the laboratory, Up-keeping of premises, In-house maintenance, Workshop facilities and support services. An Industrial design has also been registered by the group "Gripper-feeder arrangement assembly to process wires/cables of varied diameters" (Ref: 019DN2023)

Project Planning and Engineering Group

The activities of the group include: Prototype/ Product design and development, Research and consultancy, Setting up and operation of critical infrastructure, Finite Element, CFD and material Modeling , Maintenance and up-keeping of R&D equipment, Central workshop , Skill development , Technology up-scaling and detailed Engineering Packages (BEP/ DPR), and Pilot plant operation and maintenance.

Prototype/ Product design and development

In the reported period, the division has contributed to the requirements of several projects like Electrodeposition of corrosion-resistant Cr-carbide coatings on SS 316L for Sink Roll applications in Continuous Galvanizing Lines; Technological intervention in the Dokra handicrafts for increased productivity, aesthetic and quality; Material analysis and reclamation of flame tube for gas turbine generator 1250 2E; and Piloting NML's Retort process(Pidgeon) for Mg Metal extraction with integrated vacuum distillation refining at scale of 100-120 kg Mg/day metal output.

Research and consultancy

In the reported period, the division has undertaken a major project entitled "Near net shape 3D manufacturing of Inconel 718 by optimizing controlled parameters of wire arc additive manufacturing with Cold metal".

Setting up and operation of critical infrastructure

In the reported period the division has been working on setting up of infrastructural requirements for the successful installation and trial runs of Rolling Mill and Inert Gas Atomiser; and Operations of 493KWP solar power plant for catering the electrical load requirement of Laboratory, due to which huge monthly savings in the running expenditure is observed.

CFD (Computational Fluid Dynamics) and Numerical Modeling

The division is actively contributing in process modeling activities of major research projects: Development of an AI based smart alarm system for predicting critical temperature zone of large industrial structure; and Development of Gas Atomized Iron Alloy Powders for Soft Magnetic Core Applications.

Basic Engineering Packages

The group has been involved in Preparation of Detailed Project Report (DPR) for the laboratory upscaling projects of major research projects.

Maintenance and up-keeping of equipment

The division has limited manpower but actively involved in the in-house maintenance to support

the high-value equipments of the laboratory. This will save a lot of AMC costs and will reduce the breakdown time of the equipment. During the reporting period, the three breakdown services were performed.

Skill Development

The division is involved in skill developmental training activities in the area of welding, 3D printing and carpentry under CSIR Skill Initiatives. In the reported period, the division has undertaken the Women Technology Park (WTP) for capacity building and entrepreneurship development project and also supported skill India initiative by CSIR. Under WTP project we achieved the below milestones-

- CSIR-NML in association with NIAMT, Ranchi organized four Job Oriented Training (JOT) and one Entrepreneurship Development Program (EDP) under Women Technology Park. The program has trained 104 participants in the field of waste management, carpentry, Basic Computer, art & craft and graphic design. As a result, the program has created a skilled workforce that can contribute to the local economy.
- CSIR-NML and NIAMT, Ranchi has developed the infrastructure for a common facilitation center and incubation center. This provides a space for women to collaborate and work on their projects.
- CSIR-NML has designed the course plan for 3D printing and basic computers. This provides participants with technical skills that are in high demand in the market.
- 12 trainees got job in various organizations

Central Workshop

Central Workshop receives jobs from various divisions, for specimen preparation of different materials, fitting, machining & fabrication of prototypes and repairing of miscellaneous jobs. All these jobs are completed in time to the satisfaction of the indenters. Major facilities available in the workshop are: CNC Lathe, Universal Milling, Shaper, Radial drill, Pillar Drill, Double column band saw, Shearing, Pipe bending M/C, TIG/ MIG welding, EDM wire cut machine. Major achievements made during the period are: Catered to workshop service jobsheets: 497; Design, drafting and fabrication support services jobsheets: 55; Upgradation of workshop facilities by installation of new Lathe Machine to increase productivity and accuracy.

Works Services and Maintenance Group

This group has diverse responsibility to upkeep infrastructure, create new infrastructure and renovation of facilities in 7 campuses (Main laboratory, 2 pilot plants, 4 residential campuses) of CSIR-NML. These services include civil engineering, electrical engineering and refrigeration & air conditioning, lifts, water supply etc. The work accomplished by the group can be categorized in 3 major categories namely- new infrastructure, renovation jobs and routine maintenance jobs. List of major works undertaken are enumerated below.

New Infrastructure

The infrastructure management team has successfully completed new facilities creation jobs as per the requirements of the laboratory. In addition, we take annual Maintenance & Overhauling of infrastructure & maintenance jobs. Some of the new facilities developed are: Creation of work space for installation of Inert Gas Atomizer (IGA) at LSTF Area; Supply, Installation, Testing and Commissioning of water cooler cum purifier for the year 2022-23-24, Jamshedpur; Design, fabrication, supply, installation, testing and commissioning of New ring fountain with RGB LED Colour lighting in existing pool at CSIR-NML, Jamshedpur; and New rolling mill foundation.

Renovation Jobs

The infrastructure management team has successfully completed new facilities creation jobs and annual maintenance & overhauling

of infrastructure & maintenance jobs. Some of the new facilities developed are: Special repair and painting of MS-I (Twelve Storied) building in CSIR-NML housing complex, Agrico for the year 2022-23 & 2023-24; Raising of boundary wall in Golmuri Colony residential campus of CSIR- NML; Maintenance of Lifts; Maintenance of H.T & L.T Breakers; and Horticultural work and associated up-keeping.


Renovation of Director's Bungalow- CH Area.



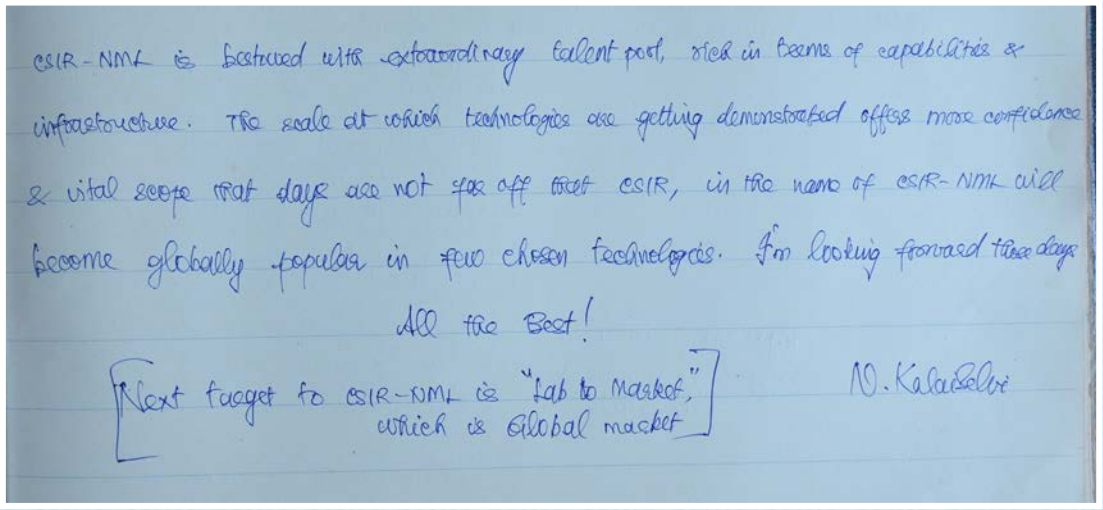
External repairs, renovation and road paving block work in Agrico Housing complex



Renovation: Old TEM Lab.; Magnetic Lab.; Pyro Electric Metallurgy Lab



Electrification Work: Agrico Main Gate; Old TEM Lab.; Magnetic Lab


CSIR-NML is bestowed with extraordinary talent pool, rich in terms of capabilities & infrastructure. The scale at which technologies are getting demonstrated offers more confidence & vital scope that days are not far off that CSIR, in the name of CSIR-NML will become globally popular in few chosen technologies. I'm looking forward those days

All the Best!

[Next target to CSIR-NML is "Lab to Market," which is Global market]

N. Kalaiselvi

"CSIR-NML is bestowed with extraordinary talent pool, rich in terms of capabilities & infrastructure. The scale at which technologies are getting demonstrated offers more confidence & vital scope that days are not far off that CSIR, in the name of CSIR-NML will become globally popular in few chosen technologies. I'm looking forward those days.All the Best! Next target to CSIR-NML is "Lab to Market," which is Global market."

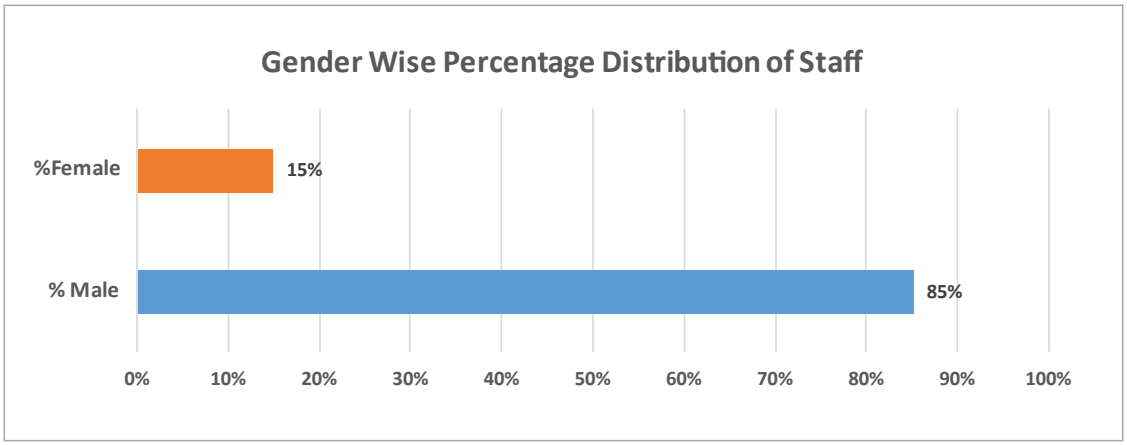
Dr. N. Kalaiselvi
Secretary, DSIR & Director General, CSIR
22nd May 2024

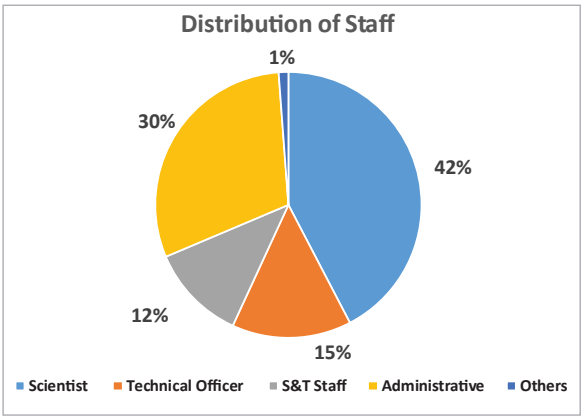
Human Resource

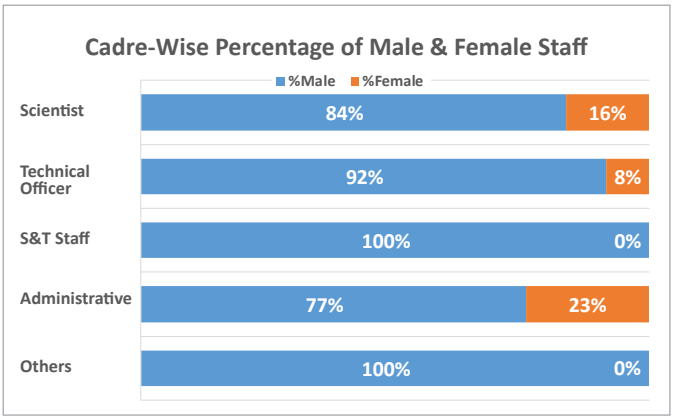
HUMAN RESOURCE STATUS

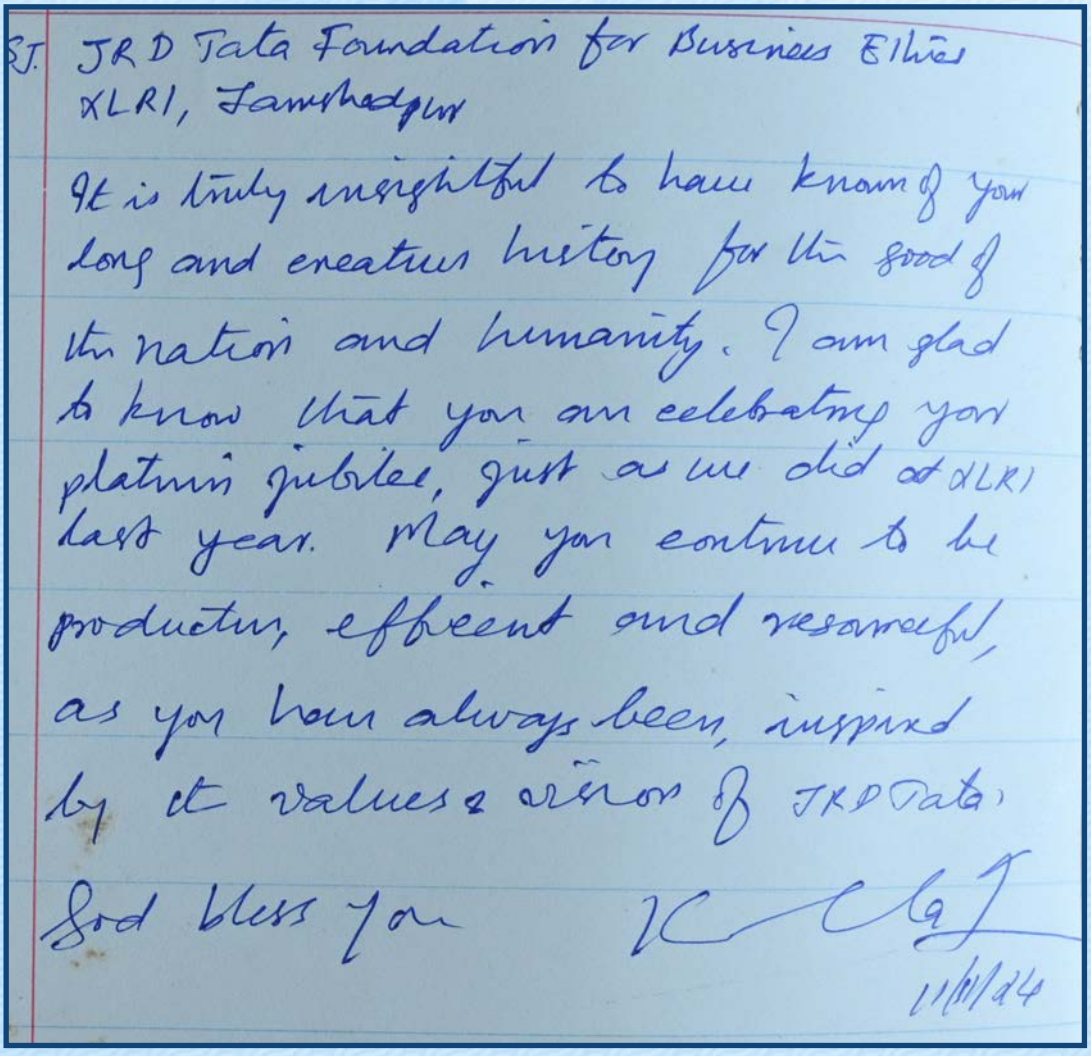
	Manpower	No. of MALE	No of FEMALE	TOTAL	% MALE	%FEMALE	% TOTAL
1	Scientist	91	17	108	84	16	42
2	Technical Officer	34	3	37	92	8	15
3	S &T Staff	30	0	30	100	0	12
4	Administrative	59	18	77	77	23	30
5	Others	3	0	3	100	0	1
	TOTAL	217	38	255	85	15	100

*As On 31.03.2025









SJ. JRD Tata Foundation for Business Ethics
XLRI, Jamshedpur

It is truly insightful to have known of your long and creative history for the good of the nation and humanity. I am glad to know that you are celebrating your platinum jubilee, just as we did at XLRI last year. May you continue to be productive, efficient and resourceful, as you have always been, inspired by the values & vision of JRD Tata.

God bless you

11/11/24

" It is truly insightful to have known of your long and creative history for the good of the nation and humanity. I am glad to know that you are celebrating your platinum jubilee, just as we did at XLRI last year. May you continue to be productive, efficient and resourceful, as you have always been, inspired by the values & vision of JRD Tata."

God bless you.

Dr. Kuruvilla Pandikattu SJ.

Chair Professor of JRD Tata Foundation on Business Ethics at XLRI

Jamshedpur

11th November 2024

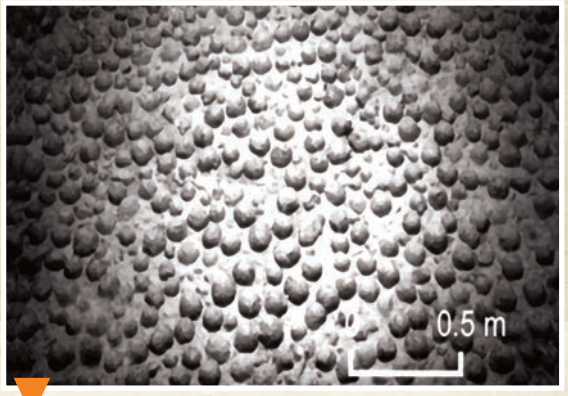
1986-95

The Functionaries

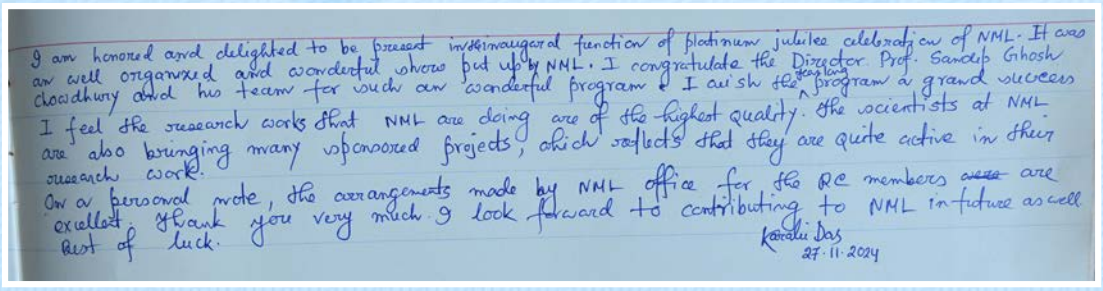
Graphite Crucibles & Metallization of Non-conductors

A Sea Nodule

Chemically Polished Aluminium Conductor



Distribution in sea floor - Sea Nodules



I am honored and delighted to be present in inaugural function of platinum jubilee celebration of NML. It was an well organized and wonderful show put up by NML. I congratulate the Director Prof. Sandip Ghosh Chowdhury and his team for such an wonderful program. I wish the ~~program~~ program a grand success. I feel the research works that NML are doing are of the highest quality. The scientists at NML are also bringing many sponsored projects, which reflects that they are quite active in their research work.
On a personal note, the arrangements made by NML office for the RC members ~~were~~ are excellent. Thank you very much. I look forward to contributing to NML in future as well
Best of luck.
Karabi Das
27.11.2024

"I am honored and delighted to be present in the inaugural function of platinum jubilee celebration of NML. It was an well organized and wonderful show put up by NML. I congratulate the Director Prof. Sandip Ghosh Chowdhury and his team for such an wonderful program. I wish the program a grand success. I feel the research works that NML are doing are of the highest quality. The scientists at NML are also bringing many sponsored projects, which reflects that they are quite active in their research work.

On a personal note, the arrangements made by NML office for the RC members are excellent. Thank you very much. I look forward to contributing to NML in future as well."

Dr. Karabi Das,

Professor & Dean (Outreach)

Member, Board of Governors

Indian Institute of Technology Kharagpur

27th Nov 2024

Staff News

Superannuation

(We thank them for their dedicated services)

Dr. S.K. Tiwari
Chief Scientist
31st May 2024

Shri S. N. Hembram
Principal Technical Officer
31st May 2024

Mrs. Pompha Devi
Multi-Tasking Staff
30th June 2024

Dr. M. K. Mohanta
Chief Scientist
31st July 2024

Shri. P D Lakra
Section Officer
31st July 2024

Shri. Ramena Raju
Section Officer
31st July 2024

G Dharma Rao
Multi-Tasking Staff
31st July 2024

Dr. Shobhana Dey
Chief Scientist
30th November 2024

Dr. B. Ravi Kuma,
Chief Scientist
31st December 2024

Dr. Paras Nath Mishra
Sr. Principal Scientist
31st December 2024

Shri S. C. Das
Laboratory Assistant
28th February 2025

Shri P. K. Roy
Chief Technical Officer
28th February 2025

Shri S. K. Bose,
Senior Technician (2)
28th February 2025

New Joinees

(Welcome to the new joinees and wishing them a rewarding career)

Ms. Shruti Priya
A.S. Officer (General)
D.O.J. 13th March 2025

Shri Veerendra Kumar
A. S. Officer (General)
D.O.J. 18th March 2025

Shri Rahul Gandhi
A. S. Officer (General)
D.O.J. 21st March 2025

Ms. Anchal Kumari
A. S. Officer (General)
D.O.J. 27th March 2025

Shri N. K. Tiwary
A. S. Officer (F & A)
D.O.J. 25th March 2025

Shri. Satyabhan
A. S. Officer (F & A)
D.O.J. 27th March 2025

Shri Ankit
A. S. Officer (S and P)
D.O.J. 28th March 2025

Staff transferred From Sister Laboratories to CSIR-NML

(We Welcome them at the laboratory and wish them a rewarding career ahead.)

Shri Viplave Vishal
Administrative Officer
CSIR-Head Quarters, New Delhi
06th May 2024

Shri Dibyendu Banerjee
Assistant Section Officer (S&P)
CSIR–Central Glass & Ceramic Research Institute (CSIR–CGCRI), Kolkata
05th August 2024

Shri Bhola Azad
Stores and Purchase Officer
CSIR-Central Salt and Marine Chemicals Research Institute (CSIR-CSMCRI), Bhavnagar.
02nd September 2024

Shri Niraj Kumar
Assistant Section Officer (General)
CSIR-Central Institute of Mining and Fuel Research (CSIR-CIMFR), Dhanbad.
13th September 2024

Shri. Amarendra Kumar Singh
Section Officer (Finance & Accounts)
CSIR-Central Institute of Mining and Fuel Research (CSIR-CIMFR), Dhanbad.
14th November 2024

Shri Shailendra Kumar
Section Officer (Stores & Purchases)
CSIR- Central Mechanical Engineering Research Institute (CSIR-CMERI), Durgapur
04th February 2025

Staff transferred to Sister Laboratories from CSIR-NML

(We wish them all the best for their future endeavors.)

Shri Subhajit Banerjee
Administrative Officer
CSIR-Central Mechanical Engineering Research Institute (CSIR-CMERI), Durgapur
10th April 2024

Shri A. K. Das Choudhury
Stores & Purchase Officer
CSIR-Institute of Minerals and Materials Technology (CSIR-IMMT), Bhubaneswar
20th September 2024

Sad Demise of Staff

Mr. Birendra Kumar
Senior Technical Officer (2)
07th December 2024

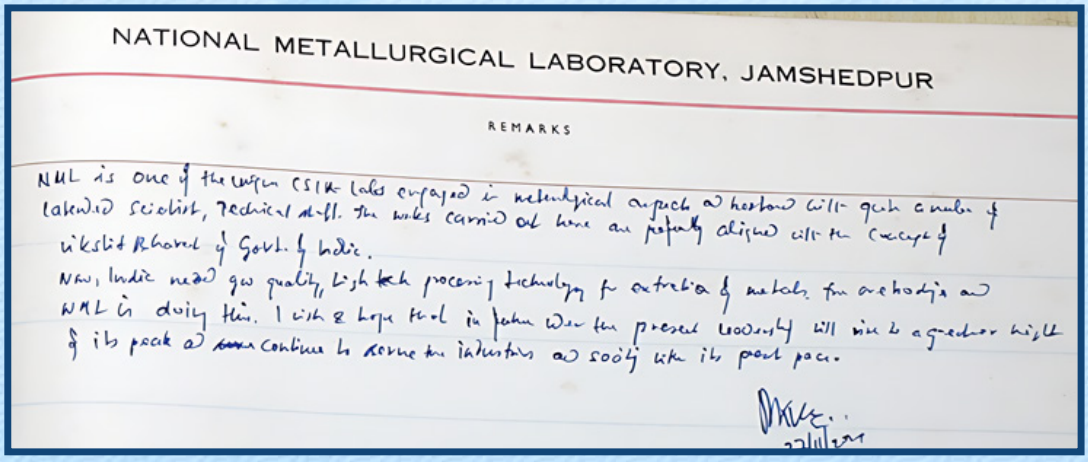
Dr Ranjan Kumar Sahu
Chief Scientist
30th March 2025

Administration

The Administration provides a variety of support services for conducting R&D in the laboratory. The division has aligned itself to realize the vision of CSIR-NML and facilitates the overall system towards meeting the set goals and targets. The division has significant roles to play in every facet of the career development of the staff as well as providing sustained support right from their recruitments to superannuation, and often, even after superannuation. The Administration connects all the staff and facilitates in fulfilling various vital needs of the employees, like, academics, career, housing and health in the following manner:

- Formulate and implement the policies concerning administrative procedure for smooth functioning of the Institute.
- Provide advice to the functional bodies (committees/ functional groups) within the organization.
- Maintain liaison with CSIR Headquarters on matters related to administration/vigilance/legal.
- Provide healthy working conditions and atmosphere to Institute by correct interpretation as well as implementation of governing rules and regulations.
- The Administrative Head of the Laboratory advises the Director for decisions on administrative matters.
- Implement instructions of the Director/CSIR on various matters.

The division is presently headed by the Administrative Officer, who is over all In-charge of the activities and supported by the Section Officers, and a group of ASOs, SSAs, JSAs and other supporting staff. The division also coordinates the work of the Health care centers, security services and Rajbhasa cell. In the recent past, the Administration has undergone a major shift in terms of work culture, towards implementing paperless processes through e-Office, Smart Performance Appraisal Report Recording Online Window (Sparrow) and Account Manager System (AMS) software. An improved work culture and decentralized leadership at all levels has been introduced to bring the desired changes. A sustained effort has been initiated to inculcate the passion to ensure faster service delivery system to match with the expectations of CSIR-Enterprise Transformation initiatives.



NATIONAL METALLURGICAL LABORATORY, JAMSHEDPUR

REMARKS

NML is one of the unique CSIR labs engaged in metallurgical aspects and bestowed with such a number of talented scientists, technical staff. The works carried out here are perfectly aligned with the concept of Viksit Bharat of Govt. of India.

