वार्षिक प्रतिवेदन
ANNUAL REPORT
2025-26

सीएसआईआर
CSIR
भारत का नवाचार इंजन
The Innovation Engine of India

CSIR-National Metallurgical Laboratory
Jamshedpur - 831007, India