Now, India needs good quality, high tech processing technology for extraction of metals, from ores and NML is doing this. I wish & hope that in future under the present leadership will NML be a greater high of its peak and continue to serve the industries and society with its great pace.

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Dr. Prakash Kumar

Director

CSIR- National Geophysical Research Institute (NGRI)

Hyderabad, Telangana

27th November 2024

Stores & Purchase Division

CSIR-NML's Stores & Purchase (S&P) Division is a committed team of dedicated officials who are primarily responsible for procurement of goods & services including imports from foreign countries. The team works as a support system to cater to the Research and Development (R&D) needs and also to meet the long term strategic goals of this Institute and also the team strive to keep the system of R&D and other supporting services running in smooth condition by taking care of procurement activities related to materials / services in time and within the ambit of public procurement.

The division is involved in the purchase and distribution of goods towards fulfilling the needs of research. The Division ensures efficient management of all indents received and timely execution of the process. The division strives to fulfil the mandates of the GoI for purchasing "Make in India" products thus promoting the native technologies of the Indian industries and MSMEs in particular. The procurement of goods is encouraged through the Government E-marketplace and supports the "Vocal for Local" campaign.

The division has completely migrated to the recently launched ACCESS portal launched by CSIR for use in its constituent laboratories for indenting and purchase. Thus the current system is completely digitised

Impression

"I would like to thank you and your team for your effort towards developing a process for recycling of Monel scrap for production of plating grade nickel and copper sulphate. The developed process is very simple, innovative and much cheaper than the conventional acid dissolution process. With online demonstration and theoretical explanation our chemist could successfully reproduced the results. Subsequently we pilot the process on 10 kg scale with your continuous guidance and help. Based on the data generated during piloting of the process and feedback from you we decided to set-up a commercial plant to produce plating grade copper and nickel sulphate. We have already commissioned a Monel scrap recycling plant to produce about 200 MT Copper and nickel plant and planning to increase the capacity in near future with increasing the modular set-up. Thank you very much for your continuous guidance and timely solution for in each stage till start of commercial production. We expect similar help and guidance in future also."

Ms. Apurva Goenka, Director

Colour Chromes Pvt. Ltd.

31st January 2025

Finance & Accounts

Finance & Accounts Division of CSIR-NML is actively engaged in planning, organizing, directing, and controlling the financial activities of the Lab including accounting of all the financial transactions of the year as per GFR and CSIR guidelines. This division provides central accounting and financial information to the Director, CSIR-NML, CSIR Headquarters, and other stakeholders through the management information system.

The following are the major activities of the Finance & Accounts Division.

- Preparation of Budget Estimate and Revised Estimate for CSIR-NML and submitting the same to CSIR for allocation of funds.
- To ensure that there are adequate funds available to acquire the resources needed to help the organization achieve its objectives.
- To ensure cost control while facilitating adequate spending within laid down guidelines and procedures in the matter.
- To ensure adequate cash flow and proper management of funds through the transfer of funds from CSIR.
- To provide appropriate financial information relating to different heads of accounts and projects to the Director, Project Leaders, and other decision makers so that informed judgments and decisions are made. Posting of monthly progressive expenditure in the NML intranet to keep all employees informed about the fund position.
- To prepare financial documents such as the Receipts and Payments account and Balance Sheet of the organization on a given date for submission to CSIR and decision makers including submission to CAG (Audit) for certification of accounts.
- Preparation and Submission of Utilization Certificate to sponsors of the projects as and when required.
- Pre-audit of all the bills before making the final payment to avoid any irregularity or deviation from the financial Rules.
- Processing promptly all payments payable through the Treasury Single Account (TSA) at the RBI in the PFMS system of the Government of India.
- Promptly, accurately, and efficiently recording all the receipts and payments in the relevant ledgers and books of accounts.
- Closing of GPF/CPF accounts, remittance of funds to NSDL relating to National Pension Scheme and Professional tax, income tax, etc., within the due date to the appropriate authority.
- Accounting, processing, and ensuring timely filing of various GST returns and payment of GST due to the Government.
- To provide progressive reports on monthly expenditure, OB, Bank reconciliation, Audit Paras, etc., to maintain transparency.

Performance Highlights for the financial year 2024-25

- Utilized Budget Grant allocated by CSIR- Rs.7262.56 lakhs + Rs.5454.538 lakhs (pension)
- Utilization from Laboratory Reserve-Rs. 896.391 lakhs
- Generation of interest by investment of surplus funds- Rs. 901.434 lakhs
- Generation of Lab Reserve - Rs.1720.507 lakhs.
- Bank reconciliation of the Cash Book completed up to 31st March, 2024.
- GPF Account as on 31-03-2025 has been reconciled, finalized and closed.
- During the year new cases of 12 pension and 22 family pension cases have been completed with issuing of PPO and pension papers on time.
- NML finance successfully switched over to PFMS system for payments out of Govt. grant, where payments are directly made tovendors by RBI under Single Treasury Account system.
- Several CAG Audit para have been settled.
- Three ASOs have joined the F&A Deptt.
- Provision of QR Code for online money receipt in the NML official Account.

Impression

"Special thanks to the materials processing team for their expert suggestions and support in conducting the experimental work as per plan. Impressed by the prompt actions by the team. We could carry out experimental cold rolling with intermediate annealing's to reach the target thickness during our stay and will continue with our work in this domain and avail valuable lab services offered by NML-Jamshedpur. Glad that we could visit other impressive lab facilities such as Melting and Creep testing and interact with enthusiastic professionals at NML Jamshedpur. Once again expressing gratitude for the warm hospitality extended to us."

Mr. Narendra Girase

R&D Manager

Alleima India Pvt Ltd, Pune

24th March 2025

Hindi Cell

Official Language Implementation

CSIR-NML has an active Program for the Im- plementation of the official language, Rajbha- sha Hindi. In addition to the regular official works and various translations into Hindi, CSIR-NML proactively initiates a series of ac- tivities throughout the year, which include pub- lications, conducting trainings, workshops, talks, annual competitions, and divisional in- spections for enhancement of Hindi use in the divisional activities.

Publications in Hindi

Annual Report, CSIR-NML Newsletter and Brochures have been published in Hindi and English, which are circulated to CSIR units and various organizations of the Govt of India. Press releases were issued in Hindi and published in daily newspapers.

Promotional Activities for Hindi Im-plementation

- Four inspections were conducted by the Hindi Officer covering various divisions for identifying the areas of Hindi implementation and enhancing the use of Hindi in divisional activities.
- Incentive Scheme for working in Hindi has been introduced, and employees are actively participating. Nineteen Employees were given awards in this scheme.

Hindi Workshop

Four Table Workshops were conducted in the various sections of the Laboratory. The objectives of the workshops were to address the issues encountered in preparing the Quarterly Hindi Progress Report, Hindi Noting and Drafting, and imparting training on Unicode.

Hindi Competition

Hindi Competitions were organized from 2st to 9th September, 2024, for CSIR-NML Employees. The competitions included discussions on implementation of Hindi, self-written poetry recitations and singing, etc. The program had wide participation by NML employees.

World Hindi Day

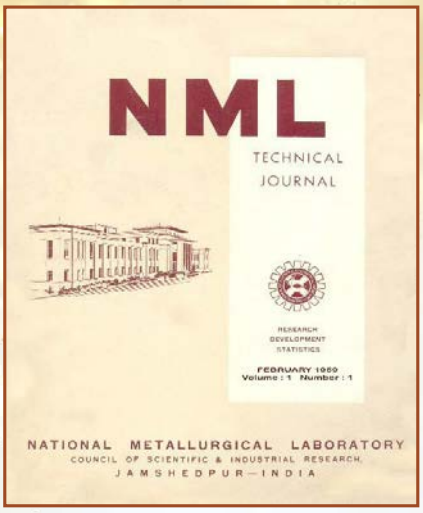
On the **"World Hindi Day"**, technical lectures were organized on **10th January, 2025**, on different scientific topics. In this event, many senior scientists, research scholars, and members of the technical lecture organizing committee of CSIR-NML participated with enthusiasm. The dedicated scientific lectures in the Hindi language were simple, easy to understand, and very comprehensible.

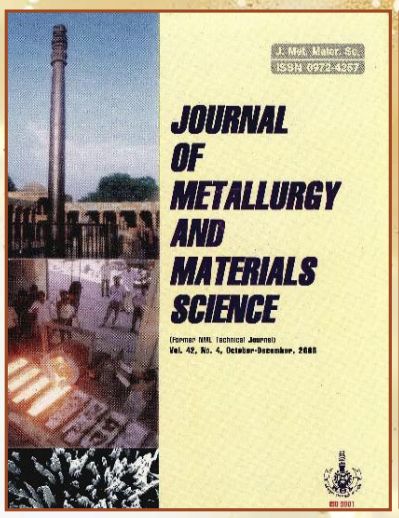
Activities of Hindi implementation for TOLIC, Jamshedpur

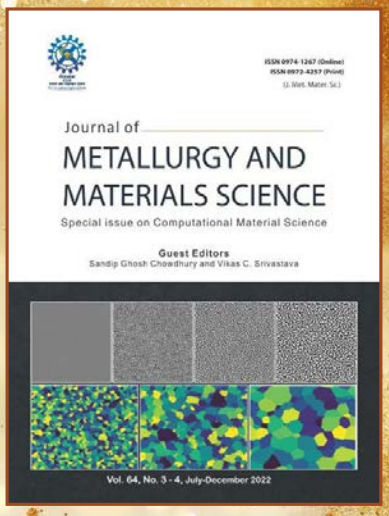
CSIR-National Metallurgical Laboratory is the Secretariat of the Town Official Language Implementation Committee (TOLIC), Jamshedpur. It has 69 Members from all the Central Govt offices located in and around Jamshedpur, with the Director, CSIR-NML as Chairman of this committee. Under the aegis of the Town Official Language Implementation Committee, Jamshedpur, a literary and cultural program was organized **on** 28th October, 2024 at CSIR-National Metallurgical Laboratory, Jamshedpur. More than Two hundred officers from different Central Government offices graced the occasion. Along with the staging of a short play "Sandhya-Chhaya", Songs, Ghazals by famous artists were also performed. The presence of all HODs of different central Government organizations infused enthusiasm into the function.

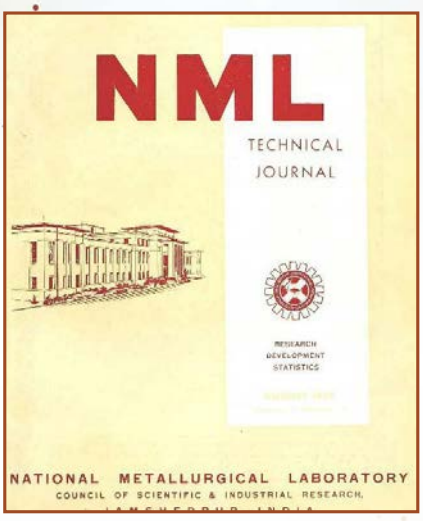
- Popular drama staged by Artists:-

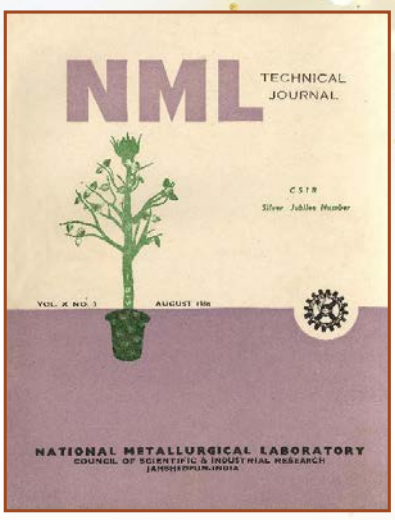
NML Journals Since 1959

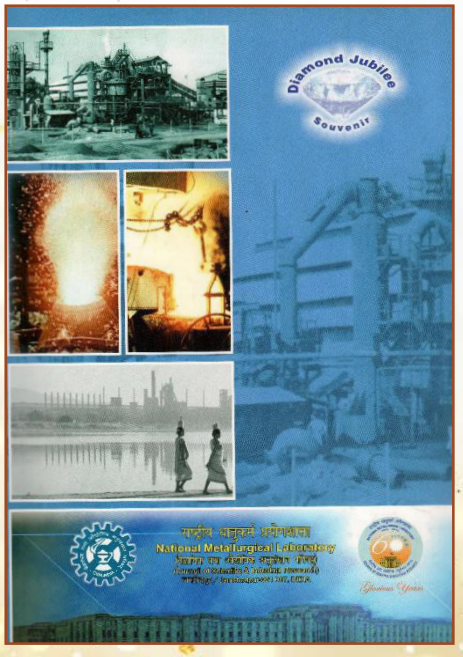












Diamond Jubilee Souvenir

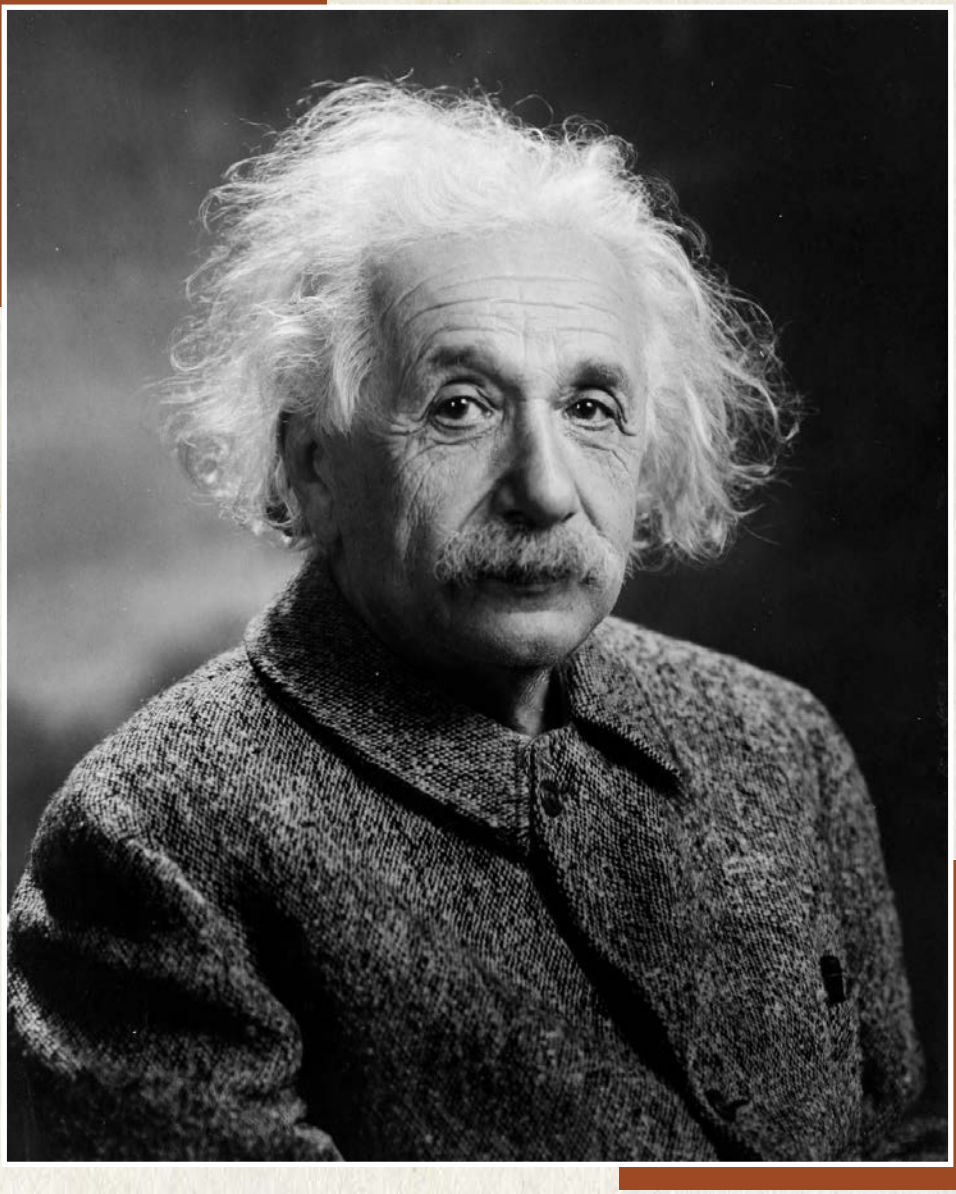
NML Coffee Table Book

1996-2005

Social Responsibilities

Visit of Hon'ble President Dr. Abdul Kalam

Visit of Dr. R. Mashelkar, DG, CSIR



The greatest scientists are artists as well.

-Albert Einstein

Contribution to Society

Women Technology Park

CSIR-National Metallurgical Laboratory (NML), in association with the National Institute of Advanced Manufacturing Technology (NIAMT), Ranchi, is implementing a Women Technology Park (WTP) sponsored by the Department of Science & Technology (DST). The title of the project is Women Technology Park (WTP) for capacity building and entrepreneurship development at Ranchi and East Singhbhum. The project is approved under the Science for Equity, Empowerment & Development (SEED) program of DST. The objective of the project is to train rural women in the areas of office Management & Entrepreneurship skills, animation, Video Making & IOT building and entrepreneurship development. In FY 23-24, CSIR-NML trained 147 women participants in the areas of Animation & Video Making, 3D printing and Computer Basics, office Management & Entrepreneurship Skill, and Animation, Video Making & IOT (Batch I & II). In the area of entrepreneurship development, the participants were trained in computer basics and 3D printing. Participants learned basic computer skills, professional soft 3D design skills, and marketing skills.

Informal sector capacity building up-gradation with formation of recycling clusters under MSME scheme and enabling technology for recovery of resources from electronic waste thereby promoting resource efficiency and circular economy

The Joint Mega Project (CSIR-NML, C-MET, CIPET) on e-waste recycling entitled "Informal sector capacity building up-gradation with formation of recycling clusters under MSME scheme and enabling technology for recovery of resources from electronic waste thereby promoting resource efficiency and circular economy" commenced from the 3rd of July 2023, which is an extension of the awareness programs carried out by MeitY through various agencies and the R&D works carried out by various national laboratories. The project will enable the informal sector to get formalized by getting the various recycling technologies developed at national laboratories. The major aim of the proposal is to enable the informal sector to obtain adequate training and state-of-the-art recycling technologies and thereby formalize. The formalized clusters will be facilitated with MSME cluster formation scheme (CFC) to create infrastructure, respectively State Government and MSE-CDP program of MSME. The informal sector will be upgraded to a formal entity with adequate capacity building and handholding with indigenously developed PCB recycling technologies and plastics processing technology of CSIR-NML, C-MET, and CIPET-LARPM for enhancing the recovery of resources from electronic waste, thereby promoting resource efficiency and circular economy. The major objectives of the project are: a) Creation of 50 master trainers for handling 15000 informal operators engaged in the area of e-waste, identification of value chain and to convert them to micro entrepreneurs; b) Dissemination of technology for recycling PCBs & recycling of e-waste, plastics through setting up of recycling common facility in form of clusters of micro-entrepreneurs in different states of the country; c) Creation of content (manuals) in various scripts, power point presentations and video recordings and shall be translated to different Indian languages. The related training aims to provide knowledge to recover saleable metal/salts of valuable metals from the waste printed circuit boards (PCBs) using the hydrometallurgical route. To achieve the above objective following steps will be taken: a) Collection, storage, dismantling, classification, and depopulation of scrap computers; b) Pre-treatment and beneficiation of the depopulated naked PCBs; c) Hydrometallurgical recovery of metals (Cu, Al, Au) from the metallic concentrate of PCBs.

Science Technology and Innovation Hub in village Gamharia, Saraikela Kharsawan block, West Singhbhum District, Jharkhand State

The project sponsored by DST aims to improve the livelihood of the ST community in the Gamharia village through technological intervention. XITE Gamharia and CSIR-NML provide the targeted community with different skill-based and entrepreneurship development-based training. Different technological interventions, like waste-to-wealth, water management, etc., will be done, and hands-on training will be given to the local populations to enhance their quality of life. Training will be given to adopt some of these technologies for doing business. Another objective of the project is facility creation in terms of establishing a rural tool room centre. In FY 24-25, CSIR NML, in association with XITE and training partner Karuna-Shechen (NGO), organized a one-day training cum awareness program on Mushroom cultivation for the village women. Five women participants from the project area took part in the program. Afterward, a hands-on training was organized in the village on 20th December 2024. Approximately 10 women participants took part in the program. In the first batch, they produced 18 kg of mushrooms and sold them for Rs. 3600.00. It gives them immense pleasure, and they are motivated to do this for their financial upgradation. In the second phase of Mushroom cultivation, we are targeting to provide training to 20 villagers from each village. Besides mushroom cultivation, CSIR NML plans to train in lemongrass cultivation and oil extraction. CSIR-IIIM Jammu is helping us with this initiative. They have demonstrated lemongrass cultivation and the economic benefits of it. Almost 20 villagers participated in the awareness camp. The villagers are mostly interested in lemongrass cultivation.

CSIR Jigyasa 2.0

During its Platinum Jubilee year, CSIR launched the CSIR-Jigyasa Virtual Laboratory Project, an effort motivated by the Prime Minister's vision of a new India and Scientific Social Responsibility (SSR) for CSIR. The goal of the "CSIR-Jigyasa 2.0 Programme: Virtual Lab Integration" initiative is to motivate children to learn science easily, joyfully, and with excitement. As part of this project, CSIR-NML plans to set up different kinds of scientist-teacher engagement programs and develop cutting-edge educational resources and materials through Virtual Laboratory (VL) using cutting-edge digital technology with an emphasis on materials, metallurgy, minerals, and metals. Students in grades VIII through XII are the intended beneficiaries of this project, which primarily focuses on government-funded rural schools. In FY23- 24, CSIR-NML organized various programs for the students and teachers and connected 30 nos. of schools located around Jamshedpur. Under the Jigyasa program, we have conducted 11 nos. of one-day NML visits for 1530 students and 88 teachers. We have also conducted 2 nos. of visit of scientists to different schools, 1 nos. of teacher's workshop (online in association with KAMP) for 115 teachers, 5 nos. of Popular lecture series for 541 students and 25 teachers, 2 nos. of Vigyan Jyoti program for 88 girls students and 7 teachers, 1 no. of STEM club catering 45 students and 5 teachers and 3 nos. of students micro projects for 65 students. Under this project, we have also mentored 1 ATL school for 29 students. CSIR-NML has participated in World's Largest Climate Clock assembly and demonstration along with Energy Swaraj Foundation, where 61 students and 8 teachers from 5 schools participated. CSIR-NML also conducted 2 outreach programs for the students, one at IISF at Digha and the other one at JNV Chaibasa, where 99 students and 1 teacher participated. CSIR-NML has also developed 5 nos. of "DO IT YOURSELF (DIY)" kits, like RGB color mixing, solar fan and light, wireless electricity, gravitational energy conversion, and electrical to sound energy converter, demonstrating the basic concepts of science. Apart from this, CSIR-NML has developed 11 nos. of virtual content, comics, simulation, quiz, animation, and videos. The topics covered were tensile strength of materials, corrosion rate, E-waste management, measure of central tendency, accuracy and precision, continuous casting, extraction of metals, advanced materials,

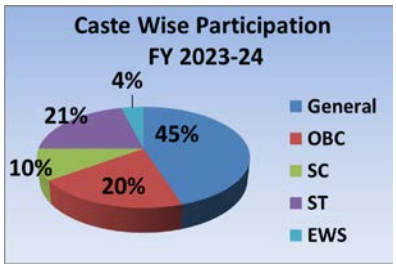
etc. Through this Jigyasa activity, CSIR-NML has impacted 2458 students, out of which 50.24% are girl students.

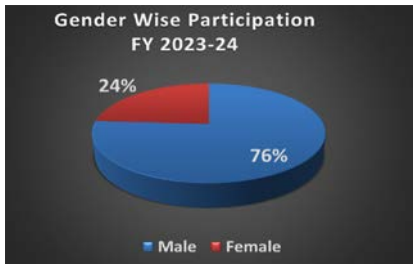
Skill Development Program

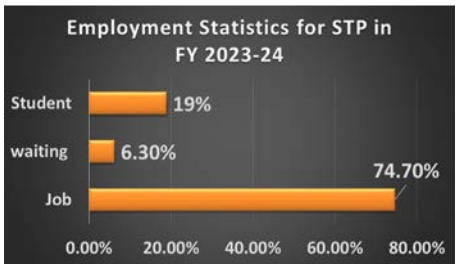
The "CSIR-Integrated Skill Initiative" programme was started by the Council of Scientific and Industrial Research (CSIR), in partnership with the Indian government, in alignment with the "Skill India" mission. The CSIR-Integrated Skill Initiative aims to provide skilled labour at different levels by offering and improving skills in every conceivable field, starting with school dropouts and progressing to farmers, ITI diploma holders, graduates, and everyone in between. It also covers the upskilling and reskilling of professionals working in industries. These training programs vary from a few days to months in duration. The focus is to develop skills in the areas of metals, metallurgy, manufacturing, waste utilization, soft skills, and entrepreneurship development. In FY 2023 – 2024 and FY 24-25, CSIR-NML trained 1486 participants through corporate training programs, societal training programs, and others. CSIR-NML conducted corporate training programs, namely, Remaining Life Assessment & Failure of Engineering Components, and Exposure Training on Metallic Pipe. CSIR-NML conducted Societal Training programs (STP) for college students and others. The societal training includes Internship training in metallurgical engineering, Innovative Product prototype making, Hands-on experiments on water splitting for green hydrogen generation, Computer 3D Printing & product development (C3DPD), and other internship training. CSIR NML also organized an Exposure to the research facility for undergraduate students. Apart from this, CSIR NML has organized winter training for M.Tech, undergraduate, and diploma students. During the celebration of One Week One Lab. (OWOL), CSIR-NML organized Shilpakar mela for the artisans working in metal artefacts. They were also exposed to the demonstration of energy energy-efficient brass melting furnace for cost-effective, safe, and pollution free brass melting. CSIR-NML is also focusing on the orientation of the training as per National Skill Development Corporation (NSDC) guidelines.

Impact analysis of skill development activities carried out in FY 23-24:

In FY 23-24, 701 participants were registered under skill development. Impact assessments were carried out in two sessions: one in the month of September 2024 and the other in the month of December 2024. Among the total participants, 24 % were female and 31 % were from SC/ST category. We have received responses from 300 participants. CSIR-NML tried to serve every segment of society. The training statistics and employment data are as follows, based on the responses received till December 2024. Out of 300 respondents from FY 23-24, 224 participants received jobs out of which 43% of participants were from the aspirational class.

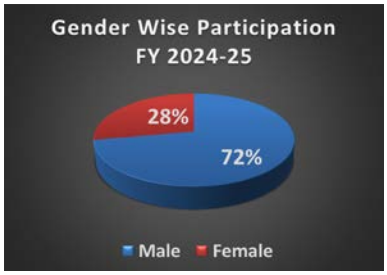


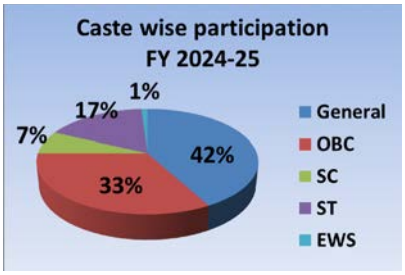


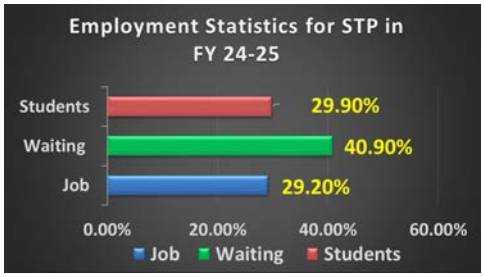


Impact analysis of skill development activities carried out in FY 24-25:

In FY 24-25, 779 participants were registered under skill development. Impact assessments were carried out in the month of March 2025. Among the total participants, 28 % were female and 24 % were from SC/ST category. We have received responses from 181 participants. The training statistics and employment data are as follows, as responses received till March 2025. Out of 181 respondents from FY 24-25, 53 participants received jobs out of which 51 % of participants are from the aspirational class.







St. Mary's English High School

One Day NML Visit by R.V.S Academy, Jamshedpur

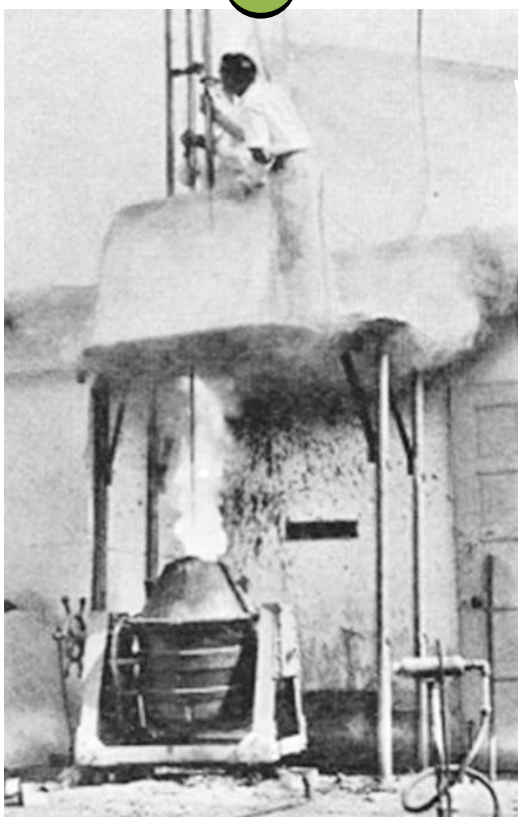
Assistant Manual Metal Arc Welding / Shielded Metal Welding Welder

Kasidih High School, Jamshedpur

Summer Camp-2024

"Swachhata Hi Seva" Campaign (17th September -1st October)

A number of events were organized in this campaign. A lecture on role of Swachhata on Hygiene was delivered by Dr Priyanka Singh, Medical Officer, CSIR-NML for the "Safai Karmachari". The importance of personal hygiene and how to maintain it, was explained by Dr Singh. Quiz competition focussed on Swachha Bharat was organised at one of schools in Jamshedpur. A cleaning drive was undertaken at the Tatanagar Railway Station. A dedicated team from CSIR-NML and Tatanagar Railway authority participated in the initiative under the leadership of Director, CSIR-NML, Area Manager, Tatanagar and the Nodal officer, CSIR-NML. Besides cleaning, the event featured the plantation of 10 trees in designated areas around the station. The "Safai Mitras" of the Railway Authority were also felicitated for their daily contributions to cleanliness. On the closing day, CSIR-NML planted 10 Ashok trees at the boundary of the Lab. In the closing ceremony, distribution of prizes of the Quiz competition and felicitation of Sixty (60) "Safai Mitras" of CSIR-NML for their daily efforts to keep the campus clean and green were conducted.



1957

1963

1971-72

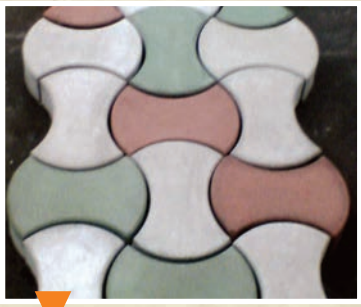
First Oxygen Steel Making in India - top and side blown converters 0.1 to 0.5 tonnes for mini steel plants

2006-2015

The Clientele

Column Flotation

India post 'Special cover' (on NML)



Geopolymer Tiles from Fly ash

Automated Ball Indentation Test

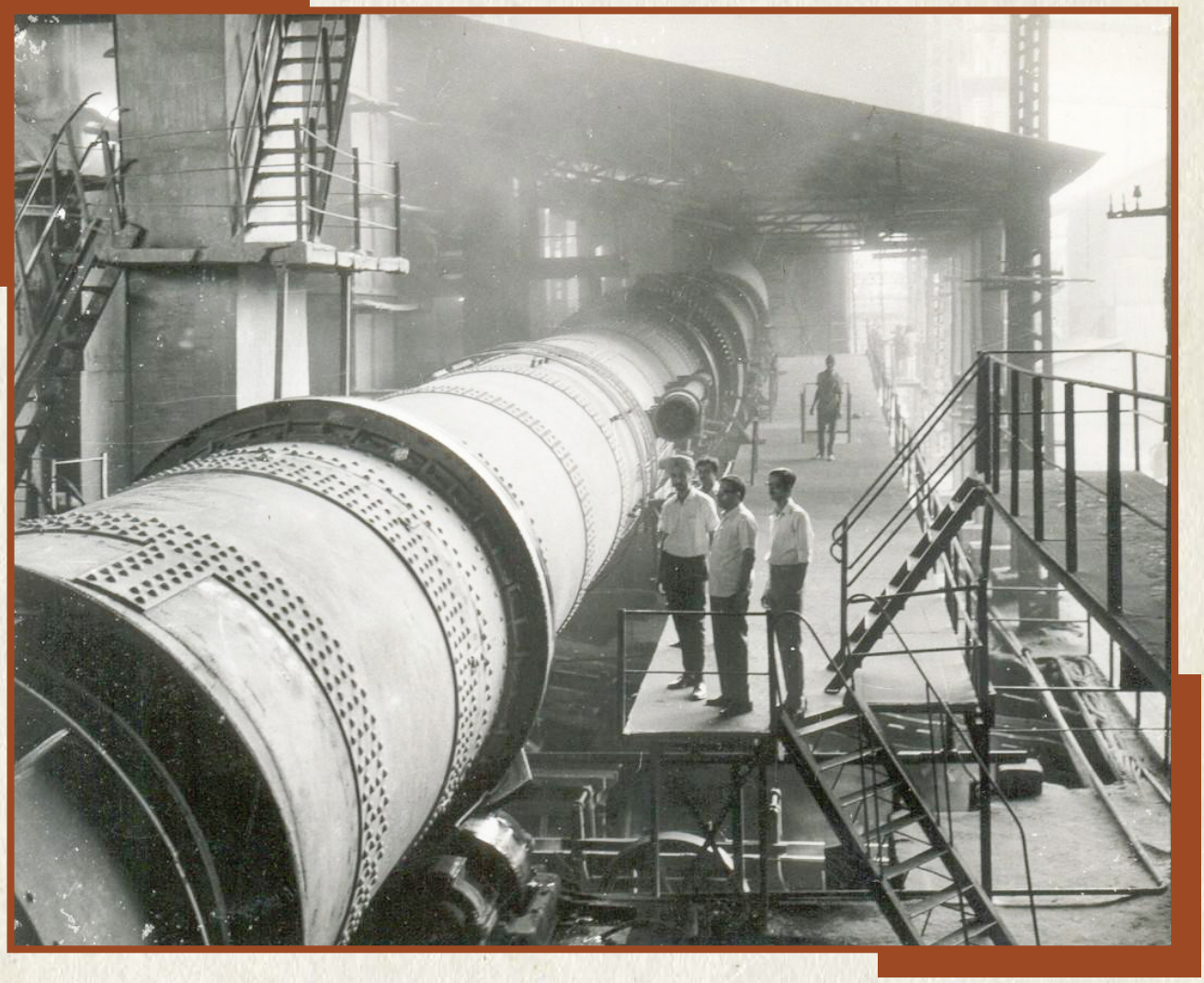
Anti Tarnishing Lacquers

Operation of 500A Sodium Cell & Sodium Collection

Pilot Plant for mine water reclamation

Iron Making Process used by Tribals

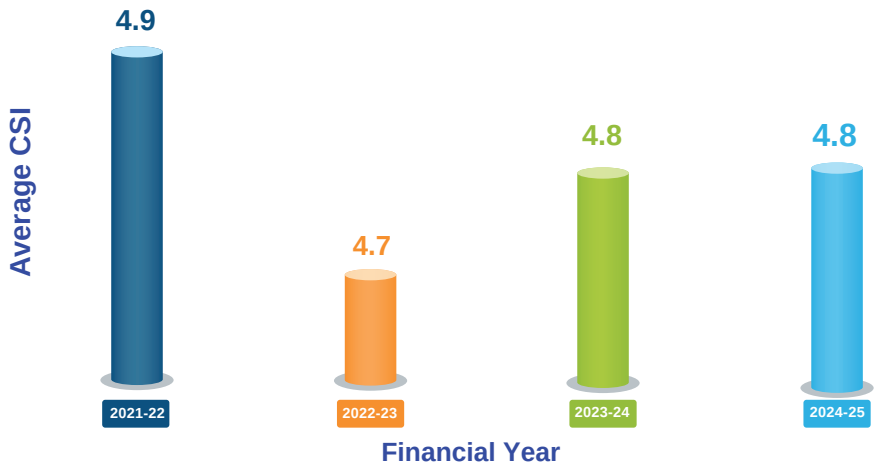
First pilot and commercial sponge iron in India



30000 t/day commercial sponge iron plant Andhra Cement (1975-76)

Customer Satisfaction Index & Feedback

Average Customer Satisfaction Index (CSI) (Max.5)



"It was a overall good exposure and learning experience. Would like to make more products in association making India less dependent on the imported products."

--Advanced Metals Inc.

--SSP 1376

"Overall good collaborative research experience with the beneficiation team. We did a novel project in the area of flotation and achieved the satisfactory results. We are looking forward for the next projects with the team."

--Tata Steel Limited

--SSP 1325

"Excellent support Will surely use this facility if we have any further requirement."

--Tata Steel R&D

--SSP 1362

"The recommended composition/heat treatment cycle has already been implemented for realization of components. This project has enhanced the scientific understanding behind the alloy design and design of heat treatment Cycle."

--Vikram Sarabhai Space Centre (VSSC), ISRO

--GAP 0286

"Excellent overall satisfaction from the work done. The financial benefits realized are double of the R&D investment".

--Ferro Alloys Corporation Limited

--SSP 1297


METAL POWDERS
NATIONAL METALLURGICAL LABORATORY
AIR-ATOMIZED ALUMINIUM
WATER-ATOMIZED ALUMINIUM
DISTILLED ZINC-DUST
LITHOGRAPHIC
MAGNESIUM


METAL POWDERS
NATIONAL METALLURGICAL LABORATORY
NITROGEN-ATOMIZED Cu - Pb
NITROGEN-ATOMIZED LEADED BRONZE
NITROGEN-ATOMIZED BRONZE
AIR - ATOMIZED YELLOW BRASS
AIR-ATOMIZED SOLDER

Our Clientele

adani | Power

60

ECL

GTRE - DRDO

GEOLOGICAL SURVEY OF INDIA 1851

SAINT-GOBAIN

AIR FORCE SCHOOL, ADAMPUR

GMDC FUELING THE GROWTH

नालको NALCO

Rajaguru spinning mills (p) ltd

SUDARSHAN Outshine. Outdo.

TAKRAF

MCL Mahanadi Coalfield Limited Mine Safety Information

MeitY Government of India

मॉयल MOIL

MSME MICRO, SMALL & MEDIUM ENTERPRISES

DRDO DEFENCE R&D ORGANISATION NMRL

NRB - DRDO

INDIAN RAILWAYS

SIEMENS


Coal India
ECL


Cummins


BARC
ATOMS IN THE SERVICE OF THE NATION


Coal India
सीएमपीडीआई
मिनी रत्न
cmpdi
Mini Ratna


TATA STEEL
WeAlsoMakeTomorrow


TUBACEX
INDIA
TUBACEX
GROUP


UltraTech
CEMENT
The Engineer's Choice


Coal India
Western Coalfields
Limited (WCL)


IREL (India) Limited
(Formerly Indian Rare Earths Ltd)
A Govt. of India Undertaking
A Miniratna–I Company
Unleashing Values


JSW


GACL
Promoting Green Technology


HINDUSTAN ZINC
Zinc & Silver of India


CCL
FUELLING SUSTAINABLE GROWTH

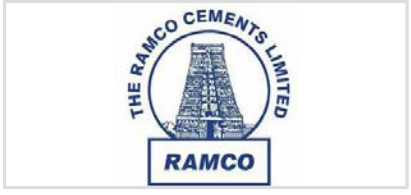

EMPOWERING ACCESS TO SPACE
ENABLING SPACE OPERATIONS
LPSC


Gnano


JINDAL INDIA POWER LTD.
Formerly known as Jindal India Thermal Power Ltd.


ए आर सी आई
ARCI


सत्यमेव जयते
DRDO
DRDO


THE RAMCO CEMENTS LIMITED
RAMCO


एनटीपीसी
NTPC
50
OF POWERING GROWTH

Collaborations

1. Secrecy and Technology Transfer Agreement signed with Chandigarh Chemicals, Haryana
2. General Research Collaboration & Marketing Agreement signed with Tega McNally Minerals Ltd., Kolkata
3. Non-Disclosure Agreement signed with Ecoaavritti Solutions Private Limited, Secunderabad
4. Consultancy Agreement signed with Omkar Global Hi Tech Private Limited, Jamshedpur
5. Sponsored Agreement signed with Indian Rare Earths Limited Tech
6. Non-Disclosure Agreement signed with Tata Chemicals
7. Non-Disclosure Agreement signed with Vossloh Cogifer, New Delhi
8. General Research Collaboration Agreement signed with Jammu University
9. Secrecy and Technology Transfer signed with Accelor Microsystems, Mohali
10. General Research Collaboration Agreement signed with Kashi Vishwanath Steels Pvt Ltd. Kashipur, Uttarakhand.
11. Non-Disclosure Agreement signed with Mishra Dhatu Nigam Ltd, Hyderabad
13. Sponsored Agreement signed with BARC, Mumbai
14. Non-Disclosure Agreement signed with Mahabir Refractories, Refractories
16. Sponsored Agreement signed with Makaney Metals, Mumbai
17. General Research Collaboration Agreement signed with RDSO, Lucknow
18. General Research Collaboration Agreement signed with Research & Development Centre for Iron & Steel (RDCIS) SAIL, Ranchi
19. Sponsored Agreement signed with BHEL, Hyderabad
20. Non-Disclosure Agreement signed with Non-Disclosure Agreement with BHEL, Hyderabad
21. Non-Disclosure Agreement signed with Alleima India Private Limited, Mumbai.
22. Secrecy and Technology Transfer Agreement signed with Eyantram Waste Management Pvt. Ltd., Bengaluru
23. Non-Disclosure Agreement signed with Lyten Inc., California, USA
24. Non-Disclosure Agreement signed with Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia

2016-2025

Events and Visitors

Inauguration of
Hot Dip Process Simulator
by Dr. Tridibesh Mukherjee,
Chairman, Empowered Board
and Former Dy. MD,
Tata Steel Limited, Jamshedpur

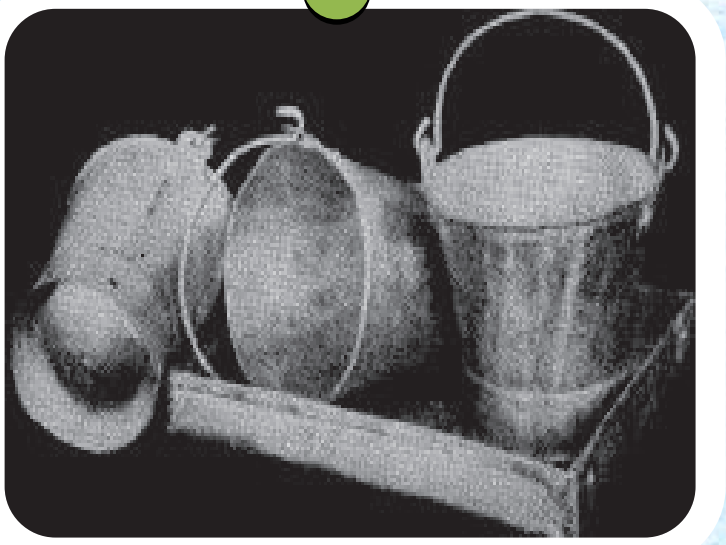
CSIR's First Battery Dismantling &
Metal Extraction Pilot Scale Facility.
Inaugurated by Dr. V. K. Saraswat, Niti Aayog

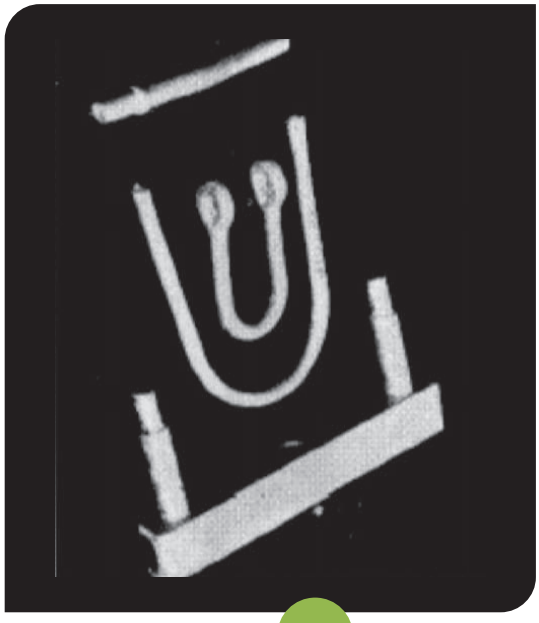
Inauguration of Atomiser Facility

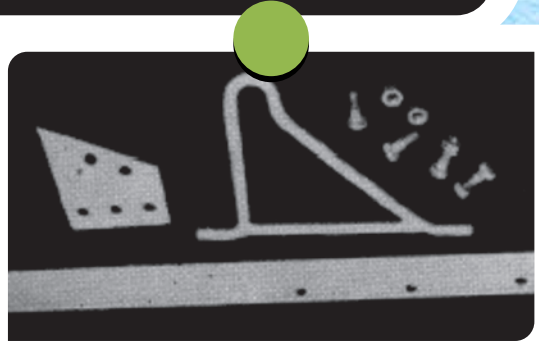
Tungsten Recycling Facility

Tungsten Powder &
Oxide Tungsten

Galvanizing at CSIR-NML



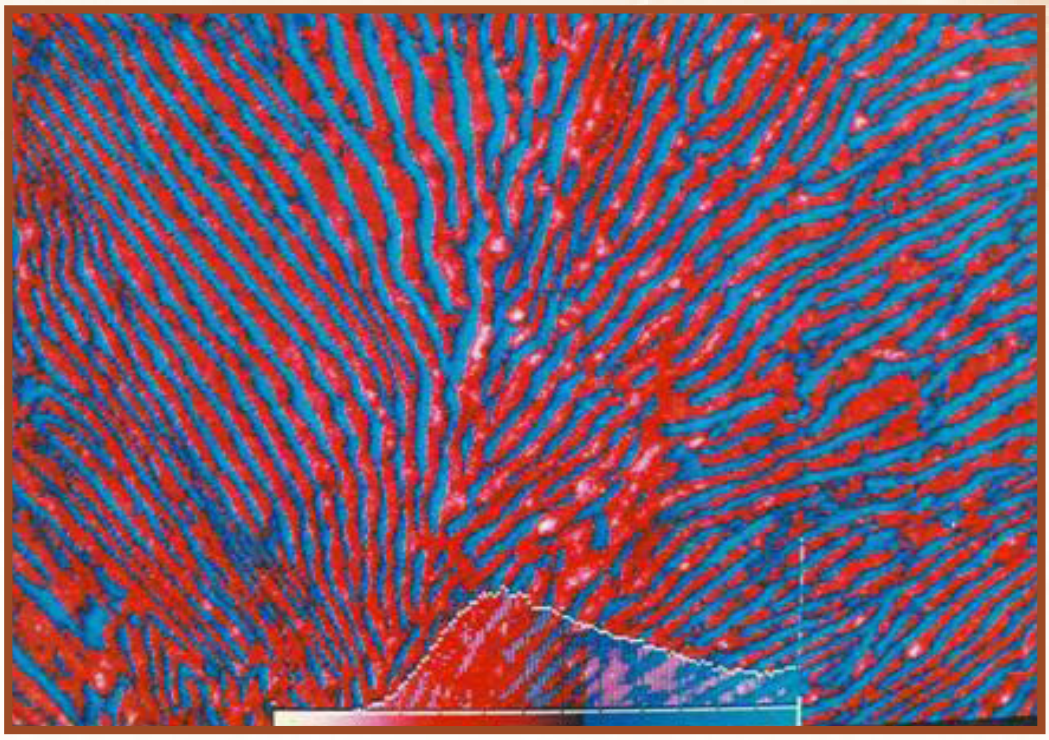




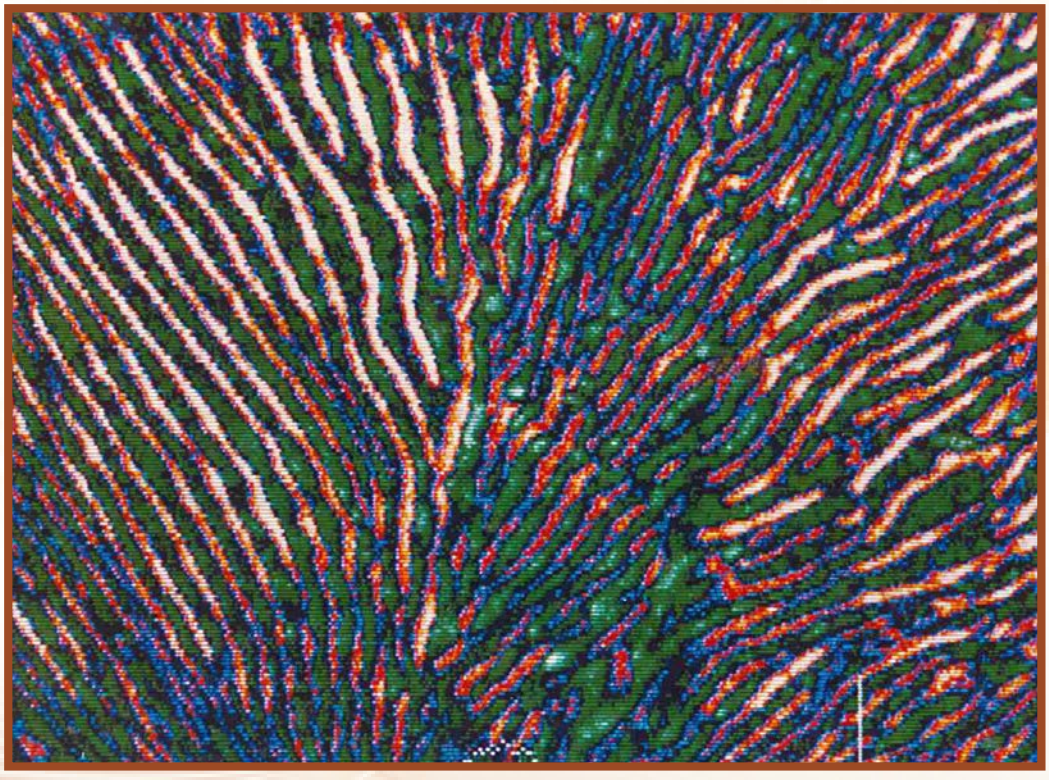
Platinum Jubilee Events

Events Calendar

December 2024	• Lecture # 1 by Eminent Speaker • SSBMT Outdoor Zonal Tournament
January 2025	• National Conference # : ICRMS 2025
February 2025	• Outreach Program #1 Marine Corrosion
April 2025	• Industry Conclave • Lecture #2 by Eminent Speaker
May 2025	• MSME Conclave
June 2025	• National Conference # 2 • Lecture # 3 by Eminent Speaker
July 2025	• Industry Conclave Madras Centre
September 2025	• Outreach Program # 2 • Lecture # 4 by Eminent Speaker
November 2025	• International Conference : CRITMET



Pearlitic Steel- Peacock Tail Microstructure



Eutectoid steel Microstructure

Special Days & Events

Seminar (s) Organised

Behind the Teachers Desk [BTTD-2024] (19th- 21st June 2024)

The 3-days seminar was organised by the Indian Institute of Metals (IIM), Jamshedpur Chapter, in association with Tata Steel Limited, CSIR-National Metallurgical Laboratory, National Institute of Technology Jamshedpur, and AcSIR. Dr Naresh Chandra Murmu, Director, CSIR - CMERI, Durgapur, graced the inaugural function as Chief Guest. Around 100 participants from different institutes across India, such as IIT Bombay, IIT Varanasi, IIT Kharagpur, IIT Mandi, IIT Dhanbad, IIT Jammu, IIT Hyderabad, NIT Durgapur, NIT Raipur, NIT JAMSHEDPUR, NIT Andhra Pradesh, VNIT Nagpur, MNIT Jaipur, Jadavpur University, Govt. College Of Engineering & Ceramic Technology Kolkata, Manipal Institute Of Technology, NIAMT Ranchi, JNTU-Gurajada, Vizianagaram, Mahatma Gandhi University, Kerala, Kazi Nazrul University, Asansol, RGUKT Andhra Pradesh, BIT Sindri, AcSIR etc. BTTD 2024 received around 15 sponsors from industries as well for organising a student seminar of this level. Five Keynote Lectures were delivered by some of our countrys most renowned and eminent metallurgists: Dr Atanu Pal, Chief Technology Officer, TSL, Dr Indranil Chattoraj, Adjunct Professor, IIT Jodhpur & Former Director, CSIR NML, Dr P.K. Banerjee, Outstanding Scientist, CSIR – CIMFR, Dhanbad, Dr S.K. Satpati, Chairman & Managing Director, Uranium Corporation of India Ltd, and Dr S. Sivaprasad, Chief Scientist & Head, Materials Engineering Division, CSIR NML Jamshedpur. Around 56 oral papers were presented under six themes ranging from mineral processing to advanced materials and characterisation, covering metallurgy and materials science related domains. The metallurgical quiz 2024 was also organized for the student participants. Industrial visits for students in different industries around Jamshedpur was organised.

Prof. S. N. Sinha Memorial Materials and Metallurgy Quiz (August 9th, 2024)

The Prof. S. N. Sinha Memorial Materials and Metallurgy Quiz (SNSM3Q-2024), a prestigious academic competition for Standard XI and XII students, was successfully organized by the Indian Institute of Metals- Jamshedpur Chapter on Friday, at the Council for Scientific and Industrial Research-National Metallurgical Laboratory (CSIR-NML).

Conference(s) Organized

National Conference on Innovations in coal and mineral characterisation for sustainable resource utilisation [ICMCS-2025] (30th -31st January 2025)

As a Part of the Platinum Jubilee Celebration of CSIR-NML, a National Conference on "Innovations in Coal & Mineral Characterization for Sustainable Resource Utilization (ICMCS-2025)" was organized at Fairfield by Marriott, New Town, Kolkata. The Chief Guest of the event, Shri Manoj Kumar, Chairman & Managing Director, CMPDI, Ranchi, along with Dr. Sandip Ghosh Chowdhury, Director, CSIR-NML, and other dignitaries to formally inaugurate the seminar with the release of the seminar souvenir. Over the two-day event, more than 100 delegates from 30 institutes across the country are participating, with 37 technical papers presented across six sessions, covering cutting-edge topics in coal and mineral research. The conference also featured two plenary lectures delivered by industry leaders: Shri Sundara Ramam DB, Vice President, Raw Materials, Tata Steel Ltd., and Shri Joy Gopal Ghosh, Associate Principal (Geology and Exploration), Geovale Services. The six technical sessions of the conference cover diverse areas, including emerging trends in coal characterization, exploration techniques, and sustainable approaches to resource utilization.

Industrial Conclave on Maritime Corrosion Monitoring and Management [MCMM-2025] (28th February 2025)

MCMM-2025 was organized at the Marine Corrosion Research Station (MCRS), Digha, West Bengal as part of the Platinum Jubilee celebrations. This one-day program included plenary talks by eminent experts and discussions on Sustainable Solutions for Marine Corrosion. Industry experts, researchers, and academicians participated in the event and discussed innovative strategies. Dr. Nagahanumaiah, Director of the Central Manufacturing Technology Institute (CMTI),

Bengaluru inaugurated the conclave as the chief guest. He addressed on the adverse economic impact of corrosion-related damages and the need for sustainable solutions. The conclave featured four industrial talks focused on corrosion mitigation strategies. Mr. Vijay Kulkarni from Fosroc India spoke on 'Corrosion Mitigation Solutions for Marine Corrosion,' while Mr. Dhruvesh Sah from Vector Corrosion Technologies (Canada) discussed techniques to safeguard marine civil infrastructure. Additionally, Dr. Sanjay Chowdhury and Mr. Soumira K. Basi from Berger Paints (India) Limited elaborated on the role of coatings and paints in protecting marine structures from corrosion. Various industry leaders presented real-world challenges related to corrosion and participated in a panel discussion on "Prevention Strategies for Marine Corrosion and Setting up of a Marine Corrosion Simulation Center."

Exhibition under CSIR-NML Jigyasa Program (28th February 2025)

An exhibition was organized under the Jigyasa Program for the students and teachers from Digha Vidyabhavan and Digha D.J. Sikshasadan High School. Approximately 67 students and 2 teachers visited the exhibition. The research and development of CSIR-NML was showcased in the area of corrosion and its protection. Students enjoyed hands-on experiments on some small demonstration items developed by CSIR-NML under the Jigyasa Program.

International Conference on Corrosion and Coatings [iC3 2025] (6th-7th February 2025)

The Indian Institute of Metals (IIM)Jamshedpur Chapter in association with Tata Steel Limited, CSIR-NML, and NIT Jamshedpur organized Conference. The conference was inaugurated by the chief guest Dr. Sandip Ghosh Chowdhury, Director, CSIR-NML; Guest of Honour, Dr. A K Manohar, Executive Director National Thermal Power Corporation Ltd.; Dr. Ashok Kumar, Chairman, IIM Jamshedpur Chapter & Head, Dr. Raghuvir Singh, Chairman, i3C 2025; Mr. Tapan Rout, Convenor, i3C 2025. Mr. Sudhanshu Pathak, Ex-Vice President, Steel Manufacturing, Tata Steel Limited; Dr. Ramanuj Narayan, Director, CSIR-IMMT, Mr. Praveen Thampi, Chief CRM TSK, Cold Rolling Mill, Mr. Atul Srivastav, Vice president, Welspun Group, were also present. The conference souvenir was also released during the inaugural function. This conference featured four plenary lectures and 15 keynotes lectures and 40 contributory lectures. More than 15 posters were showcased the technological achievements of the laboratory in this area. More than 100 delegates and speakers from 34 reputed institutes from different parts of the county and aboard (hybrid mode) participated in the conference. The two-day deliberations focused on advances in coatings and high-temperature corrosion in oil and gas, chemical, nuclear and thermal power plants, construction, and mobility industries.

Training(s) Organized

Mineral Characterisation, Beneficiation and Agglomeration (MCBA 2024) (23rd – 26th July 2024)

The SAIL-Mines Executives from different mining units of SAIL – Rourkela Steel Plant (RSP), Gua Ore Mine (GOM) and Bhilai Steel Plant (BSP), participated in the first round of training program.

Corporate Training on Mineral Characterization, Beneficiation and Agglomeration [MCBA-2024] (3rd December 2024)

Corporate Training on Mineral Characterization, Beneficiation and Agglomeration [MCBA-2025] (07th - 10th January 2025)

CSIR-NML organized Corporate Training Program on Mineral Processing for SAIL Executives. The training program featured in-depth lectures, laboratory visits, and hands-on training with cutting-edge equipment. The training aimed to enhance technical skills, provide practical knowledge, and encourage industry - academic collaboration in tackling contemporary issues in mineral processing.

Exposure Training on "Metallurgical Failure Investigation of Rail Components" [MIRC-2025] (22nd - 24th January 2025)

Ten officials from Research Designs and Standards Organisation (RDSO) attended the three-day training programme.

Significant Meeting(s) Held

Annual Meeting of Town Official Language Implementation Committee[TOLIC] (30th April 2024)

TOLIC Members from various government offices of East Singhbhum attended the meeting and deliberated on the activities undertaken for promotion of Hindi language in the official work and dissemination of information. Dr. Sandip Ghosh Chowdhury, Director-CSIR-NML was felicitated in during the proceedings.

81st Research Council (RC) Meeting (27th November 2024)

The meeting was held in hybrid mode. Mr. Amarendu Prakash, Chairman SAIL and Chairman RC joined through online platform. The RC members present were: Dr. R. Balamuralikrishnan, Member, Shri Chaitanya Bhanu, Member, Prof. Karabi Das, Member, Ms. Sukla Mistry, Dr. Prakash Kumar, Member, Dr. R.M. Mohanty, Member, Dr. S. G. Chowdhury, Director CSIR-NML and Member. The RC members planted trees under the "Ek Ped Ma Ke Nam" campaign of GOI.

Nagar Rajbhasha Karyanvayan Samiti-(28th October 2024)

Celebration of National Festivals

Independence Day 2024

The 78th Independence Day was celebrated by the staff and staff families with great enthusiasm. The celebrations commenced with a flag-hoisting ceremony followed by a vibrant cultural program, featuring patriotic songs, dances, and skits performed by the employees and their children.

Republic Day Celebration 2025

The national festival was celebrated in the laboratory and residential complexes with enthusiasm. The national-flag was hoisted by the Director, CSIR-NML.

Observance on Occasion(s) of National Relevance

Swachhata Pakhwada (1st -15th May, 2024)

In alignment to the "Swachh Bharat" mission of Government of India, a cleanliness drive of 15 days was observed and various programs were organized in all office and residential campuses of CSIR-NML, including Swachhata -Pledge taking ceremony by the staff, Cleanliness drives, Tree Plantation Programs, Sit and Draw competitions for staff children and Essay, Quiz, and Extempore competitions for staff. The valedictory ceremony of the 15 days' program was held on the 15th of May 2024 at CSIR-NML. The function was graced by Shri Rajiv Mangal, Vice President, Safety, Health & Sustainability, Tata Steel, as the chief guest.

National Technology Day (10th May, 2024)

The theme of 2024 celebration was "Indigenous Technologies for Viksit Bharat". Dr. Debashish Bhattacharjee, Vice President of Technology & R&D at Tata Steel Ltd., graced the occasion as the chief guest for the main function. A presentation outlining ongoing technological & societal programs and the technological achievements of the past year and the upcoming milestones was given by Head Research Planning & Business Development of CSIR-NML. This followed by the technology day lecture, delivered by the chief guest, on "Inspiring Young Innovators". The CSIR-NML Annual Report 2023-24 was released on the occasion by the dignitaries.

International Yoga Day (15th June 2024)

Yoga sessions were organized in the residential campuses of CSIR-NML to promote employee health, well-being, and peace through the practice of yoga. Yoga, a transformative practice, represents the harmony of mind and body, the balance between thought and action.

Hindi Week (14th – 20th September 2024)

The week-long celebration aimed to promote Hindi as a language of communication and administration within the institute, fostering a sense of national pride and unity. A number of events such as Hindi dictation contest, Hindi essay writing contest & Hindi poetry recitation contest were organized.

Rashtriya Ekta Diwas (30th October 2024)

Rashtriya Ekta Diwas Pledge was taken by CSIR-NML staff.

Vigilance Awareness Week (29th October - 3rd November 2024)

A number of events were organized on the occasion like lecture, essay writing, drawing and slogan writing competitions. The theme of this year's Vigilance Awareness Week was "Culture of integrity for nations prosperity".

National Science Day (10th March 2025)

83rd CSIR Foundation Day (26th September 2024)

The occasion was celebrated with commemorative events like essay writing & quiz competition. CSIR-NML felicitated such employees who had served 25 years of dedicated service to the laboratory. Dr. Shankar Venugopal, Vice President, Mahindra Research Valley, Chennai was the chief guest for the main function held at CSIR-NML. He delivered a lecture on " The New Materials that are shaping the future of mobility".

International Science Festival (IISF 2024)- Curtain Raiser (11th November 2024)

The event was graced by the presence of eminent personalities like Mr. Ranjot Singh, Chairman, CII Jharkhand State Council & Managing Director, Emdet Jamshedpur Pvt. Ltd as the Chief Guest. Prof. Ranjit Prasad, Ex Professor, NIT, Jamshedpur as the Guest of Honor and Prof. Fr. Kuruvilla Joseph Pandikattu, XLRI as the Key-Note speaker. Dr. Sandip Ghosh Chowdhury, Director, CSIR-NML and Dr. Trilochan Mishra, Chief Scientist and Convenor IISF 2024 were amongst the dignitaries present on the dais.

CSIR-NML Platinum Jubilee Foundation Day (26th November 2024)

CSIR-National Metallurgical Laboratory (CSIR-NML) marked a significant milestone on November 26, 2024, as it celebrated its Platinum Jubilee year of establishment. This momentous occasion commemorated 75 years of pioneering research and innovation in the field of metallurgy and materials science. Dr. N, Kalaiselvi, Secretary DSIR and DG, CSIR graced the occasion and Mr. Chaitanya Bhanu, Vice President, Tata Steel was the guest of Honor for the main function. Dr. Sandip Ghosh Chowdhury, Director, CSIR-NML and Mr. Aditya Mainak, Administrative Officer, CSIR-NML were present amongst the dignitaries on the dais. The main function began with the ceremonial lamp lighting by the dignitaries and welcome address of Director, CSIR-NML. The capsule video of CSIR-NML was screened. DG, CSIR administered the Constitution Day Preamble reading Ceremony. Dr. Kalaiselvi Madam unveiled the CSIR-NML platinum jubilee logo and the forthcoming events and programs. On the occasion, the CSIR-NML Technology Handbook 2024 was released by the dignitaries. DG, CSIR inaugurated the CSIR-NML "Center of Excellence" on Wear and Corrosion Resistant Technology and the Marine Corrosion Research Station at Digha, near Bay of Bengal, remotely. Customarily, on this day CSIR-NML recognized the exceptional achievements of the staff and staff children. The vote of thanks was proposed by Mr. Aditya Mainak, Administrative Officer of the laboratory. The main function concluded with the national anthem. An exhibition "Odyssy of CSIR-NML" was organized on the occasion to showcase the technological achievements of laboratory in last 75 years. DG, CSIR laid the foundation stone of Mg Pilot plant. The Platinum Jubilee celebrations were graced by the presence of former directors, superannuated staff and distinguished guests from academia, industry, and government.

Glimpses of 75th Platinum Jubilee Foundation Day Celebration

52nd Shanti Swarup Bhatnagar Memorial Tournament (SSBMT) (18th -20th December 2024)

The SSBMT 2024 (4th Zonal Outdoor) is organized in memory of Dr. Shanti Swarup Bhatnagar, the first Director General of CSIR. It brings together participants from various CSIR laboratories nationwide. CSIR-NML had the honour of hosting the prestigious 52nd SSBMT outdoor 4th zonal tournament of CSIR. The inaugural function was graced by esteemed dignitaries, including chief guest, Mrs. Premlata Agarwal; Padma Shri awardee and Dr. Anuradha Madhukar; Secretary Sports Promotion Board-CSIR and other notable personalities from the scientific and sports communities. The event commenced with a grand flag march by the eight participating teams of CSIR followed by the ceremonial lighting of the lamp and the administration of the sportsmen's pledge. Chief guest, Mrs. Premlata Agarwal, in her inaugural address, mentioned that "sports is a way of life" and further emphasized the importance of sports in health, and overall personality development. CSIR-NPL team was selected as the best flag-marched team. The inaugural program ended with a vote of thanks. The tournament featured a series of exciting matches in various sports disciplines, including cricket and volleyball. Teams from eight CSIR laboratories, including CSIR-IHB, Palampur, CSIR-CSIO, Chandigarh, CSIR-NAL, Bengaluru, CSIR-IMTECH, Chandigarh, CSIR-AMPRI, Bhopal, CSIR-NPL, New Delhi, CSIR-CBRI, Roorkee and CSIR-CIMAP, Lucknow competed for the coveted trophies. The event aimed to promote camaraderie and sportsmanship among CSIR employees, while also paying tribute to the visionary scientist, Dr. Shanti Swarup Bhatnagar. The tournament concluded with a grand closing ceremony on 20th December 2024, where the winners were felicitated.

Visit of School Students under Project Anveshana (8th January 2025)

School Students of SS +2 High School Patamda visited CSIR-NML under project “Anveshana”. The District Administration, East Singhbhum and CSIR-NML jointly organized a workshop for students of Government school as a part of project Anveshana & CSIR-Jigyasa District Administration, East Singhbhum and CSIR-National Metallurgical Laboratory, Jamshedpur jointly organized a workshop for Government School students under Project Anveshan and CSIR-JIGYASA. Under the programme, students of SS+2 High School Patamda visited CSIR-NML, Jamshedpur. The aim of the workshop is to familiarize the students with research facilities and develop scientific temper in them. The students visited various research facilities of CSIR-NML.

Distinguished Visitors

Visit of Dr. S.K. Jha, CMD Midhani (24th April 2024)

Dr. Jha is the Research Council member of CSIR-NML. The purpose of his visit was to ensure future collaboration between CSIR-NML and Midhani in mutual areas of interest.

Visit of Dr. N. Kalaiselvi, Director-General, CSIR and Secretary-DSIR, GOI (22nd May 2024)

The purpose of her visit was to know in depth and experience the ongoing R&D activities in the laboratory. She visited the R&D labs, pilot plant facilities and inaugurated the Inert Gas Atomizer facility and interacted with the scientists and researchers.

Visit to R&D labs, and pilot plant facilities

Dr. Kalaiselvi visited the state-of-the-art facilities at CSIR-NML and the poster presentations on the recent technological achievements. She visited the facilities like dry beneficiation facilities, beneficiation and extraction of strategic & critical minerals; pilot plant facility related to Tungsten Scrap Recycling, Sea-nodules processing and Potash;and the pilot plant facility of Li Battery Recycling facility.

Inauguration of "Inert Gas Atomizer (IGA)" Facility by DG CSIR

Dr. (Mrs.) N. Kalaiselvi, Director General, CSIR performed ribbon cutting ceremony and unravelled the inauguration plaque for the newly built Inert Gas Atomzier cabin. Next, she switched on the control unit of IGA. After switching-on the power for IGA, DG madam was requested to load the silver+copper granules into the melting chamber of IGA with an aim to prepare sterling silver powder (93% Ag +7% Cu) for making 3D printed silver jewellery. The IGA is the state-of-the-art facility, first of its kind in India. It was supplied by M/s BluePower, Germany installed by their Indian Representatives M/s Precious Alloys Pt. Ltd, Mumbai. The model of the IGA is AU1000 with HTC module required for high temperature operations.

Visit of Prof. Chetan Solanki and Team from Energy Swaraj Foundation (7th -10th September 2024)

Prof. Chetan Solanki, a distinguished faculty member from the Indian Institute of Technology Bombay (IITB), and his team from the Energy Swaraj Foundation. Prof. Solanki delivered a lecture on the need of implementation of solar energy panels as an alternate to current energy sources for mitigating climate change. The visit fostered valuable collaboration and knowledge exchange between the two institutions.

Visit of Dr. Shekhar C. Mande, Former Director General, CSIR (July 2024)

Dr. Mande visited the facilities and witnessed the activities undergoing under the CSIR-NML Urban Ore Recycling Centre.

Visit of Shri DK Gaur, RDSO (18th January 2025)

Visit of Mr. Karel Vanheusden, Vice President and Dr. Ratnakumar Bugga, Senior Fellow Lyten Inc, USA (28th February 2025)

Lyten is a materials company specialized in the development and production of lithium-sulphur batteries. The purpose of this visit was to explore the collaboration opportunities between the two institutions for the development of the Downs cell for Li production and purification.

Visit of Dr. G. K. Das, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia (18th March 2025)

Dr. Das Visited CSIR-NML for a detail discussion on the India-Australia Collaboratory project. A potential research and business relationship related to CSIRO's Titanium-vanadium recovery process with CSIR-NML was discussed.

CSIR-NML Staff Club Activities

Blood Donation Camp (6th June 2024)

The CSIR-NML Staff Club celebrated its silver jubilee by organizing a Blood Donation Camp. The event aimed to collect vital blood donations. The club has a rich history of engaging in various social and humanitarian activities, and this blood donation camp added another feather to their cap. All donors received certificates of appreciation as tokens of gratitude.



A Vibrant Food Mela at CSIR-NML Club House (5th August 2025)

A delectable food extravaganza was organized at the NML Club House in Agrico. The event showcased a diverse array of culinary delights, prepared with passion and expertise by the staff members and their families.



Independence Day Cultural Program 2024

To commemorate our Independence Day, various competitions were organized at the laboratory and residential premises. Hindi poetry competition and Sit and Draw Competition (Kids) was organized at the. The event was exclusively open to all employee ward members, providing a platform for young minds to express their patriotism and creativity.



National Sports Day Celebration (31st August 2024)

To commemorate National Sports Day, separate volleyball tournaments for male and female participants were organized at two of its residential complexes: NML Colony Golmuri and NML Flats Agrico.


Annual Sports Day (25th -26th January 2025)




Open Bridge Tournament (22nd-23rd February-2025)



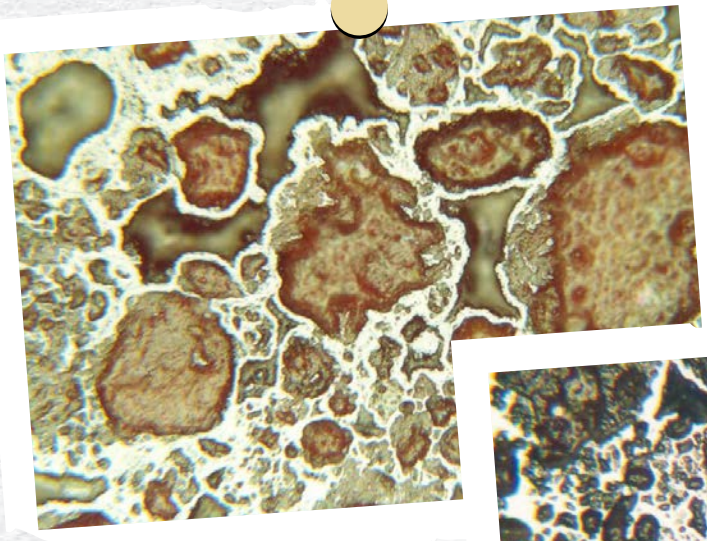
Tennis Ball Cricket Tournament (25th January 2025)

As a part of Republic Day celebration, a tennis ball cricket tournament has been organized.

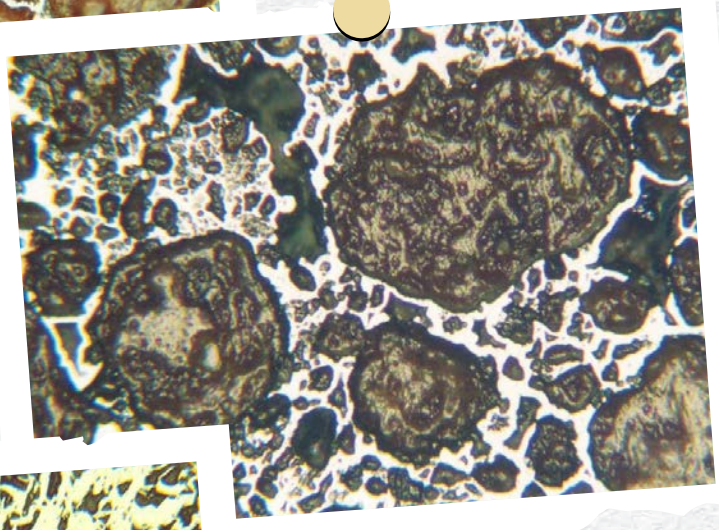

Games for Kids & Women (25th January 2025)

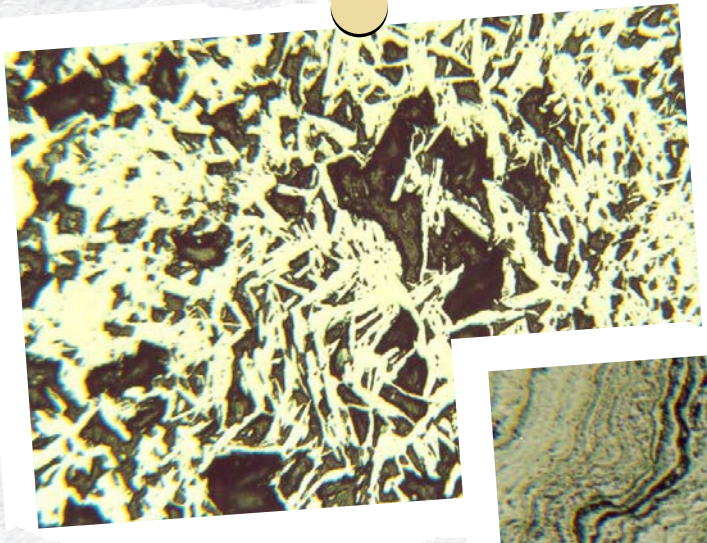
Women's Hit the Wicket (8th-9th March 2025)

Microscopic Images

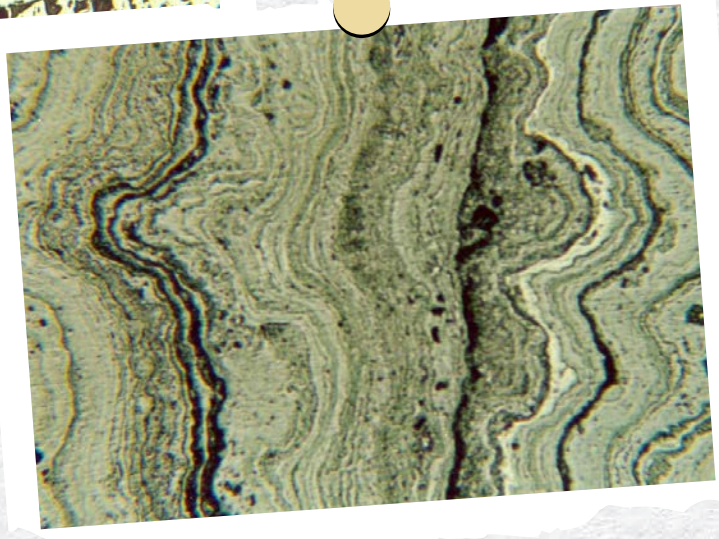


Lateritic Iron Ore





Hematite Iron Ore



Goethic Iron Ore

Eminent Speakers

Platinum Jubilee Lectures Delivered by Eminent Speakers

Speaker	Topic & Description	Date	
Dr. B. P. Gautham Chief Scientist TCS Research Pune	1st Platinum Jubilee Lecture	12th February 2024	
Professor B S Murty Director Indian Institute of Technology (IIT) Hyderabad	2nd Platinum Jubilee Lecture on "Viksit Bharat Through Collaboration".	24th March 2025	
Professor S K Kawatra Chair and Professor Michigan Technological University Michigan, USA	3rd Platinum Jubilee Lecture on *"Big Picture of Iron Ore Processing"*	25th March 2025	

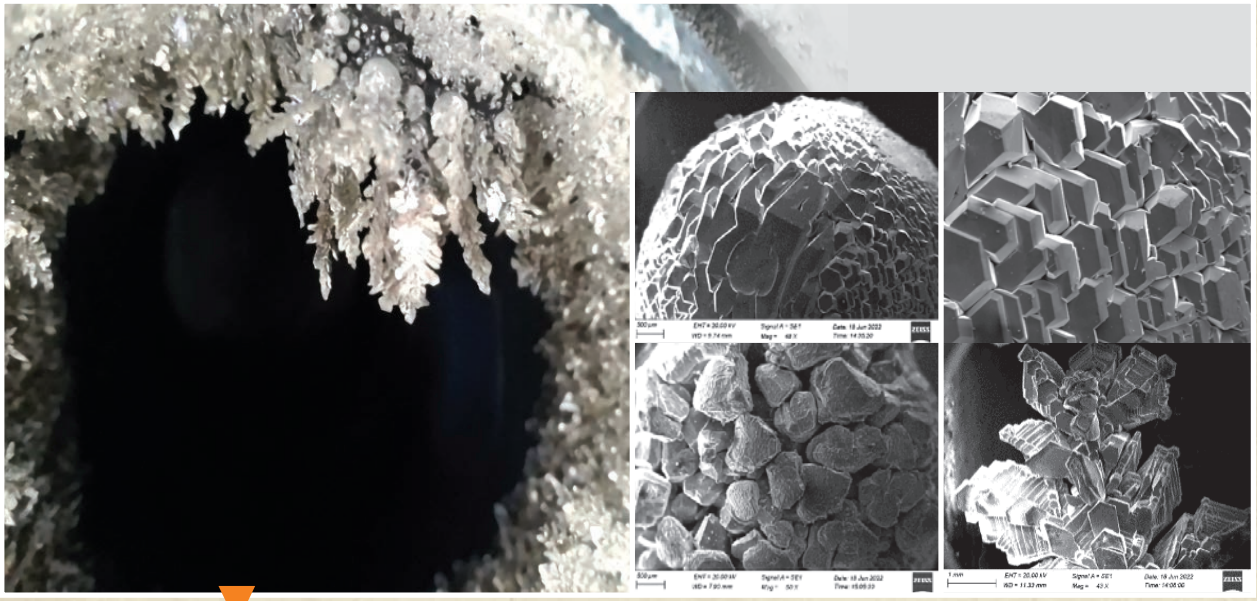
Lectures Delivered by Eminent Speakers

Speaker	Topic & Description	Date	
Mr. Nitesh Maheshwari Chartered Accountant N Maheshwari & Associates	*"Taxation for salaried employees"*	02nd July 2024	
Prof. Chetan Solanki Founder-Energy Swaraj Foundation	*"Need for sustainable energy practices and the role of energy efficiency in mitigating climate change".*	10th September 2024	
Shri. R. S. Mani Distinguished Scientist (ICT) at CSIR HQ	*"Data Protection and Data Privacy"*	20th September 2024	
Dr. Shankar Venugopal Vice President at Mahindra & Mahindra	*CSIR Foundation Lecture on "The New Materials that are Shaping the Future of Mobility"*	26th September 2024	

Speaker	Topic & Description	Date	
Mr. Dharmendra Kumar Controller of Stores and Purchase at CSIR-IICT, Hyderabad	*"Public Procurement"*	30th October 2024	
Professor Kenneth F. Kelton Arthur Holly Compton Professor Emeritus Department of Physics and the Institute of Materials Science and Engineering, Washington University US	*"Crystal Nucleation in Liquids and Glasses" 12th Professor P Ramachandra Rao Memorial Lecture jointly organized by CSIR-NML and Department of Metallurgical Engineering and Prof. NP Gandhi Memorial Metallurgy Trust (IIT(BHU) Varanasi, India) and Department of Materials Engineering (IISc, Bengaluru, India). Organized in online mode.*	22nd October 2024	
Prof. Hanumantha Rao Emeritus Professor Norwegian University of Science and Technology (NTNU)	*"Green extraction of rare earth elements (REE) using froth and foam flotations". Jointly organized by CSIR-National Metallurgical Laboratory & Indian Institute of Mineral Engineers.*	15th November 2024	
Ms. Ammi Kumari Ethics Coordinator and Manager Tata Steel	*"Sexual Harassment at working place Prevention Week"*	16th December 2024	
Mr. Arvind Prasad Yog Guru JRD Sports Complex Tata Steel	*"The Role of Yoga in Modern Workplace Lifestyle"*	17th January 2025	
Dr. Tapas Kumar Roy Head, Steel Making and Casting Research Group Tata Steel Limited	*" Understanding the evolution of some defects from casting to rolling " Jointly organized by CSIR-NML and IIM Jamshedpur Chapter..*	28th January 2025	
Dr. Bhanu Pant Fellow IIM Visiting Professor IIT Roorkee (Former Outstanding Scientist, VSSC, ISRO, Trivandrum)	*"Rocketry- an Indian Perspective"*	14th February 2025	
Mr. Arvind Prasad Yoga Instructor, JRD Sports Complex Tata Steel	*International Women's Day lecture on "Yoga for Mental Health and Welfare" Organized by CSIR-NML Staff Club*	07th March 2025	

2016-2025

Achievements



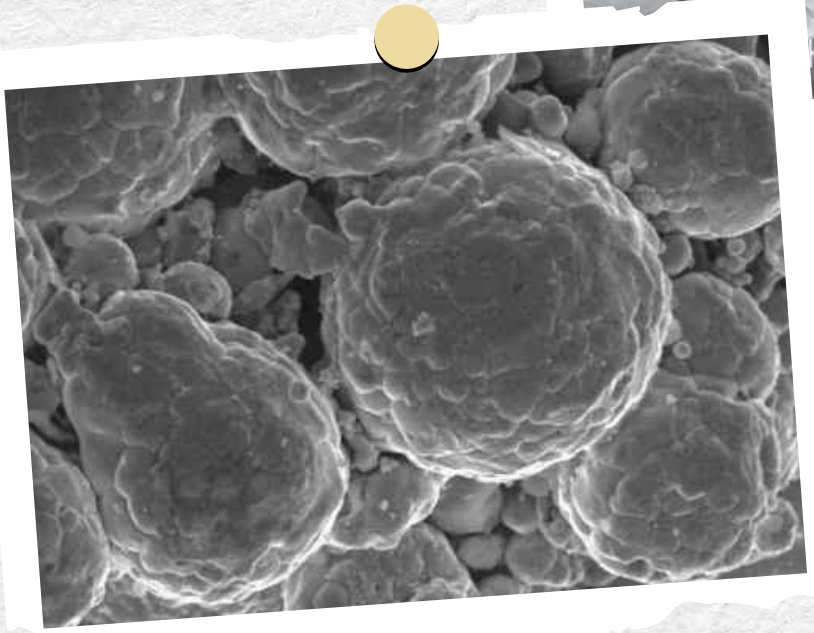
SEM analysis of droplets. Surface of droplet and dendrite

Pyrophoricity of Mg resulted in fire and rapid oxidation

Mg sponge produced in pigeon process prototype with 99.9% purity-

Iron Powder

Cu powder Electrolytic from Cu bleed solution



Ni powder H2 reduction from Cu bleed solution

Awards and Recognition

National/International Awards/Recognitions

Rashtriya Vigyan Puraskar

Vigyan Yuva - Shanti Swarup Bhatnagar 2024

The Government of India bestows this esteemed recognition to acknowledge and celebrate outstanding contributions to scientific research by young scientists.

Dr. Abhilash
Senior Principal Scientist

M.S. Khan Memorial Award

The award recognizes the exceptional contributions and outstanding achievements in the field of metallurgy. field.

Dr. Ammasi A.
Principal Scientist

Dr. Premkumar M.
Principal Scientist

Young Metallurgist (Metal Science) Award, 2023

The award is conferred by Ministry of Steel

Dr. Biraj Kumar Sahoo
Principal Scientist

IEI Young Engineers award 2024-25 (Institutions of Engineers India)

This award was for in recognition of exceptional contributions in the field of metallurgical & materials engineering research, technology development, and technology transfer. This prestigious award was conferred by the Institution of Engineers India, the world's largest multidisciplinary engineering professional society, in the 37th National Convention of Metallurgical and Materials Engineers held on 6-7 Dec 2024 at Salem.

Dr. Gaurav Kumar Bansal
Senior Scientist

Acta Student Award

P. S. Manoranjan Jena
AcSIR Student

CII-National Corrosion Championship Trophy 2025

Dr. Mahesh Gulab Walunj
Sr. Scientist

Aprajita Samman

"Aprajita samman" on occasion of Women's Day 2025 by Prabhat Khabar (National Daily), Jamshedpur (12th March 2025)

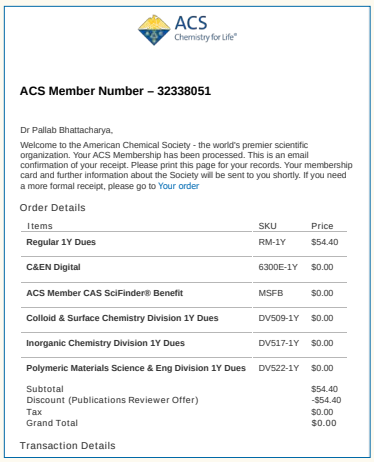
Dr. Pratima Meshram

Fellowships Received

Dr. Ranjeet Kumar Singh
Principal Scientist
Raman Research Fellowship 2024-25
Tenure: 30-03-2025 to 29.07.2027
Institute: Univ. of Pretoria, S. Africa

Dr. Pallab Bhattacharya
Principal Scientist

Honorary membership for one year from the American Chemical Society (ACS) 18th November 2024.



ACS
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Dr Pallab Bhattacharya,

Welcome to the American Chemical Society - the world's premier scientific organization. Your ACS Membership has been processed. This is an email confirmation of your receipt. Please print this page for your records. Your membership card and further information about the Society will be sent to you shortly. If you need a more formal receipt, please go to Your order

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Grand Total		$0.00

Transaction Details

Dr. Nikhil Kumar
Scientist

Life Membership: Materaial Research Society of India (LMB3958)

Scientific Excellence Award

Felicitation with "**Scientific Excellence Award**" by Organising Committee of 28th International Conference on Nonferrous Metals held at **Bhubaneswar** on 11-12 July 2024, jointly organized by Corporate Monitor (Kolkata), CSIR-IMMT (Bhubaneswar) and JNARDDC (Nagpur).

Dr. Navneet Singh Randhawa
Senior Technical Officer

Paper/Poster Awards

Dr. Gaurav Bansal
Principal Scientist

Dr. Biraj Kumar Sahoo
Principal Scientist

Dr. Avanish Kumar Chandan
Senior Scientist


BTTD 2024

exhibits significant increase in corrosion resistance. Results shows impedance of the coated specimens 2.5 times as compared to the bare sample and the corrosion rate decreases by 1.5 times. Sealing to reduce the porosity in the coating is performed on the as-coated sample in ammonium fluoride solution at 60 degrees Celsius for 50 minutes at pH~4.80. Subsequently specimens were taken for electrochemical studies. This further increases the impedance to 3.3 times the as-coated sample and 8 times the bare specimens. This study shall be subjected to salt spray exposure to compare the corrosion resistance in more aggressive environment.

Keyword: Corrosion, Conversion Coating, Phosphating, TMT bars, Corrosion Protection

Theory guided study on the effect of heat treatment on the microstructural properties and hardness of Hadfield steel

Rajdeep Chatterjee[1*], Rishav Rai[2], Biraj Kumar Sahoo[3], Avanish Kumar Chandan[3], Gaurav Kumar Bansal[3]
[1]Department of Metallurgical Engineering, Indian Institute of Technology (BHU), Varanasi-221005
[2]Department of Metallurgical and Materials Engineering, National Institute of Technology, Jamshedpur-831014
[3]Materials Engineering Division, CSIR- National Metallurgical Laboratory, Jamshedpur
*Email: rajdeep.chatterjee.met20@itbhu.ac.in; Phone: 7461067157

ABSTRACT

Hadfield steel, a high manganese austenitic steel, reigns supreme in wear-intensive industries like mining and minerals processing. This dominance is credited to its exceptional blend of toughness and hardness, translating to superior impact and wear resistance, respectively. A key factor in Hadfield steel's success is its ability to strain harden under impact. This means the steel becomes progressively harder as it encounters wear and tear, naturally mitigating further wear during operation. However, unlocking these exceptional mechanical properties hinges on a meticulously designed heat treatment strategy. Crucially, the control of alloy carbides through specific heat treatment processes is paramount. These carbides directly influence the critical balance between wear strength and toughness in Hadfield steel. This research work delves into the impact of various heat treatment cycles employed during the manufacturing of Hadfield steel. To achieve this, the study will utilize sophisticated techniques like optical microscopy (OM) and scanning electron microscopy (SEM) to analyse microstructural characteristics, including grain size and carbide distribution, before and after the steel undergoes heat treatment. Additionally, the influence of heat treatment on the mechanical properties of the steel will be evaluated using a hardness tester. By meticulously examining the intricate relationship between heat treatment parameters and the resulting material properties, this research aspires to significantly enhance our understanding of Hadfield steel heat treatment processes. This knowledge will ultimately pave the way for the development of optimized heat treatment strategies, fostering superior performance and extended service life in wear-intensive applications.

First Prize in Oral Presentation (BTTD 2024); CSIR National Metallurgical Laboratory Jamshedpur;

Authors: Rajdeep Chatterjee, IIT BHU and Rishav Rai, NIT Jamshedpur, Gaurav Bansal, NML, Biraj Kumar Sahoo, NML, Avanish Kumar Chandan, NML

Paper: 'Theory guided study on the effect of heat treatment on the microstructural properties and hardness of Hadfield steel' in the Behind the Teacher's Desk (BTTD) student's seminar held on 19-21 June 2024 at CSIR NML Jamshedpur.

Best Poster Presentation Award

Poster: "Effect of heat treatment process on microstructure & mechanical Title of Presentation - Properties of Q&P steel"

Authors: Swapna Dey*, G.K. Bansal, G.K. Mandal, B.K. Sahoo, S. Sivaprasad

Conference: "IUMRS-ICA 2024" held at Indore during December 3 - 6, 2024.

Dr. Gaurav Kumar Bansal
Principal Scientist

Dr. Gopi Kishore Mandal
Senior Principal Scientist

Dr. Biraj Kumar Sahoo
Principal Scientist

Dr. S. Sivaprasad
Chief Scientist

Best Technical Paper Award

Paper: "Effect of microstructural phases on flow accelerated corrosion (FAC) behavior of API 5L X60 grade steel"

Authors: Lalit Kr Meena, Y Usha, G P Chaudhari, Raghuvir Singh and presented by Lalit Kr Meena in the session on "Corrosion in different industrial sectors"

Dr. Lalit Kr Meena
Senior Scientist

Conference: 2nd International Conference on Corrosion and Coatings (i3C) during 6-7th Feb, 2025 at Jamshedpur

Mrs. Y Usha,
Sr. Scientist

Paper: "CFD simulations of varying bend geometry and fluid velocity in a 90° elbow pertaining to the Flow Accelerated Corrosion (FAC)"

Authors: Y. Usha, Lalit Kr. Meena, Raghuvir Singh and presented by Y. Usha in the Session: "Corrosion modelling, simulation, and prediction"

Conference: 2nd International Conference on Corrosion and Coatings (i3C) during 6-7th Feb, 2025 at Jamshedpur.

Oral presentation in Corrosion modelling, simulation, and prediction Best Technical Paper Award

Authors: Mahesh walunj, Lokesh Pathak, V.S. Raja

Conference: 2nd International Conference on Corrosion and Coatings (i3C) during 6-7th Feb, 2025 at Jamshedpur.

Book /Book Chapter Published

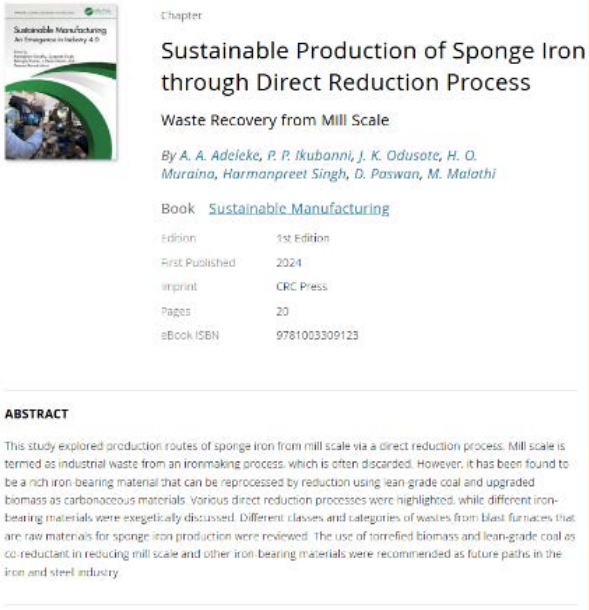
Book Chapter Title: Sustainable production of sponge iron through direct reduction process: Waste recovery from mill scale

Authors from CSIR-NML:

Dr. M. Malathi
Principal Scientist

Dr. D. Paswan
Principal Scientist

Book Title: Sustainable Manufacturing; 1st Edition; © 2024 Informa UK Limited, an Informa Plc company; 2024



Chapter

Sustainable Production of Sponge Iron through Direct Reduction Process

Waste Recovery from Mill Scale

By A. A. Adeleke, P. P. Ikubanni, J. K. Odusote, H. O. Muraina, Harmanpreet Singh, D. Paswan, M. Malathi

Book Sustainable Manufacturing

Edition	1st Edition
First Published	2024
Imprint	CRC Press
Pages	20
eBook ISBN	9781003309123

ABSTRACT

This study explored production routes of sponge iron from mill scale via a direct reduction process. Mill scale is termed as industrial waste from an ironmaking process, which is often discarded. However, it has been found to be a rich iron-bearing material that can be reprocessed by reduction using lean-grade coal and upgraded biomass as carbonaceous materials. Various direct reduction processes were highlighted, while different iron-bearing materials were exegetically discussed. Different classes and categories of wastes from blast furnaces that are raw materials for sponge iron production were reviewed. The use of torrefied biomass and lean-grade coal as co-reductant in reducing mill scale and other iron-bearing materials were recommended as future paths in the iron and steel industry.

Book Chapter Title : Additive Manufacturing of Magnesium Alloys for Biomedical Applications

Book Title : Advances in Applied Mechanics, INCAM 2022, Lecture Notes in Mechanical Engineering, 2024, https://doi.org/10.1007/978-981-97-0472-9_13.

Authors from CSIR-NML:

Dr. Md. Murtuja Hussain
Principal Scientist

Dr. Mahesh Gulab Walunj,
Senior Scientist

Additive Manufacturing of Magnesium Alloys for Biomedical Applications

Abdul Rahman, Murtuja Husain, Naresh Prasad, and Mahesh Gulab Walunj

Abstract Magnesium alloys, with their stiffness comparable with that of bone, might serve as a new class of biodegradable materials that reduce the adverse effects of stress shielding. Due to its biodegradability, magnesium implants used in medicine do not need revision surgery. Increased enthusiasm for using additive manufacturing's cutting-edge design options to push medical innovation to new heights indicates a promising future for this industry. The high chemical reactivity exhibited by magnesium alloys poses a significant challenge in the context of 3D printing, owing to the potential combustibility risk that they present. The task of producing solid structures with a balance between durability and resistance to corrosion is already difficult because magnesium has a low boiling point and contains biocompatible alloying components. The goal of this research is to offer an exhaustive overview of the procedures currently in use for 3D printing magnesium structures and recommendations for the most effective additive methods for this class of alloys.

Keywords Additive manufacturing · Magnesium · Biomedical · Implants

1 Introduction

Magnesium alloys have become a potential group of light-weight metal alloys that can be used in a variety of ways, such as in aviation, transport, and implants. The novel magnesium alloys possess favorable attributes such as low density, superior mechanical characteristics, and exceptional machinability, making them highly suitable for deployment in the aforementioned applications [1]. Degradable magnesium (Mg) alloys are used in orthopedics [2], cardiology [3], and urology [4]. Because Mg totally degrades, long-term problems are reduced or avoided. Bioresorbable

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M. Husain · M. G. Walunj
National Metallurgical Laboratory, Jamshedpur 831014, India

D. Kumar et al. (eds.), *Advances in Applied Mechanics*, Lecture Notes in Mechanical Engineering, https://doi.org/10.1007/978-981-97-0472-9_13

Book Chapter Title : Defect Engineering for Tailoring Thermoelectric Properties of Electroceramics

Author from CSIR-NML:

Dr. Paritosh Dubey
Senior Scientist

Book Title: Defects Engineering in Electroceramics for Energy Applications, https://doi org/10.1007/978-981-97-9018-0.

Defect Engineering for Tailoring Thermoelectric Properties of Electroceramics

Rajan Walia, Yogendra K. Gautam, Sagar Vikal, Ashwani Kumar, Paritosh Dubey, and Prashant Shahi

Abstract The field of thermoelectric materials has garnered significant attention due to its potential to revolutionize energy conversion and harvesting technologies. Delving into the fascinating realm of utilizing defect engineering strategies to enhance and tailor the thermoelectric properties of Electroceramic materials, this book explores the intricate relationship between crystal defects and thermoelectric performance. This chapter defines various thermometric, electroceramic, and 2D materials. It provides a comprehensive overview of defect types, their origins, and their influence on material behavior. With the aid of computational simulations and state-of-the-art experimental methods, defect engineering strategies are unveiled, enabling precise control over material properties. This chapter highlights the harnessing of defect engineering principles to unlock the full potential of electroceramics thermoelectric materials. The chapter provides a detailed study of the impact of defect Engineering on tailoring the thermometric properties of electroceramics, thermoelectric devices, and energy conversion technologies.

Keywords Thermoelectric materials · Electroceramics · Thermometric properties · Crystal defects · Defect engineering · Energy conversion

Book Chapter Title: Metal-organic frameworks (MOFs): Chemistry, properties, and energy storage applications (Bentham Science Publishers 2004)

Author from CSIR-NML:

Dr. Nikhil Kumar
Scientist

Metal-Organic Frameworks (MOFs): Chemistry, Properties, and Energy Storage Applications

Buy this Content

Authors: Nikhil Kumar[1], Nisha Gupta[2], Pallab Bhattacharya[3]

View Affiliations

Source: Multidimensional Nanomaterials for Supercapacitors: Next Generation Energy Storage , pp 88-119

Publication Date: May 2024

Language: English

Book Chapter Title: A gas sensor array based on metal selenides; Book Title: Emerging materials for energy and sensing applications, *eds.* K.S. Gour, V.N. Singh, *CRC Press*, USA, 2025.

A Gas Sensor Array Based on Metal Selenides

By Sanju Rani, Manoj Kumar, Kuldeep Singh Gour, Gopal Rawat, Vidya Nand Singh

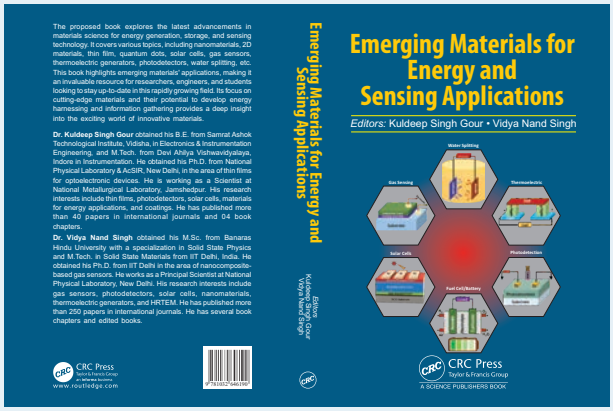
Book Emerging Materials for Energy and Sensing Applications

Edition	1st Edition
First Published	2025
Imprint	CRC Press
Pages	17
eBook ISBN	9781032673691

Book Title: Emerging materials for energy and sensing applications, *CRC Press*, USA, 2025. https:// doi.org/10.1201/9781032673691

Author from CSIR-NML:

Dr. Kuldip Singh Gour
Scientist



CSIR Foundation Day Awards (26th September 2024)

Meritorious Children Awards

Meritorious Studentship Award for the wards of staff securing 90% marks or above in each of a minimum of three science subjects in the Senior Secondary Examination (12th class) 2024.

Mr. Ankit Sahoo
94.67 %
S/o Dr. K. L. Sahoo, Chief Scientist

Miss Aditi Upadhyay
93.00 %
D/o Dr. A. K. Upadhyay, Pr. Technical Officer

CSIR-NML Foundation Day Awards (26th November 2024)

Meritorious Studentship Awards

The First Category of awards is presented to those children/wards of CSIR-NML staff who have secured 90% or above marks in their Class 10th and 12th Board Examinations (ICSE/CBSE/Jharkhand Board) in the year 2024.

Miss Aditi Upadhyay
Class 12th
D/O Dr. A.K. Upadhyay
Sr. Technical Officer

Miss Pramannya Nagrare
Class 10th
D/O Shri Pravin A. Nagrare
ASO.

Mr. Ankit Sahoo
Class 12th
S/O Dr. K.L. Sahoo
Chief Scientist

Ms. Nyasa Mahato
Class 10th
D/O Dr. Bhupeshwar Mahato
Sr. Technical Officer

Mr. Siddhant Dash
Class 10th
S/O Shri Byomkesh Dash
Chief Scientist.

Mr. Soham Verma
Class 10th
S/O Dr. Ranu Verma
Section Officer

Mr. Adarsh Kumar Upadhyay
Class 10th
S/O Shri Ashish Kumar Upadhyay
Sr. Technical Officer

Ms. Shradhanjali Pothal
Class 10th
D/O Shri Lalatendu Pothal
Sr. Technician

Ms. Manya Gupta
Class 10th
D/O Dr. Manoj Kumar
Senior Principal Scientist

Ms. Ananya Mohanty
Class 10th
D/O Dr. Ashok Kumar Mohanty
Senior Principal Scientist

Ms. Taniya Sana Runda
Class 10th
D/O Shri Manoj Kumar Runda
Sr. Technical Officer

The second category of award recognizes those exceptional students who have achieved a perfect score of 100% in any subject in their Board Examinations.

Miss Ananya Mohanty
Class 10th
D/O Dr. Ashok Kumar Mohanty
Senior Principal Scientist

Mr. Soham Verma
Class 10th
S/O Dr. Ranu Verma
Section Officer

Miss Tanisha Sifa Runda
Class 10th
D/O Shri Manoj Kumar Runda
Sr. Technical Officer

Prof. P Ramachandra Rao Award for Best Employee of the Year

Technical : Mr. H.S. Tirkey, a Senior Technician in the Engineering Division

Non-Technical: Mr. Sitaram Murmu,Senior Scientific Assistant (Stores & Purchase)

Prof. S P Mehrotra Award for Best Colloquium Speaker, conferred by Prof. Mehrotra conferred the award to Dr. Jana.

Awardee: Dr. Animesh Jana, Senior Scientist

Prof. B R Nijhawan Award for Best Paper Published in the Last Calendar Year.

Paper : "Microwave-plasma induced one-step synthesis of $Ni(PO_3)_2$ (Nickel Phosphite) nanosphere-loaded bio-waste derived N, P co-doped carbon for an asymmetric supercapacitor with prolonged life," published in the Journal of Materials Chemistry C in the year (2023).

Awardees: Ms. Nisha Gupta and Dr. Pallab Bhattacharya

Prof. Shilowbhadra Banerjee Award for the best in-house (i-PSG) project conferred by Prof. Shilowbhadra Banerjee, Former Director, CSIR-NML.

Awardees : Krishna Kumar, Y Usha, M Madan, Rohit B Meshram, M Uday Bhaskar Rao, Navneet Singh Randhawa, Nimai Halder, Ganesh Chalavadi, and Ashok K.)

The Awarded Project : "Investigations on the NML's retort technology for magnesium metal production," undertaken under Project No. OLP-0393.

Krishna Kumar *Y Usha* *M Madan* *R B Meshram* *M Uday Bhaskar Rao* *N S Randhawa* *Nimai Halder* *G Chalavadi* *Ashok K*

Invited Talks Delivered by Staff

Dr. Sanjay Kumar
Chief Scientist

- Keynote address in the 18th European Symposium on Comminution & Classification held during 24th -26th June 2024 at Miskolc, Hungary. He is the first Indian to deliver the keynote in this very prestigious symposium. Also Chaired a session on 'Comminution in recycling and classification' in the Symposium.
- Participated in the panel discussion in the Symposium on "Accessibility and Inclusion in Technology Development and Transfer" during 09th -10th Jan 2025 at University of Hyderabad. Also chaired a session on 10th Jan 2025 in the Symposium.
- Invited lecture on "From Trash to Cash through Circular Economy" in the 'Corporate Recyclers Conclave' held in Ranchi on 18 Jan 2025.

Dr. Sanchita Chakravarty
Chief Scientist

Keynote lecture on "*Extraction of Rare Earth Elements from Coal Ash: A Sustainable Approach*" at the **"International Conference on Science, Technology and Applications of Rare Earths (ICSTAR 2024)"** held at Hotel Residency Tower, Thiruvananthapuram, India August 21-23, 2024.

Dr. Trilochan Mishra
Chief Scientist

- Key note lecture in International Conference on Advances in Materials and Chemical Sciences (AMCS-24) held at BIT, Mesra during 18-20th December.
- Invited as chief guest on the "Research Scholar Day" celebration at IIT, Roorkee Sharanpur campus on 29th Nov 2024.

Dr. Jagannath Pal
Chief Scientist

- Invited talk in the National Level Workshop on "Advancement in Minerals Processing Techniques with special reference to Iron and Coal (AMPTIC-2024)" during 16th-20th July 2024 at National Institute of Technology Jamshedpur.
- Invited speaker for the panel discussion in CII Global Summit on Advanced Materials, 'Critical Minerals, & Metals' held on 11th July 24 at IHC, New Delhi for the topic "Innovations in Steel: Advancing the Industry"

Dr. Gopi Kishore Mandal
Senior Principal Scientist

- Invited talk on 'An insight into the development of low-density cost-effective Ni-based medium entropy alloys' in the '5th Indo-Austrian Symposium on Materials Engineering (IASME 2024)', organized by the department of Metallurgical and Materials Engineering (MME) at IIT Kharagpur, during December 12-13, 2024.
- Keynote lecture on 'Perspectives on the design and development of Ni-Fe-Cr-based medium entropy alloys as potential high-temperature materials' in the Structure Property Correlation session during the 78th IIM Annual Technical Meeting (IIM-ATM 2024), held at GKVK Campus, Bangalore during Nov 20-22, 2024.
- Invited talk on 'Role of pre-coat on galvanizing and galvaannealing of high strength steel' during international conference on "ADVANCES IN PROCESSING TECHNOLOGY OF FLAT STEEL PRODUCTS (APT-FS 2024)" September 20-21, 2024 at Bokaro Steel City, Jharkhand, India

Dr. Abhilash
Senior Principal Scientist

- Invited talk on "Critical Minerals and Metals Processing & Extraction (CSIR-NML's Snapshot of Indigenous Feed and Processes)" at Critical Minerals Summit on 1st May 2024 organized by CEEW, Ministry of Mines, and Shakti Foundation at New Delhi
- Invited talk on "Avenues of Exploring Critical Minerals and Metals Processing & Extraction of NML" at 4th Tranche Auction of Ministry of Mines, Jaipur on 3rd May 2024

Dr. Ranjeet Kumar Singh
Principal Scientist

- Invited talk on "Augmentation of iron ore resources" in National Seminar on Augmentation in Metal Production: Journey Towards Green" (AMPG -2024) on Saturday, 21st September 2024 at Kolkata.
- Keynote lecture on "Mineral Processing: Recent Trends" in the 4th National Workshop AMPTIC -2024 at NIT Jamshedpur during 16th- 20th July 2024.

Dr. Pratima Meshram
Principal Scientist

Invited lecture on "Sustainability in Metallurgy of secondary Resources" in Five Days Workshop on Recent Advances in Extractive Metallurgy (RAiEM-2024) organized by Department of Metallurgical and Materials Engineering, National Institute of Technology Srinagar on 31st August 2024


CERTIFICATE OF APPRECIATION
FIVE DAYS WORKSHOP
Organized By
DEPARTMENT OF METALLURGICAL AND MATERIALS ENGINEERING

Dr. Shailendra Kumar Jha
Principal Scientist

- Invited Lecture in the two days National Conference on Green Technology and Sustainable Development (GTSD-2024), 30-31st May 2024, NIT Patna.
- Keynote Speaker at the international conference, "Frontiers in Nanomaterials Sciences: Aspects in Biotechnology and Chemical Engineering" (FINS, 2K24), December 21-23, 2024, jointly organized by the Department of Chemistry and Department of Chemical Engineering & Technology at the National Institute of Technology Patna, India.

Dr. Premkumar M
Principal Scientist

- Invited talk on the topic " Modern energy landscape: Exploring Alloy Development with Free Rare Earths and Critical Metals " 'Heavy Minerals & Lithium for Energy Security' (REES-2024 Series) at Grand Hyatt Kochi, Kerala between August 29th - 30th, 2024.
- Invited talk on the topic "workshop on "Developments in Iron-based Magnetic Materials" at TATA Steel R&D division on July 26th 2024.

Dr. Paritosh Dubey
Senior Scientist

- Invited talk on "Durable and hard Cu-alloy-based composite coating for anti-icing applications" in National Seminar on Cutting Edge Innovations in Nanotechnology and Advanced Materials for a Sustainable Future, Organized by the Department of Physics, Marwari College, Darbhanga on 24th August
- Invited talk on "Effect of microstructure on wear and corrosion performance of HVOF sprayed AlCoCr0.75Cu0.5FeNi high entropy alloy coating" in 2nd National Thermal Spray Conference & EXPO, Jointly Organized by CSIR – IMMT & iTSA, 21st – 23rd February 2025

Dr. Naveena
Senior Scientist

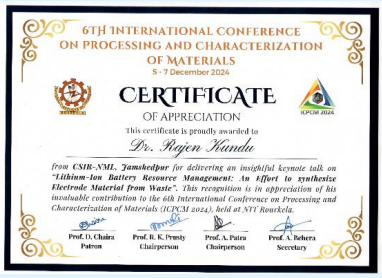
Invited talk in the area of miniaturised specimen testing in the Structural Integrity Conference & Exhibition (SICE), a flagship event of Indian Structural Integrity Society (InSIS) (http://www.insis.in), organized during 22nd -24th October 2024 at VNIT, Nagpur.

Dr. G. Sudhakar Rao
Senior Scientist

Invited talk on "Stress Corrosion Cracking in Structural Materials" in the online short-term course "Advanced Materials Testing and Characterization" from 29th July to 02nd August 2024, organized by the Department of Materials Science and Engineering, National Institute of Technology, H.P.

Dr. Rajen Kundu
Scientist

Keynote lecture on "Lithium-Ion Battery Resource Management: An Effort to Synthesized Electrode Material from Waste" at the 6th International Conference on Processing & Characterization of Materials (ICPCM 2024) organized by the Department of Metallurgical and Materials Engineering, National Institute of Technology, Rourkela (NIT Rourkela) on 07th December 2024.


6TH INTERNATIONAL CONFERENCE ON PROCESSING AND CHARACTERIZATION OF MATERIALS
5 - 7 December 2024
CERTIFICATE
OF APPRECIATION
This certificate is proudly awarded to
Dr. Rajen Kundu
from CSIR-NML, Jamshedpur for delivering an insightful keynote talk on "Lithium-Ion Battery Resource Management: An Effort to synthesize Electrode Material from Waste". This recognition is in appreciation of his invaluable contribution to the 6th International Conference on Processing and Characterization of Materials (ICPCM 2024), held at NIT Rourkela.
Prof. D. Chaira Patron
Prof. B. K. Prusty Chairperson
Prof. A. Patra Chairperson
Prof. A. Behera Secretary

Dr. Nikhil Kumar
Scientist

Popular Lecture Series for School Students on 13th Aug. 2024 at CSIR NML Jamshedpur.

Topic: X-ray: Importance of an accidental discovery in our lives

Dr. Navneet Singh Randhawa
Senior Technical Officer

Invited talk entitled "Recycling of Metallurgical Slags Towards Circular Economy & Value Creation (presented on digital platform) " in the 5-day workshop on "Recent Advances in Extractive Metallurgy" from 27th August to 31st August 2024 in NIT Srinagar.

Mr. K Sudhakara Rao K
Senior Technical Officer

Invited talk entitled "Weld-ability Study of Powder Metallurgy AISI 4115 Steel Using Pulsed Current Gas Tungsten Arc Welding Process" at National Welding Seminar 2024 on 13th December 2024, organized by The Indian Institute of Welding (IIW-India), Jamshedpur branch.

High Citation/ Impact Factor/Most Downloaded Publication

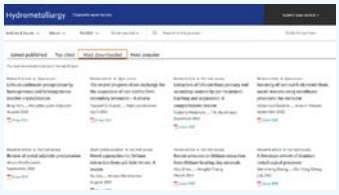
Dr. Sanjay Kumar
Chief Scientist

- On Google Scholar, his publications have received more than 1000 citations in the calendar year 2024. His total citations crossed 8000 with 24 papers having more than 100 citations.

Dr. Pratima Meshram
Principal Scientist

- **Publication of Impact Factor: 15.1**

  Making low-carbon energy sustainable, Emily Grubert, Lira Luz Benites Lazaro, Alexander Popp, Leon Merfort, Tianyi Luo, Vassiliki Kati, Pratima Meshram, Felix M. Dorn, Diana Hernández, Voices (One Press), 7(2), 163-166 (2024).



- Most Downloaded papers in last 10 years

  i. Journal: Hydrometallurgy

  https://www.journals.elsevier.com/hydrometallurgy/most-downloaded-articles

Dr. KuldeepSingh Gour
Scientist

- **Publication of Impact Factor: 13.4**

  M. Gaikwad, V. Burungale, D. Gavali, D. Malavekar, S.W. Park, F. Zheng, K.S. Gour, M.R. Alfaro Cruz, J.H. Kim, Tailoring charge transfer at the in-situ formed FeOOH/FeCo-LDHs interface via Cr modification for efficient PV-assisted solar hydrogen production coupled with methanol oxidation, Chemical Engineering Journal, 498, (2024), 1549582.

- **Publication of Impact Factor: 8.5**

  N. Kumar*, K.S. Gour*, A. Haider, R. Kumar, S. Park, Nanoporous metal-organic frameworks for electroreduction of nitrogen and carbon dioxide: A review, ACS Applied Nano Materials, 24 (2024), 28074–28097.

- **Publication of Impact Factor: 5.3**

  K.S. Gour, P.S. Pawar, M. Lee, V.C. Karade, J. S. Yun, J. Heo, J. Park, J.H. Yun, J.H. Kim, Fostering charge carrier transport and absorber growth properties in CZTSSe thin films with an ALD-SnO2 capping layer, ACS Applied Materials & Interfaces, 16, (2024) 30010-30019.

- **Publication of Impact Factor: 5.2**

  M. Kumar, S. Sani, K.S. Gour, K. Kumar, R. Yadav, S. Husale, M. Kumar, V.N. Singh, Detrapping of the carriers from shallow states in highly responsive, fast, broadband (UV-Vis-NIR), self-powered SnSe/Si photodetector with asymmetric metal electrodes, Materials Advances,5, (2024) 3220-3227.

Dr. Rajen Kundu
Scientist

- **Publication of Impact Factor: 8.5**

  Kundan Kumar, Rajen Kundu*, "Doping Engineering in Electrode Material for Boosting the Performance of Sodium Ion Batteries", ACS Applied Materials & Interfaces, 2024, 16 (29), 37346–37362. https://doi.org/10.1021/acsami.4c06305

Dr. Abhilash
Senior Principal Scientist

Dr. Pratima Meshram
Principal Scientist

- **Publication of Impact Factor: 6.1**

  Sankar, T.K., Abhilash & Meshram, P. Environmental Impact Assessment in the Entire Life Cycle of Lithium-Ion Batteries. Reviews Env.Contamination (formerly:Residue Reviews) 262, 5 (2024). https://doi.org/10.1007/s44169-023-00054-w

- **Two all-time Most Cited Publications in Mineral Processing and Extractive Metallurgy Review Journal:** https://www.tandfonline.com/action/showMostCitedArticles?journalCode=gmpr20

- **Top 2% cited scientists in Elsevier Stanford Ratings 2024**
- https://tech-talk.org/wp-content/uploads/2024/09/elsevier-top-2-researchers-in-india.pdf;https://elsevier.digitalcommonsdata.com/datasets/btchxktzyw/7

Member of National /International Committees

Dr. Sanjay Kumar
Chief Scientist

- Chairman of the Organizing Committee Circular Economy Conference CIRCON2024 held during 03-04 Oct 2024 at Jamshedpur. The event was organized Jointly by CSIR-NML, Tata Steel and Indian Ceramic Society, Jamshedpur Chapter
- Program Advisory Committee member by Department of Science & Technology, New Delhi to the following University Technology Enabling Centre's: a. Guru Ghasidas Viswavidhayala, Bilaspur, b. University of Hyderabad, Hyderabad, c. Medicap University, Indore, d. Kalinga University, Bhubaneswar.
- Chairman of the Apex Committee for the organization of 52nd SSBMT Outdoor Zonal tournament at CSIR-NML during 18-20 Dec 2024. This is the first time CSIR-NML has hosted the SSBMT Outdoor tournament.
- An international expert by the Serbian Science Fund to review the proposals submitted for funding in the area of waste utilization.
- Re-elected as Council Member of Indian Ceramic Society for the year 2025-27.
- Elected as a Member of the Editorial Board of Bulletin of Indian Institute of Ceramics for the year 2025-26.

Dr. Trilochan Mishra
Chief Scientist

- Editorial board member of Open Chemical Engineering Journal (Bentham Publisher).
- Member of Bureau of Indian Standards (BIS) for Inorganic Chemical Section Committee (CHD-1)
- Scientific Advisory member of "International Conference on Advances in Materials and Chemical Sciences (AMCS-24)" held at BIT, Mesra during 18-20th December

Dr. Raghuvir Singh
Chief Scientist

- Guest Editor of Transactions of the Indian Institute of Metals (TIIM): Special Issue on Corrosion & Coatings; May 2024
- Organized an International Conference on Corrosion & Coatings as a **Chairman** during Feb. 6-7 2025 at Hotel Vivanta, Jamshedpur.
- Organized an outreach program, as a **Chairman,** at Hotel Le ROI & MCRS Digha on 2nd Industrial Conclave on Maritime Corrosion Monitoring and Management (MCMM) during Feb. 28th, 2025

Dr. Gopi Kishore Mandal
Senior Principal Scientist

Chaired a technical session during an international conference on "ADVANCES IN PROCESSING TECHNOLOGY OF FLAT STEEL PRODUCTS (APT-FS 2024)" September 20-21, 2024 at Bokaro Steel City, Jharkhand, India.

Dr Manoj Kumar
Senior Principal Scientist

Editorial board member of Journal International Journal of Materials Science and Applications (http://www.ijmsa.org/editorial-board)' on 18 September 2024.

Dr. Abhilash
Senior Principal Scientist

- Editorial Board Member of Mineral Processing and Extractive Metallurgy Review (Taylor Francis)
- Editorial Board Member of Russian Journal of Nonferrous Metals (Springer)
- Editorial Board Member of Discover Applied Sciences (Springer)
- Editorial Board Member of Scientific Reports (Nature)
- Review Editor of Frontiers in Chemical Engineering
- Associate Editor of Frontiers in Microbiology- Geomicrobiology
- Academic Editor of International Journal of Analytical Chemistry (Wiley)
- Academic Editor of Journal of Chemistry (Wiley)
- Youth Editorial Committee Member of Journal of Central South University (Springer)
- Member of PEC DST-TDB, Govt of India
- Member of International Scientific Committee – International Biohydrometallurgy Council

Dr. Palash Poddar
Senior Principal Scientist

Convenor from CSIR-NML for Bureau of Indian Standards (BIS) for Magnesium and magnesium alloys- Magnesium alloy ingots and castings.

Dr. Pratima Meshram
Principal Scientist

- Editorial board member of International Journal of Chemical engineering (I.F.=2.12, SCI)
- Editorial board member of International Journal of Mineral Processing and Extractive Metallurgy
- Editorial board member of Austin Journal of Environmental Sciences

Dr. Shailendra Kumar Jha
Principal Scientist

- Member of the Board of Studies (BoS)
- Committee for Applied Sciences and Humanities in the Department of Applied Science and Humanities, National Institute of Advanced Manufacturing Technology (NIAMT) Ranchi (Formerly - National Institute of Foundry and Forge Technology (NIFFT)). Our task was to assist in the design and development of the course structure for the new M.Tech. program in Material Engineering (Nanotechnology) for the academic year 2024-25.

Dr. Pallab Bhattacharya
Principal Scientist

- Editorial Board Member of the journal Discover Materials of the prestigious Springer Nature publishing house.
- Reviewer of Springer Nature Journals 2024, Appreciation Received

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Share on social media: Showcase the great work you've done this year using the hashtag #SNreviewers, and follow and tag us @SpringerNature.

We look forward to working with you in 2025!

Dr. Kuldeep Singh Gour
Scientist

- Guest Editor for Book entitled "Advancements in Emerging Semiconductor Materials for Diverse Applications"; Journal: Materials, Publisher: MDPI
- Guest Editor for Book entitled "Emerging Photovoltaic Absorber Materials for Thin Film Solar Cells"; Journal: Frontiers in Electronics
- Editorial board member in the Journal Advances in Materials

Awards @ Various Celebrations 2024

CSIR Foundation Day (26th September 2024)

Essay Writing - Hindi
Shri. Anil Majhi (First), Shri. Arindam Sen (Second), Dr. Nikhil Kumar (Third)
Essay Writing - English
Miss. Prachi Kumari (First), Dr. Sreeda P. (Second) , Dr. Beena Kumari (Third)
Quiz
Shri. Kunal Bera & Shri. Somnath Das (First), Shri. Chandan Kumar Chowdhury & Shri. Ellife Kumbhar (Second) Shri. Purnendu Kumar & Shri. Ravi Kumar (Third)

Hindi Pakhwada Celebrations (1st - 14th September 2024)-Essay Writing	
Hindi Speaking	Non-Hindi Speaking
Dr. Nikhil Kumar (First)	Shri. Somnath Das (First)
Shri. Mrinal Kumar (Second)	Shri. Jiten Mahato (Second)
Shri. Vikas Kumar (Third)	Shri. Arindam Sen (Third)
Shri. Omprakash Mahato (Consolation)	Shri. Purnendu Kumar (Consolation)
Hindi Pakhwada Celebrations (1st - 14th September 2024)-Dictation Writing (Non-Hindi Speaking)	
Shri. Somnath Das (First) | Shri. Arindam Sen (Second) Shri. Omprakash Mahato (Third) | Shri. Nitish Kumar Bhakat (Consolation)	
Hindi Pakhwada Celebrations (1st - 14th September 2024)-Hindi Poetry Recitation (Hindi Speaking)	
Hindi Speaking	Non-Hindi Speaking
Shri. Abhishek Kumar Jha (First)	Ms. Sarita Kandeyong (First)
Shri. Jyoti Kumar (Second)	Shri. Nitish Kumar Bhakat (Second)
Ms. Chanchal Kumari (Third)	Mrs Gayatri Devi (Third)
Ms. Sneha Vishwakarma (Consolation)	Shri. C R Chakraborty (Consolation)

Glimpses of Awards Ceremony Hindi Pakhwada

Hindi Pakhwada Celebrations (1st - 14th September 2024)-Special Commendation Awards for working in Hindi during 2023-24.		
Shri. Parmarth Suman	Shri. Ravi Ranjan Kumar	Shri. Shekhar Sanga
Shri. Sudhir Kumar	Mr. Rohit Mudi	Shri. Rajiv Ranjan
Mohd. Naeemuddin Ansari	Shri. Jitendra Chowdhury	Shri. Vikas Kumar
Shri. Santosh Kumar Rai	Shri. Piyush Ranjan	Shri. Anjani Kumar Sahu
Shri. Anil Kumar	Shri. Sitaram Murmu	Shri. C.R. Chakravarty
Shri. Jyoti Kumar	Shri. Amit Prakash	Shri. Nandlal Paswan

CSIR Foundation Day (26th September 2024)-Essay Writing	
Hindi	English
Shri. Anil Majhi (First)	Miss. Prachi Kumari (First)
Shri. Arindam Sen (Second)	Dr. Sreeda P. (Second)
Dr. Nikhil Kumar (Third)	Dr. Beena Kumari (Third)

Vigilance Awareness (November 2024)-Essay Writing	
Hindi	English
Mr. Birbal Gope (First)	Dr. Sreeda P (First)
Mr. Somnath Das (Second)	Mr. Sivananda Acharya (Second)
Mr. Vikas Kumar (Third)	Miss Taniya Banerjee (Third)
Vigilance Awareness (November 2024)-Slogan Writing	
Hindi	English
Mr. Nitish Kumar Bhakat (First)	Mrs. Y. Usha (First)
Dr. Kuldeep Singh Gour (Second)	Mr. Purnendu Kumar (Second)
Mr. Somnath Das (Third)	Dr. Rachit Ghosh (Third)
Vigilance Awareness (November 2024)-Drawing	
Mr. Ellife Kumbhar (First)	Miss Sneha Vishwakarma (Second)
Miss Prachi Kumari (Third)	

Swacchata Pakhwada (1st – 15th May 2024)-Essay Writing /Hindi	
Hindi	English
Mr. Mrinal Aditya (First)	Mr. Chandan Kr Chowdhury (First)
Mr. Arindam Sen (Second)	Mr. Omprakash Mahato (Second)
Ms. Chanchal Kumari (Third)	Mr. Ellife Kumbhkar (Third)
Swacchta Pakhwada (7th May 2024)-Quiz Competition	
Dr. Satyajit Mukherjee and Dr.Animesh jana (First)	
Mr. Rajiv Ranjan Srivastava and Dr.Rachit Ghosh (Runner-up 1)	
Ms. Ellife Kumbhar and Mr.Krishna Kant (Runner-up 2)	
Swacchta Pakhwada (10th May 2024)-Extempore Competition	
Mr. Ved Prakash (First)	
Dr. Nikhil Kumar (Second)	
Dr. Satyajit Mukherjee and Dr. Suman Tewary (Third)	
Mrs. Pinky Patra (Consolation)	

Media Appearances of Researchers

IITM TECH TALK
Contributing to a better world
https://tech-talk.iitm.ac.in/recycling-lithium/

In order to recycle these batteries and extract metals including lithium, cobalt, nickel, and manganese, recycling processes such as pyrometallurgy, hydrometallurgy or a combination of them are explored globally. However, these methods either use strong acids or high temperature and costlier organic solvents which make them environmentally non-benign. Therefore, there is a need for a harmless, sustainable, and environment friendly way to extract metals from LIBs

Ionic liquids (ILs) seem to be an answer for an environment friendly, efficient, and harmless way to extract metals from spent LIBs. These liquids have more advantages in extraction over organic solvents because of their properties such as low vapour pressure, negligible toxicity, and they are also eco-friendly.

Ms. Richa V. Jaiswal | *Prof. Ramesh L. Gardas* | *Mr. C. Baiju* | *Dr. Pratima Meshram* | *Dr. Abhilash*

In this review, the authors Dr. Pratima Meshram, Ms. Richa V. Jaiswal, and Dr. Abhilash from the CSIR-National Metallurgical Laboratory, Jamshedpur, India, and Mr. C. Baiju and Prof. Ramesh L. Gardas from the Department of Chemistry, Indian Institute of Technology Madras, Chennai, India, have reviewed various ionic liquids, and their involvement in the separation of metals from spent lithium and nickel based batteries.

Horticulture Awards


Jigyasa
PROMOTING SCIENTIFIC TEMPER THROUGH STUDENT - SCIENTIST CONNECT PROGRAM
jigyasa program @ CSIR-NML
VIGYAN JYOTI
EMPOWERING GIRLS IN STEM

Intellectual Property Rights

Patent Applications Filed in India

S. No.	Title	Application No.	NFNO
1	Production of calcium carbide and ferrosilicon-phosphorus from basic oxygen furnace slag and method thereof	202411040869	0108NF2023/IN
2	A process for developing corrosion-resistant coating on biodegradable Mg-alloys for implant applications	202411048161	0075NF2024/IN
3	An energy-efficient process for ultrahigh-strength steel with excellent toughness	202411058888	0089NF2024/IN
4	Selective electrodeposition-oxidation process for recovery of copper and tungsten-oxide powder from hard tungsten-copper scrap	202511009629	0019NF2025/IN
5	Extraction of vanadium as high pure V2O5 from pet-coke/ coal gasification cinders and process thereof	202511014065	0036NF2025/IN

Complete After Provisional Filed in India

S.No.	Title	Application No.	NFNO
1	Advanced Zinc Alloy Coating and a Process Thereof	202411025006	0241NF2023/IN

Patents Granted in India

S. No.	Title	Application No.	NFNO	Patent No.
1	A process for the preparation of austempered high chrome bainitic cast iron for grinding media application	201811013971	0020NF2018/IN	531317
2	Heating Assembly II, Indian Application No: 201821038531 filed on 10 Oct 2018	201821038531	0195NF2018/IN	535494
3	A cost effective, on-line smart sensing system for defect detection and identification in high end wires drawn at high speed	201811036002	0073NF2018/IN	536000
4	A process for the recovery of gold from scrap parts of transmission and sophisticated electronic devices	202011004158	0092NF2019/IN	536275
5	A process for the selective extraction of europium (eu) and yttrium (y) from phosphor powder of obsolete fluorescent lamps	202011001812	0090NF2019/IN	537800

S. No.	Title	Application No.	NFNO	Patent No.
6	An improved suction casting assembly for the preparation of bulk metallic glass	2851DEL2014	0095NF2014/IN	543789
7	A process for hot stage modification of copper smelter slag for recovery of iron and subsequent use of slag in cement	202011001830	0091NF2019/IN	550143
8	A Process for recovering zinc dross as different grades of high-purity zinc sulphate salts	201811006332	0001NF2018/IN	558160
9	A process for the preparation of as-cast nanostructured Fe-based soft magnetic alloys with high saturation induction	201611011375	0009NF2016/IN	558417

Designs Filed or Registered

S. No.	Title	Application No	Registration No	Ref NO
1	Gripper-Feeder arrangement assembly to process wires/cables of varied diameters	404696-001	193903	019DN2023

Copyrights Filed or Registered

S. No.	Title	Ref NO
1	An e-Project Management System for In-house Projects Approval, Monitoring & Administration (CSIR-NML-IPSG)	035CR2024

Publication

SCI Publication

1. Abhilash; Shrivastava, SK; Rahman, MR; Meshram, Pratima, Red Mud Neutralisation by CO2 Promotes Alkali Recovery and Higher Scandium Extraction, WASTE AND BIOMASS VALORIZATION; 2024
2. Aldbea, FW; Vazquez, CV; Othman, UA; Sharma, A; Boukhachemd, A; Mailoude, OM; Kraini, M; Singh, PK, Structural and optical properties of Iodine doped zinc oxide nanoparticles, JOURNAL OF MATERIALS SCIENCE-MATERIALS IN ELECTRONICS; 2024
3. Alhozaimy, A; Hussain, RR; Al-Negheimish, A; Ahmed, M; Singh, DDN, Kinetics and mechanism of gallic acid as an ecofriendly corrosion inhibitor for steel rebars in mortar, SCIENTIFIC REPORTS, 2024
4. Ambashta, RD; Alex, TC; Singla, R; Sahoo, DP; Sarkar, PS; Bajpai, RK; Shivakumar, YC; Manohar, S; Kumar, S, Evaluation of Different Fly Ash-Blast Furnace Slag Formulations for Design of Geopolymers in Radioactivity Disposal Applications, TRANSACTIONS OF THE INDIAN CERAMIC SOCIETY; 2024
5. Ammasi, A; Karthik, PMR; Vishal, D, Slag-Metal- Refractory Interactions During Dissolution of Hydrogen-Based Directly Reduced Iron (H-DRI) in Liquid Iron Melt, JOURNAL OF SUSTAINABLE METALLURGY; 2024
6. Ammasi, A; Pal, J, Use of Additives as Internal Heat Sources in Hematite Ore Pellets- A Review, MINERAL PROCESSING AND EXTRACTIVE METALLURGY REVIEW; 2024
7. Austen, IC; Chennakesavulu, K; Reddy, GR; Vasumathi, N; Kumari, Ajita; Gharai, M; Kumar, TA; Vijaya Kumar, TV, Utilizing a sustainable surfactant from Cucurbita pepo seeds for eco-friendly flotation of non-coking coal in sustainable energy applications, BIOMASS CONVERSION AND BIOREFINERY; 2024
8. Bagui, Sumanta; Singh, Chandra Veer; Sahoo, Biraj Kumar; Mandal, Monalisa; Naveena; Tarafder, Soumitra; Sivaprasad, S., Effect of hold-type on cyclic life and microstructural evolution of an austenitic stainless steel, MATERIALIA; 2024
9. Balusamy, T; Sathyaraj, PM; Ravichandran, K; Narayanan, TSNS, Influence of Surface Mechanical Attrition Treatment Parameters on the Residual Stress of EN8 Steel, JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE ; 2024
10. Banerjee, R; Chakladar, S; Chattopadhyay, SK; Chakravarty, Sanchita, A comparative study on the association and extractability of rare earth elements from laboratory ash, bottom ash, fly ash: A perspective on Indian coals, MINERALS ENGINEERING; 2024
11. Banerjee, R; Chakladar, S; Kumar, Alok; Chattopadhyay, SK; Chakravarty, Sanchita, Petrology and Association of Rare Earth Elements in magmatically altered high ash coal of Indian origin, INTERNATIONAL JOURNAL OF COAL SCIENCE AND TECHNOLOGY; 2024
12. Banerjee, T; Kundu, Rajen, Mini-Review on Organic Electrode Materials: Recent Breakthroughs and Advancement in Metal Ion Batteries, ENERGY & FUELS; 2024
13. Banerjee, T; Kundu, Rajen, Outlook of Solid-State Electrolytes: A Boost in Next-Generation Li-Metal-Based Solid-State Batteries, ENERGY & FUELS; 2024
14. Bawkar, Shilpa Kalamani; Parween, Rukshana; Yoo, Kyoungkeun; Singh, Pramod Kumar; Jyothi, Rajesh Kumar; Jha, Manis Kumar, Sustainable environmental technology to reclaim copper from industrial effluent, GEOSYSTEM ENGINEERING; 2024
15. Belwanshi, V; Sehra, K; Aryan; Dixit, A; Kasturi, P; Saxena, M, Degradation Mechanism of Piezoresistive Sensors Under the Influence of γ-Ray Irradiation, IEEE SENSORS JOURNAL; 2024

16. Bhattacharya, A; Barik, RK; Ghosh, A; Patra, S; Sen, M; Das, A; Mitra, R; Chakrabarti, D, Relative influence of microsegregation and structural unit size on the strength-impact toughness properties of an armor grade steel, MATERIALS SCIENCE AND ENGINEERING A; 2024

17. Bhattacharya, A; Biswal, S; Barik, RK; Mahato, B; Ghosh, M; Mitra, R; Chakrabarti, D, Comparative interplay of C and Mn on austenite stabilization and low temperature impact toughness of low C medium Mn steels, MATERIALS CHARACTERIZATION; 2024

18. Bora, DK; Ghosh, D; Jana, A; Nagarale, RK; Panda, Asit Baran, γ-FeOOH Nanosheet with Enormous Cationic Defect: Efficient and Durable Bifunctional Electrocatalyst Suitable for an Industrial-Scale AEM Electrolyzer, ACS APPLIED ENGINEERING MATERIALS; 2024

19. Chakladar, S; Kumari, S; Kumar, A; Mohanty, A; Chakravarty, S; Kolker, A, Distribution of trace elements and rare earth elements in coal from the Bhalukasba Surni coal block, Rajmahal coalfield, Eastern India, INTERNATIONAL JOURNAL OF COAL SCIENCE AND TECHNOLOGY; 2024

20. Chakraborty, J; Sanket, K; Srikar, S; Nambissan, PMG; Chandan, AK; Jena, PSM; Sinha, S; Dwarapudi, S, Lattice distortion in nanocrystalline Fe powder studied by positron annihilation and X-ray diffraction, PHILOSOPHICAL MAGAZINE; 2024

21. Chakravarty, K; Mondal, S; Kundu, Rajen, Improving the Energy Efficiency in a Walking Hearth Type Reheating Furnace by Energy Balance Method and Optimizing the Resources, MEASUREMENT ENERGY; 2024

22. Chandel, SS; Randhawa, NS; Singh, PK, Enhancing Recycling Potential: Exploring Reduction and Metal Separation Behavior of Iron-Rich Slag in Electric Arc Furnace Smelting for a Sustainable Future, JOURNAL OF SUSTAINABLE METALLURGY; 2024

23. Chaurasia, PK; Barik, BK; Das, A; Goecke, SF; De, A, Probing dimensional consistency during multi-track multi-layer gas metal arc directed energy deposition of aluminium alloys, WELDING IN THE WORLD; 2024

24. Choudhary, C; Bar, HN; Arif, SMD; Sahoo, KL; Mandal, D, Effect of Structural Refinement and Modification on the Mechanical Properties of Al-7Si Alloy, JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE; 2024

25. Choudhury, ASR; Kumar, S; Gupta, N; Jana, A; Bhattacharya, P, Mechanochemically Assisted Microwave-Induced Plasma Synthesis of a N-Doped Graphitic Porous Carbon-Based Aqueous Symmetric Supercapacitor with Ultrahigh Volumetric Capacitance and Energy Density, ACS APPLIED ELECTRONIC MATERIALS; 2024

26. Dak, G; Guguloth, K; Vidyarthy, RS; Fydrych, D; Pandey, C, Creep rupture study of dissimilar welded joints of P92 and 304L steels, WELDING IN THE WORLD; 2024

27. Das Chakraborty, S; Kumar, U; Bhattacharya, P; Mishra, T, Tailoring of Visible to Near-Infrared Active 2D MXene with Defect-Enriched Titania-Based Heterojunction Photocatalyst for Green H2 Generation, ACS APPLIED MATERIALS & INTERFACES; 2024

28. Das, A; Jana, A; Das, D; Biswas, S; Seshadri, H; Rao, M; De, S, Efficient Adsorption and Desorption of Uranium(VI) Using a Polymeric Adsorbent: A Combined Theoretical and Experimental Approach with Real-Life Alkaline Leach Liquor, INDUSTRIAL & ENGINEERING CHEMISTRY RESEARCH; 2024

29. Das, S; Mahato, DK; Panda, AK, Impact of thermally induced stress gradient on magneto-impedance sensitivity of As-quenched and Joule annealed microwires, JOURNAL OF MAGNETISM AND MAGNETIC MATERIALS; 2024

30. Das, Somnath; Debbarma, Jacob; Mondal, Avijit; Murugaiyan, Premkumar; Roy, Rajat K.; Panda, Ashis K., Evaluation of Shot Peened SS 347 Tubes Through a Magnetostrictive Sensing (MsS) Device, JOURNAL OF SUPERCONDUCTIVITY AND NOVEL MAGNETISM; 2024

31. Das, T; Kumar, BR; Sahoo, BK; Roy, H; Lohar, AK; Samanta, SK; Ghosh, K, Implementation of different scanning strategy to improve the mechanical and wear properties of 15-5 PH stainless steel fabricated by laser-directed energy deposition, MATERIALS TODAY COMMUNICATIONS; 2024

32. Dey, I; Saha, R; Mahato, B; Ghosh, M; Ghosh, SK, Effect of Quenching and Partitioning on Microstructure and Mechanical Properties of High-Carbon Nb Microalloyed Steel, METALLURGICAL AND MATERIALS TRANSACTIONS A; 2024

33. Dipali; Krishna, R; Ghosh, S; Sahu, SK; Sinha, S; Prasad, R, An experimental investigation and predictive modeling using machine learning technique for reclamation of metal values from scrap NdFeB magnets, JOURNAL OF INDUSTRIAL AND ENGINEERING CHEMISTRY; 2024

34. Gaikwad, MA; Burungale, VV; Gavali, DS; Malavekar, DB; Park, SW; Zheng, F; Jang, S; Gour, Kuldeep Singh; Cruz, MRA; Kim, JH, Solar-driven methanol to formate conversion coupled with energy-efficient hydrogen production through Cr dopant-induced charge transfer modulation at the in-situ formed FeOOH/FeCo-LDHs interface, CHEMICAL ENGINEERING JOURNAL; 2024

35. Gautam, P; De, AK; Rao, Mudila D; Sinha, I; Behera, CK; Singh, KK, Waste remediation: Low-temperature synthesis of hybrid Cu(OH)(2)/CuO and CuO nanostructures from spent printed circuit boards and their dye degradation studies, ENVIRONMENTAL SCIENCE AND POLLUTION RESEARCH; 2024

36. Ghosh, D; Bora, DK; Panda, Asit Baran, Enhanced electrocatalytic overall alkaline water splitting induced by interfacial electron coupling of Mn3O4 nano-cube@ CeO2/γ-FeOOH nanosheet hetero-structure, JOURNAL OF MATERIALS CHEMISTRY A; 2024

37. Gotgi, NM; Singh, RJ; Giri, AK; Panda, Asit Baran; Ghosh, D., ZnO Nanorod: An Efficient Reusable Catalyst for One-pot Multicomponent C– C Bond Formation Reactions Involving Isatins, ASIAN JOURNAL OF ORGANIC CHEMISTRY; 2024

38. Gour, Kuldeep Singh; Pawar, PS; Lee, M; Karade, VC; Yun, JS; Heo, J; Park, J; Yun, JH; Kim, JH, Fostering Charge Carrier Transport and Absorber Growth Properties in CZTSSe Thin Films with an ALD-SnO2 Capping Layer, ACS APPLIED MATERIALS & INTERFACES; 2024

39. Greifzu, G; Alex, TC; Kailath, AJ; Senna, M; Stelter, M; Kumar, R, Influence of Genesis on Mechanochemical Activation and Reactivity of Boehmite Prepared by Thermal and Hydrothermal Transformation of Gibbsite, METALLURGICAL AND MATERIALS TRANSACTIONS B; 2024

40. Grubert, E; Lazaro, LLB; Merfort, L; Popp, A; Luo, TY; Kati, V; Meshram, Pratima; Dorn, FM; Hernández, D, Making low-carbon energy sustainable, ONE EARTH; 2024

41. Gupta, A; Kumar, R; Kaushik, L; Shukla, S; Tandon, V; Choi, SH, Microstructure and Texture Evolution in Thermomechanically Processed FCC Metals and Alloys: a Review, KOREAN JOURNAL OF METALS AND MATERIALS; 2024

42. Gupta, N; Samajdar, S; Ghosh, S; Bhattacharya, P, Development of octahedral shaped Zn2TiO4 loaded Ti3C2-TiO2 ternary composite with excellent photocatalytic efficiency, INORGANIC CHEMISTRY COMMUNICATIONS; 2024

43. Haldar, N; Anand, S; Datta, S; Das, A, On Fabrication of Inconel 718 Slab by Wire Arc Additive Manufacturing: Study of Built Microstructure and Mechanical Properties, ARABIAN JOURNAL FOR SCIENCE AND ENGINEERING; 2024

44. Husain, Md Murtuja; Rajinikanth, V.; Munda, Parikshit, Metallurgical Failure Analysis of Economizer Tube of Thermal Power Plant, JOURNAL OF FAILURE ANALYSIS AND PREVENTION; 2024

45. Hussain, RR; Alhozaimy, A; Al-Negheimish, A; Singh, DDN; Ahmed, M, Synergistic protection of borate and silicate salts composite for controlling the chloride-induced pitting and uniform corrosion of steel reinforcement bars embedded in mortars, SCIENTIFIC REPORTS; 2024

46. Hussain, RR; Alhozaimy, A; Al-Negheimish, A; Singh, DDN; Ahmed, M, Synergistic effect of benzo triazole with polyethoxylated sorbitan monooleate in inhibiting corrosion of rebars and chloride diffusion through mortars, SCIENTIFIC REPORTS; 2024

47. Jayaraj, J; Srinivasan, A; Arunchandran, C; Rajinikanth, V, Corrosion and in vitro characteristics of cerium phosphate based chemical conversion coating on AZ31 magnesium alloy, APPLIED SURFACE SCIENCE; 2024

48. Jena, PSM; Sahu, JK; Tripathy, S; Pradhan, SK; Mahato, B; Paulose, N; Influence of texture on anomalous yielding behavior of thermomechanically processed nickel-based superalloy 720Li; ACTA MATERIALIA; 2024

49. Jha, A; Chakladar, S; Patra, D; Chakravarty, Sanchita, Study of mineralogy and distribution of rare earth elements in coal block of Eastern Coalfield, India, INTERNATIONAL JOURNAL OF COAL PREPARATION AND UTILIZATION; 2024

50. Jha, SK; Kumari, A; Modalavalasa, UBR; Singh, SK, Nanostructure-induced inhibition of oxygen evolution and enhancement of methanol electrooxidation on engineered anodized brass, INTERNATIONAL JOURNAL OF HYDROGEN ENERGY; 2024

51. Jyothilakshmi, S; Meshram, Pratima; Abhilash; Lee, YS; Aravindan, V, Graphite from Dead Li-Ion Batteries: A Powerful Additive for Fabrication of High-Performance Li-Ion Capacitors, ADVANCED MATERIALS TECHNOLOGIES; 2024

52. Kalshyan, Raj Kumar; Mohanasundaram, Madan; Chowdhury, Golap Mohammad; Ghorai, Satadal, Synthesis of calcium ferrite using microwave susceptor heating, CANADIAN METALLURGICAL QUARTERLY; 2024

53. Kancharla, H; Mandal, GK; Pradeep, KG; Singh, SS; Mondal, K, Understanding the Formation Mechanism of Al-Rich Interfacial Layer during Galvanizing of Cu Pre-coated High-Strength Steel Sheet, JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE; 2024

54. Kancharla, H; Mandal, GK; Prasad, NK; Vishwanath, K; Bhushan, B; Godbole, K; Singh, SS; Mondal, K, Effect of inter-critical annealing atmosphere on microstructure and subsequent corrosion behavior of hot-dip galvanized Mn containing high-strength steel, JOURNAL OF APPLIED ELECTROCHEMISTRY; 2024

55. Kar, S; Bagui, S; Mahato, B; Srivastava, VC; Mandal, GK, Coarsening Behaviour of γ' Precipitates in High Fe Containing Ni-Fe-Cr-Based Medium Entropy Alloy, METALLURGICAL AND MATERIALS TRANSACTIONS A; 2024

56. Kar, S; Shivam, V; Srivastava, VC; Mandal, GK, Achieving Exceptional Strength-Ductility Synergy via Nano-precipitation Hardening in a Ni-Fe-Cr-Co-Al Alloy, METALLURGICAL AND MATERIALS TRANSACTIONS A; 2024

57. Kar, Shubhada; Meena, LK; Srivastava, VC; Mandal, GK, Microstructural, Mechanical, And Corrosion Behaviour of Ni-Fe-Cr-Al and Ni-Fe-Cr-Al-Co Alloys, TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS; 2024

58. Kumar, A; Banerjee, R; Mustapha, KA; Chakladar, S; Lotfy, NM; Singh, VP; Mathews, RP; Singh, PK, Mineralogical compositions and distributions of trace and rare earth elements in Eocene carbonaceous sediments of Western India: implications for paleoenvironment during peat accumulation, ENVIRONMENTAL EARTH SCIENCES; 2024

59. Kumar, A; Guguloth, K; Pandey, C, Creep rupture properties of dissimilar welded joint of ferritic/martensitic P92 steel and Inconel 617 alloy, ENGINEERING FAILURE ANALYSIS; 2024

60. Kumar, A; Kumar, S; Kumar, A, Structural phase transformation in single-crystal Fe-Cr-Ni alloy during creep deformation using molecular dynamics simulation and regression-based machine learning methodology, BULLETIN OF MATERIALS SCIENCE; 2024

61. Kumar, A; Singh, VP; Mallik, A; Sahoo, BK; Singh, RC; Chaudhary, R, The utilization of agricultural and industrial waste in the synthesis of AA7075-based novel lightweight composite, JOURNAL OF MATERIALS SCIENCE; 2024

62. Kumar, K; Kumar, S; Sen, A; Mediboyana, H; Bag, SS; Kundu, Rajen, Utilizing Cold Rolling Mill Iron Oxide To Synthesize Lithium Iron Phosphate for Li-Ion Batteries, ACS SUSTAINABLE RESOURCE MANAGEMENT; 2024

63. Kumar, K; Kundu, Rajen, Empowering Energy Storage Technology: Recent Breakthroughs and Advancement in Sodium-Ion Batteries, ACS APPLIED ENERGY MATERIALS; 2024

64. Kumar, K; Kundu, Rajen, Doping Engineering in Electrode Material for Boosting the Performance of Sodium Ion Batteries, ACS APPLIED MATERIALS & INTERFACES; 2024

65. Kumar, K; Sen, A.; Das, B; Kumar, S; Chakravarty, Sanchita; Kundu, Rajen, Coal Derived Highly Fluorescent N-Doped Graphene Quantum Dots with Graphitic and Chemisorbed Nitrogen, MATERIALS RESEARCH BULLETIN; 2024

66. Kumar, Manoj; Rani, Sanju; Gour, Kuldeep Singh; Kumar, Kapil; Yadav, Reena; Husale, Sudhir; Kumar, Mahesh; Singh, Vidya Nand, Detrapping of the carriers from shallow states in a highly responsive, fast, broadband (UV-vis-NIR), self-powered SnSe/Si photodetector with asymmetric metal electrodes, MATERIALS ADVANCES; 2024

67. Kumar, MK; Ranjan, R; Jha, SK, Tailoring rGO-Cu-Cu2O as a three-dimensional catalytic system in boosting of methanol electro-oxidation reaction, ELECTROCHIMICA ACTA; 2024

68. Kumar, Nikhil; Gour, Kuldeep Singh; Haider, Arsalan; Kumar, Ravan; Park, Sungjin, Nanoporous Metal–Organic Frameworks for Electroreduction of Nitrogen and Carbon Dioxide: A Review, ACS APPLIED NANO MATERIALS; 2024

69. Kumar, P; Tyeb, MH; Mishra, S; Chakravarty, Sanchita; Majumder, AK, Limitations Associated with Proximate Analysis-Based Gross Calorific Value Modeling for Coals, MINERAL PROCESSING AND EXTRACTIVE METALLURGY REVIEW ; 2024

70. Kumar, R; Chandan, AK; Bansal, GK; Sharma, SK; Madhavi, K, Optimizing Microstructure and Mechanical Properties of Cold-Rolled Medium-Mn Steel Through Intercritical Annealing and Warm Rolling, JOM; 2024

71. Kumar, R; Kumar, S; Kailath, AJ; Sahu, RK, Mechanistic investigation of hydrogen generation from water and magnesium catalyst reaction: Advanced reactive molecular dynamics simulation, INTERNATIONAL JOURNAL OF HYDROGEN ENERGY; 2024

72. Kumar, R; Kumar, S; Sahu, RK; Kailath, AJ, Atomic Investigation of Corrosion Mechanism and Surface Degradation of Fe-Cr-Ni Alloy in Presence of Water: Advance Reactive Molecular Dynamics Simulation, TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS, 2024

73. Kumar, Rahul; Jha, Prashant Kumar; Kishore, Raj; Singh, Ranjeet Kumar; Subrahmanyam, TVS; Chaurasiya, SK; Mangipudi, Kodanda Ram; Sahu, Kisor Kumar, Analysing the flow of wet iron ore in an industrial transfer chute using discrete element method, MINERAL PROCESSING AND EXTRACTIVE METALLURGY ;2024

74. Kumar, S; Chakravarty, K; Kumar, K; Sen, A; Ghanty, C; Chakravarty, Sanchita; Kundu, Rajen, Solid-State Direct Regeneration of Spent Lithium Cobalt Oxide Cathodes for Li-Ion Batteries, ENERGY & FUELS; 2024

75. Kumar, S; Patra, A; Sahu, JK, Dislocation density-based constitutive model for cyclic deformation and softening of Ni-based superalloys, FATIGUE & FRACTURE OF ENGINEERING MATERIALS & STRUCTURES; 2024

76. Kumar, S; Sahu, RK, Fe-Al core-shell structure as an efficient catalyst for dual hydrogen production and storage by thermochemical water splitting: A reactive molecular dynamic simulation, INTERNATIONAL JOURNAL OF HYDROGEN ENERGY; 2024

77. Kumar, Santosh; Mandal, G.K.; Mukherjee, K., "Stretch Flangeability of Low Carbon Micro-alloyed Ferrite-Pearlite and Ferrite-Bainite Steel", METALLURGICAL AND MATERIALS TRANSACTIONS A; 2024

78. Kumari, P; Kundu, R, Zinc-Ion Batteries: Promise and Challenges for Exploring the Post-Lithium Battery Materials, ACS APPLIED ENERGY MATERIALS,; 2024

79. Kumari, S; Panda, R; Prasad, R; Alorro, RD; Jha, MK, Sustainable Process to Recover Metals from Waste PCBs Using Physical Pre-Treatment and Hydrometallurgical Techniques, SUSTAINABILITY; 2024

80. Kumari, Suruchi; Panda, Rekha; Bawkar, Shilpa Kalamani; Hait, Jhumki; Yoo, Kyoungkeun; Prasad, Ranjit; Jha, Manis Kumar, Hydrometallurgical recovery of copper from the leach liquor of waste PCBs, GEOSYSTEM ENGINEERING; 2024

81. Mahato, Vikash; Kumar, Sudip; Sen, Arindam; Ali, Syed Md Burhan; Ghanty, Chandan; Kundu, Rajen, Investigation of Capacity Fading Mechanism on Nanocrystalline LiNi0.5Mn0.5O2 Synthesized by Autocombustion Technique, CHEMISTRY AFRICA; 2024

82. Mani, M; Kadam, GG; Konwar, LJ; Panda, AB, Ru-supported mesoporous melamine polymers as efficient catalysts for selective hydrogenation of aqueous 5-hydroxymethylfurfural to 2,5-bis-(hydroxymethyl) furan, BIOMASS CONVERSION AND BIOREFINERY; 2024

83. Mani, M; Mariyaselvakumar, M; Tothadi, S; Panda, AB; Srinivasan, K; Konwar, LJ, MOLECULAR CATALYSIS; 2024

84. Manjunath, K; Tewary, S; Khatri, N; Cheng, K, In-process monitoring of the ultraprecision machining process with convolution neural networks, INTERNATIONAL JOURNAL OF COMPUTER INTEGRATED MANUFACTURING; 2024

85. Meena, LK; Gorja, SR; Bhardwaj, A; Singh, R, Sour Service Domains of 13Cr Martensitic Stainless Steels: A Review of State-of-Art Knowledge vis-à-vis ANSI/NACE MR0175/ISO 15156, TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS; 2024

86. Meena, LK; Madan, M; Chaudhari, GP; Singh, R, Flow-Assisted Corrosion of API 5L X56 Steel: Effect of Flow Velocity and Dissolved Oxygen, TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS; 2024

87. Meshram, Pratima; Jaiswal, RV; Abhilash; Baiju, C; Gardas, RL, An emerging trend of ionic liquids in the separation of critical metals from spent lithium and nickel based batteries, JOURNAL OF MOLECULAR LIQUIDS; 2024

88. Meshram, Rohit B.; Sahoo, KL; Yadav, GD; Marathe, KV, Production and recycling of blast furnace slag: A life cycle assessment approach in India, ENVIRONMENTAL PROGRESS & SUSTAINABLE ENERGY; 2024

89. Meshram, Rohit B.; Yadav, GD; Marathe, KV; Sahoo, KL, Evaluating the carbon footprint of sulphur recovery unit: A comprehensive analysis, JOURNAL OF ENVIRONMENTAL CHEMICAL ENGINEERING; 2024

90. "Meshram, Rohit B; Kumar, Om Prakash; Dhopte, Shilpa; Singla, Rashmi; Nath, Susanta K.; Kumar, Sanjay" Analysing Mechanical and Environmental Characteristics of porous Geopolymer Developed From Industrial Waste, SPECIAL TOPICS & REVIEWS IN POROUS MEDIA: AN INTERNATIONAL JOURNAL; 2024

91. Mishra, G.; Bhatt, M.K.; Anand, Kumar Aniket; Biswal, Sankalp; Hasan, Sk. Md.; Bagui, S.; Ammasi, A.; Samanta, Santigopal; Ghosh, A.; Karmakar, A.; Patra, S., "Strength and toughness balance in 7 %Ni steel by formation epsilonmartensite, retained austenite and Low matrix strain", MATERIALIA; 2024

92. Modalavalasa, Uday Bhaskar Rao; Jana, A; Murugaiyan, P; Krishna, KG; Saket, RK, Cathodic corrosion induced selective nano-crystallization of Nickel oxo/ hydroxo complex on (NiFeCr)SiB amorphous ribbon for alkaline oxygen evolution reaction and methanol oxidation reaction, INTERNATIONAL JOURNAL OF HYDROGEN ENERGY; 2024

93. Mohanty, PK; Jayanthu, S; Chakladar, S; Chakravarty, Sanchita, An investigation into the effect of various parameters on oil agglomeration process of coal fines, INTERNATIONAL JOURNAL OF COAL PREPARATION AND UTILIZATION; 2024

94. Mohanty, PK; Jayanthu, S; Sahu, SP; Chakladar, S, Determinant analysis of oil agglomeration of coal fines using multiple regression and neural network models, INTERNATIONAL JOURNAL OF COAL PREPARATION AND UTILIZATION; 2024

95. Munda, Parikshit; Husain, Md Murtuja; Singh, C.S.; Rajinikanth, V., Sulfidation Corrosion Failure of a Boiler Tube in a Fossil Fuel-Based Thermal Power Plant, JOURNAL OF FAILURE ANALYSIS AND PREVENTION; 2024

96. Murugaiyan, P; Mitra, A; Das, S; Kamaraj, A; Roy, RK; Panda, AK, Influence of Tensile Stress Annealing on Soft Magnetic and Core Loss Properties of Nanocrystalline Fe83Si2B9P4Nb1Cu1 Alloy, JOURNAL OF SUPERCONDUCTIVITY AND NOVEL MAGNETISM; 2024

97. Nana, Achile; Alomayri, T; Tome, S; Nath, S; Kamseu, E; Bignozzi, MC; Leonelli, C; Kumar, S, Reaction kinetics and microstructure of pegmatite-based geopolymer composites: influence of calcined clay nature, JOURNAL OF THE AMERICAN CERAMIC SOCIETY; 2024

98. Nana, Achile; Tchummegne, IK; Tome, S; Adesina, A; Alomayri, T; Singla, Rashmi; Kaze, R; Kamseu, E; Kumar, Sanjay; Leonelli, C , Comparison of feldspar and meta-halloysite geopolymers by alkaline and acidic activation, CONSTRUCTION AND BUILDING MATERIALS; 2024

99. Nandi, S; Manikandan, M; Arivazhagan, N; Rajinikanth, V; Chowdhury, SG, A Quantitative Approach to Precipitate Characterization in Wire Arc Additive Manufactured Inconel 600 Series Alloys, JOM; 2024

100. Nath, P; Bar, HN; Bhattacharjee, A; Sen, I, Designing of novel microstructure and its impact on the improved service temperature mechanical performance of 2nd and 3rd generation advanced intermetallic TiAl alloys, MATERIALS SCIENCE AND ENGINEERING A; 2024

101. Nath, SK; Meshram, Rohit B, Influence of Mechanically Activated Silico-Manganese Slag on Hydration and Properties Development of Blended Cement, TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS; 2024

102. Navaneeth, A; Sreeda, P; Maya, TMV; Surendran, U; Harikumar, PS, Unlocking sustainable groundwater governance in secondary cities: Lessons from the assessment of groundwater vulnerability in a Coastal City of India, URBAN CLIMATE; 2024

103. Ngomade, SBL; Bhonsle, AK; Rawat, N; Kuete, HIT; Nana, A; Nche, GNA; Anagho, SG; Atray, N, Biodiesel Production From High-free Fatty Acids Podocarpus falcatus Oil and Identification of Fatty Acid Methyl Esters by FT-IR, NMR (1H and 13C) and GC/MS Studies, IRANIAN JOURNAL OF SCIENCE; 2024

104. Pal, J; Ammasi, A; Bandyopadhyay, BS; Dwarapudi, S; Paul, I, An innovative approach to replace bentonite in hematite ore pelletizing with organic binder, MINERAL PROCESSING AND EXTRACTIVE METALLURGY REVIEW; 2024

105. Pal, PP; Mahato, JK; Gupta, SK; Chakravarty, Sanchita, Investigation on modified Linz-Donawitz slag for the treatment of Pb2+ion-laden wastewater - A slag utilization sustainable approach, PHYSICS AND CHEMISTRY OF THE EARTH; 2024

106. Pandey, R; Gupta, G; Pani, SK; Godwal, U; Jain, J; Karagadde, S; Chowdhury, SG; Singh, SS, Evolution of 3D microstructure and correlation with deformation behavior of as-cast Mg-4Zn-xCa alloys, MATERIALS LETTERS; 2024

107. Paswan, S; Meena, LK; Guguloth, K; Shariff, SM; Singh, R, Oxidation and Hot Corrosion Studies of Laser Hybrid Welded IN617 and P91 Alloys, TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS; 2024

108. Polimera, S; Gali, A; Rahaman, A; Chandan, MR; Balakumaran, SJ; Nath, SK, Thermo-mechanical property enhancement of rigid polyurethane foam composite using low cost, environment friendly fly ash over silica particles, JOURNAL OF VINYL & ADDITIVE TECHNOLOGY; 2024

109. Pradhan, SK; Jena, PSM; Chaithanya, PVS; Singh, R, Enhancement of Molten Salt Corrosion Resistance of Ni-Based Superalloy Through Adding Inhibitor, TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS; 2024

110. Pratihar, B; Jana, A; De, AK; De, S, 2D Boron Nanosheets for Photo- and Electrocatalytic Applications, CHEMCATCHEM; 2024

111. Pratihar, B; Roy, O; Jana, A; De, SRD, Mixed-valent cobalt phosphate/borophene nanohybrids for efficient electrocatalytic oxygen evolution reaction, JOURNAL OF COLLOID AND INTERFACE SCIENCE, 2024

112. Rahman, A; Husain, MM; Prasad, N, Microstructural and mechanical properties evaluation of Calcium and zinc-modified WE43-based nanocomposites through stir casting for biodegradable applications, CERAMICS INTERNATIONAL; 2024

113. Rahman, Abdul; Prasad, Naresh; Husain, Md Murtuja; Haque, Md Ramjanul, Nanocomposites of Magnesium Metal Matrices with Potential Medicinal Uses: A Review, TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS; 2024

114. Rai, RK; Chandra, S; Sahoo, BK; Paulose, N, Role of micro-constituents on the fatigue deformation micro-mechanisms of IN 713 C alloy, FATIGUE & FRACTURE OF ENGINEERING MATERIALS & STRUCTURES; 2024

115. Rai, RK; Paulose, N; Sahu, JK, The effects of microstructure and temperature on the deformation heterogeneities and fatigue behaviour of a Ni-based superalloy, PHILOSOPHICAL MAGAZINE, 2024

116. Rai, RK; Sahu, VK; Pradhan, SK; Rajinikanth, V; Sahoo, BK; Maji, P; Tripathy, S; Chowdhury, SG, On the influence of austenite content in orientation selectivity and shear texture evolution during hot rolling of Fe-3 wt% Si grain-oriented electrical steel, MATERIALS CHARACTERIZATION; 2024

117. Raji, MA; Baba, AA; Abhilash; Gangwar, A; Majasan, JO, Optimization of the Leaching Kinetics for Uranium Recovery from a Boltwoodite Ore as Emerging Solution to Nigerian Power Sector, JOURNAL OF SUSTAINABLE METALLURGY; 2024

118. Raji, MA; Baba, AA; Adekola, FA, Dissolution kinetics and thermodynamics of uranium from a boltwoodite ore for nuclear fuel cycle application, JOURNAL OF RADIOANALYTICAL AND NUCLEAR CHEMISTRY; 2024

119. Rajkamal, A; Sharma, Ankur; Pullagura, BK; Thapa, R; Kim, H, Engineering lithium nickel cobalt manganese oxides cathodes: A computational and experimental approach to bridging gaps, CHEMICAL ENGINEERING JOURNAL; 2024

120. Ramesh, Surla; Gautam, SK; Roy, H; Lohar, AK; Samanta, SK; Anand, A; Mukherjee, D; Kumar, S, Structure Property Correlation of Gravity Die-Cast and Rheocast Al-Mg-Sc-Zr in situ Nano-TiB2 Composite, INTERNATIONAL JOURNAL OF METALCASTING; 2024

121. Rizwee, Mumtaz; Kumar, Deepak; Husain, Md Murtuja, Enhancing the tribological characteristics of the biocompatible Ti-6Al-4 V alloy via heat treatment: An experimental analysis, JOURNAL OF TRIBOLOGY INTERNATIONAL; 2024

122. Rout, S; Abhilash; Meshram, Pratima; Zhang, PT, A Comprehensive Review on Occurrence and Processing of Phosphate Rock Based Resources- Focus on REEs; MINERAL PROCESSING AND EXTRACTIVE METALLURGY REVIEW; 2024

123. Roy, Rajat K.; Murugaiyan, Premkumar; Panda, AK, Evaluation of Post-Weld Heat-Treated 2.25Cr-1Mo Steel Joint Behaviors by Electromagnetic NDE Parameters, JOURNAL OF SUPERCONDUCTIVITY AND NOVEL MAGNETISM; 2024

124. Sahoo, SK; Tripathy, SK; Nayak, A; Hembrom, KC; Dey, S; Rath, RK; Mohanta, MK, Beneficiation of lithium bearing pegmatite rock: a review, MINERAL PROCESSING AND EXTRACTIVE METALLURGY REVIEW; 2024

125. Sahu, M; Ghosh, A; Dutta, C; Kumar, J; Sagar, SP, Creep strain prediction in power plant material via ANN modelling of nonlinear ultrasonic test results, NONDESTRUCTIVE TESTING AND EVALUATION; 2024

126. Sahu, M; Ghosh, A; Kumar, J; Singh, SN; Sagar, SP, Probability Analysis in Predicting Creep Life of Power Plant Material Using High Power Ultrasound, JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE; 2024

127. Sahu, N; Kapure, GU; Kumar, P; Tripathy, SK; Biswas, A; Randhawa, NS; Paliwal, M, Value Extraction from Ferrochrome Slag: A Thermochemical Equilibrium Calculation and Experimental Approach, MINERALS; 2024

128. Saleem, S; Mohanasundaram, M; Kapure, GU; Murthy, YR, An Insight into the Pre-reduction Mechanism of Manganese Ores Using Elemental Sulfur for Ferromanganese Production, METALLURGICAL AND MATERIALS TRANSACTIONS B; 2024

129. Salot, M; Santhy, K; Pramanick, AK; Rajasekaran, B; Awasthi, G; Singh, SG; Chaudhury, SK, Effect of microwave treatment on structural characteristics and energy bandgap of electrochemically synthesized hydrated tungsten oxide quantum dots; CERAMICS INTERNATIONAL; 2024

130. Sankar, TK; Abhilash; Meshram, Pratima, Environmental Impact Assessment in the Entire Life Cycle of Lithium-Ion Batteries, REVIEWS OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY; 2024

131. "Sen, Arindam; Kundu, Rajen; Upadhyay, Arvind Kumar; Soni, Savita; Chakravarty, Sanchita", Preparation and Certification of Benzoic Acid Reference Material for Calorimetry Analysis, MEASUREMENT ENERGY, 2024

132. Sharan, Bipin B.; Chand, P; Shanmugam, NS; Krishna, Kurapati Gopala, Effect of Weld Line Energy on Mechanical Properties and Formability of Cold Metal Transfer-Welded Dissimilar DP600-780 Thin Sheets, JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE; 2024

133. Sharma, S; Sharma, P; Singh, V; Vaishali; Vashistha, VK; Das, DK; Pal, K; Kumar, Nikhil; Devi, P, Exploitation of pyrazole C-3/5 carbaldehydes towards the development of therapeutically valuable scaffolds: a review, CHEMICAL PAPERS; 2024

134. Sharma, VD; Kansay, V; Chandan, G; Bhatia, A; Kumar, Nikhil; Chakrabarti, S; Bera, MK, Down-conversion luminescence nanocomposites based on nitrogen-doped carbon quantum dots@bioplastic for applications in optical displays, LEDs and UVC tubes, SPECTROCHIMICA ACTA PART A-MOLECULAR AND BIOMOLECULAR SPECTROSCOPY; 2024

135. Shekhar, S; Kumari, V; Sinha, S; Mishra, D; Sahu, KK, A Clean Process for the Recovery of Potash Fertilizer from Glauconitic Rock via Hydrogen Gas Pre-treatment and Mild Acid Leaching, JOM; 2024

136. Shiva, V; Christopher, J; Veerababu, J; Parthasarathi, NL; Kannan, R; Nagesha, A; Vasudevan, M, Effect of maximum applied cyclic stress on fretting fatigue stress distribution of flat-on-flat modified 9Cr-1Mo steel contact: Finite element analysis\, NUCLEAR ENGINEERING AND DESIGN; 2024

137. Shiva, V; Parthasarathi, NL; Kannan, R; Nagesha, A; Albert, SK, Influence of various contact-materials on the fretting fatigue life of P91 steel, ENGINEERING FAILURE ANALYSIS; 2024

138. Shivam, Vikas; Kar, Shubhada; Mandal, GK ; Srivastava, VC; Mukhopadhyay, NK , Microstructural Evolution and Mechanical Properties of Fe-Containing High and Medium Entropy Alloys: Recent Advances and Future Prospects, TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS; 2024

139. Sil, Amritendu; Tiwari, Yoshit; Mukherjee, D ; Nandi, Sukalpan; Mukherjee, M, Investigating the influence of post-deposition heat treatment (PDHT) on the characteristic changes in wire arc additively manufactured 410 martensitic stainless steel thin-wall structure, MATERIALS TODAY COMMUNICATIONS; 2024

140. Singh, CV; Bagui, S; Sahoo, BK; Umbare, OS; Tarafder, S; Sivaprasad, S, Comparison of low cycle fatigue behaviour of additively manufactured and wrought Inconel625 alloys, MATERIALS SCIENCE AND ENGINEERING A; 2024

141. Singh, R; Mandal, GK; Bhagat, AN; Misra, S, Special Issue on Corrosion and Coating Technology, TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS, 2024

142. Singh, RK; Paswan, S, Isothermal High-Temperature Oxidation Behaviour of Nickel-Based Superalloy IN740H, TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS; 2024

143. Singla, G; Kansay, V; Sharma, VD; Singh, V; Bhatia, A; Bera, A; Kumar, N; Bera, MK, Harnessing hetero-atom doped CQDs from Pyrostegia venusta for latent fingerprint and anti-counterfeit applications, MICROCHEMICAL JOURNAL; 2024

144. Singla, Rashmi; Mishra, T; Alex, TC; Kumar, S, Inorganic-organic hybrid geopolymers: evolution of molecular and pore structure, and its effect on mechanical and fire-retardant properties, MATERIALS AND STRUCTURES; 2024

145. Soni; Sharma, SK; Mishra, SK, Hydrophobicity and high-temperature mechanical behaviour of hard and optically transparent nanocomposite Al-Si-N thin films, JOURNAL OF MATERIALS RESEARCH; 2024

146. Sripushpa, Kakara; Usha, Yenni; Bukhari, Syed Furqan; Kamaraj, Ashok, Analysis of Vortex Stability During the BOF Tapping Process, METALLURGICAL AND MATERIALS TRANSACTIONS B; 2024

147. Sripushpa, Kakara; Yenni, Usha; Bukhari, SF; Kamaraj, Ashok, Analysis of Vortex Stability During the BOF Tapping Process, METALLURGICAL AND MATERIALS TRANSACTIONS B; 2024

148. Surendran, AK; Jayaraj, J; Veerappan, R; Gupta, M; Amirthalingam, S; Gopalan, RK, Gd Added Mg Alloy for Biodegradable Implant Applications, JOURNAL OF BIOMEDICAL MATERIALS RESEARCH PART B-APPLIED BIOMATERIALS; 2024

149. Swarnakar, P; Ghosh, M; Mahato, B; De, PS; Roy, A, Understanding the phase stability in a multi-principal-component AlCuFeMn alloy, JOURNAL OF PHYSICS D-APPLIED PHYSICS; 2024

150. Thakur, AK; Das, B; Chowdhury, SG, A data-driven approach to model the martensitic transformation temperature in strain-induced metastable austenitic steels, MATERIALS TODAY COMMUNICATIONS; 2024

151. Tiwari, SK; Rao, AU; Kharb, AS; Chawla, V; Sardana, N; Dubey, P; Verma, PC; Dubey, SK; Avasthi, DK; Chawla, AK, Characterization of sputter-deposited hydrophobic chromium doped nickel alumnide coatings for mechanical and high-temperature oxidation-resistant applications; JOURNAL OF MATERIALS SCIENCE; 2024

152. Tiwari, Sunil Kumar; Rao, AU; Kharb, AS; Verma, PC; Dubey, Paritosh ; Chawla, V; Sardana, N; Kumar, S; Avasthi, DK; Chawla, AK, Sputter-deposited zirconium doped nickel-aluminide coatings for high-temperature oxidation-resistant applications, JOURNAL OF VACUUM SCIENCE & TECHNOLOGY A; 2024

153. Tiwari, Y; Nandi, S; Manivannan, R; Chatterjee, D; Mukherjee, M; Rajinikanth, V, Investigating the influence of various tool path trajectories on the anisotropic behaviour of bulk NiCrMo-3 alloy fabrication by WADED process, MATERIALS CHARACTERIZATION; 2024

154. Usha, Y; Das, A; Bansal, GK; Krishna, KG; Mandal, GK, Heat Transfer and Fluid Flow During Laser Powder Bed Fusion of SS316L Stainless Steel, TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS; 2024

155. Vasumathi, N; Gharai, M; Kumari, A; Austen, IC; Kumar, TVV, Flotation performance and kinetics study of low-grade limestone with fatty acids-rich oilseed residue as green collector, BIOMASS & BIOENERGY; 2024

156. Verma, Piyush Chandra; Mishra, SK, Microstructure, mechanical and electrochemical behavior of magnetron-sputtered carbothermic reduced iron-boride ceramic coatings, CERAMICS INTERNATIONAL; 2024

157. Vineet; Mishra, A; Tiwari, AK; Roy, SC; Naveena; Goyal, S, Experimental and numerical study on the fatigue behaviour of pre and post heat treated additively manufactured SS 316L specimens, ENGINEERING FAILURE ANALYSIS; 2024

158. Vivek; Choudhary, S; Das, S; Mishra, SK, Development of environment-friendly reduced graphene oxide coating and corrosion behaviour on cold-rolled interstitial-free (IF) steel, BULLETIN OF MATERIALS SCIENCE; 2024

159. Yadav, Maheswari; Kumar, Uttam; De, Arup Kumar; Sinha, Indrajit, Neutral pH Fenton and photo-Fenton activity of Mo-doped iron-pyrite particles, PHYSICAL CHEMISTRY CHEMICAL PHYSICS; 2024

Non-SCI Publication

1. Adeleke, A. A.; Ikubanni, P. P.; Odusote, J. K.; Muraina, H. O.; Singh, Harmanpreet; Paswan, D.; Malathi, M., "Sustainable Production of Sponge Iron through Direct Reduction ProcessWaste Recovery from Mill Scale", SUSTAINABLE MANUFACTURING,2024
2. Baba, AA; Raji, MA; Omoniyi, K; Chindo, SY; Kareem, AG; Abhilash; Meshram, P; Lawal, A; Adekola, FA, Low-Energy Processing of a Local Boltwoodite Ore as Intermediate in Nuclear Fuel Cell, ENERGY TECHNOLOGY 2024;2024
3. Chalavadi, Ganesh; Singh, RK; Sahoo, M, Fine Size Dry Iron Ore Beneficiation Using Thin Bed Air Fluidized Dry Separator, CURRENT TRENDS IN MINERAL-BASED PRODUCTS AND UTILIZATION OF WASTES: RECENT STUDIES FROM INDIA, 2022; 2024
4. Kaur, Harkirat; Meher, Alok Kumar; Bansiwal, Amit, Nanostructured materials for the removal of geogenic contaminants from water, ADVANCES IN DRINKING WATER PURIFICATION; 2024
5. Khatri, N; Manjunath, K; Tewary, S; Kang, W; Liang, RG; Measurement of Mid Spatial Frequencies of Diamond Turned Optics by using Dual-mode Snapshot Interferometry, OPTICAL MANUFACTURING AND TESTING 2024: PROCEEDINGS OF SPIE; 2024
6. Kumar, A; Bag, S; Srivastava, VC; Amin, MR, THERMO-MECHANICAL BEHAVIOR OF MULTI-LAYER DEPOSITION FOR WIRE ARC ADDITIVE MANUFACTURING OF STRUCTURAL STEEL: WIRE ARC ADDITIVE MANUFACTURING, PROCEEDINGS OF ASME 2022 INTERNATIONAL MECHANICAL ENGINEERING CONGRESS AND EXPOSITION, IMECE2022, VOL 3; 2024
7. Kumar, Arun; Kumar, Roshan; Kumar, Sunil; Kumar, Ashok; Atomistic Investigation of Mechanical Properties of Fe-Cr-Ni Alloy Using Molecular Dynamics Simulation, ADVANCES IN APPLIED MECHANICS; 2024
8. Kumar, Nikhil; Gupta, Nisha; Bhattacharya, Pallab, Metal-Organic Frameworks (MOFs): Chemistry, Properties, and Energy Storage Applications, MULTIDIMENSIONAL NANOMATERIALS FOR SUPERCAPACITORS: NEXT GENERATION ENERGY STORAGE, 2024
9. Kumar, Roshan Ansu J Kailath, Stress-Strain Characteristics of Iron: Insights from Molecular Dynamics Simulation, JOURNAL OF FLUID MECHANICS AND MECHANICAL DESIGN; 2024
10. Kumar, Roshan; Biswas, Sanjoy; Kumar, Sunil; Kumar, Manoj, Effect of Various Configurational Parameters of Exhaust Mufflers on Transmission Loss Using TMM, JOURNAL OF AUTOMATION AND AUTOMOBILE ENGINEERING;2024
11. Kumar, Roshan; Kumar, Manoj; Usha, Y., Comparative Analysis of Aluminium and Stainless Steel Fabrication by Wire-Cut EDM: Wire Breakage and Surface Roughness Characteristics, JOURNAL OF FLUID MECHANICS AND MECHANICAL DESIGN; 2024
12. Kumari, A; Sahu, SK, Development and Assessment of Different Hydrometallurgical Processes for Sustainable Recovery of Rare Earths from Spent NdFeB Magnets, RARE METAL TECHNOLOGY 2024; 2024
13. Kumari, Beena; Madhukar, A.; Sahney, S., A R&D productivity model to achieve self-sustainability for public funded/CSIR R&D laboratories, India, INTERNATIONAL JOURNAL OF PRODUCTIVITY AND PERFORMANCE MANAGEMENT; 2024
14. Kumari, D.; Rai, Rishav; Sahoo, B.K; Chandan, A.K.; Bansal, G.K., Overview on composition-processing-structure- properties correlation in wear-resistant Hadfield steel, STEEL TECH; 2024

15. Malathi, M.; Paswan, Dayanand, Tunnel Kiln: A Techno Economic Route of Sponge Iron Making, STEEL AND METALLURGY; 2024
16. Malathi, M.; Paswan, Dayanand, Biomass Torrefaction, Densification and Utilization, RECENT TRENDS IN METALLURGY & MATERIAL SCIENCE; 2024
17. Manjunath, K., Tewary, S., Khatri, N., & Cheng, K., Effect of precipitation on surface roughness in ultra-precision machining of Ti6Al4V ELI alloy fabricated by selective laser melting, AIP CONFERENCE PROCEEDINGS; 2024
18. Ojha, D.; Sahoo, B.K; Chandan, A.K.; Bansal, G.K., Electric vehicles for future mobility: Demand, Policies and Opportunities for Advanced Steel Development, STEEL TECH; 2024
19. Paswan, Dayanand; Malathi, M., Tunnel Kiln: A Techno Economic Route of Sponge Iron Making, INTERNATIONAL CONFERENCE ON PROCESS & PRODUCT INNOVATIONS IN METAL PRODUCTION, 2024
20. Prasad, Sourav Kumar; Soupramanien, C; , Development of an Arduino-based PID temperature control system for high temperature tensile testing of automotive steel sheets, IEEE THIRD INTERNATIONAL CONFERENCE ON ARTIFICIAL INTELLIGENCE, COMPUTATIONAL ELECTRONICS AND COMMUNICATION SYSTEM (AICECS) 2024; 2024
21. Rahman, Abdul; Husain, Murtuja; Prasad, Naresh; Walunj, Mahesh Gulab , Additive Manufacturing of Magnesium Alloys for Biomedical Applications, ADVANCES IN APPLIED MECHANICS, LECTURE NOTES IN MECHANICAL ENGINEERING; 2024
22. Samanta, R.; Bansal, G.K.; Ghosh, S.K.; Mandal, G., Properties and applications of bainitic railway steel prepared by mechanical alloying, ADVANCEMENTS IN POWDER METALLURGY: PROCESSING, APPLICATIONS, AND PROPERTIES
23. Sharma, Neeraj; Husain, Md Murtuja; Das, Babul, Influence of tempering on microstructure and mechanical Properties of Low Alloy Steel, INTERNATIONAL JOURNAL OF RESEARCH AND ANALYTICAL REVIEW; 2024
24. Soupramanien, C.; Agrawal, Saurabh; Pandey, Shrawan; Kumar, Roshan, The Impact of Dwell Time on the Brinell Hardness Test Behavior of ASTM-A36 Steel: Implications for Safety and Cost Efficiency, JOURNAL OF ADVANCEMENTS IN MATERIAL ENGINEERING; 2024
25. Usha, Y.; Tewary, Suman; Ghosh, Arpita; Dutta, Chandan; Metya, Avijit K.; Palit Sagar, S., Numerical Simulation to Predict Critical Hotspot Temperature in Blast Furnace Blowpipe to Avoid Industrial Hazard, ADVANCES IN NON-DESTRUCTIVE EVALUATION, LECTURE NOTES IN MECHANICAL ENGINEERING; 2045

"Coming Together is The Begining.
Keeping Together is Progress.
Working Together is Success"

Henry Ford

"Reach high, for stars lie hidden in you. Dream deep, for every dream precedes the goal."

-Rabindra Nath Tagore

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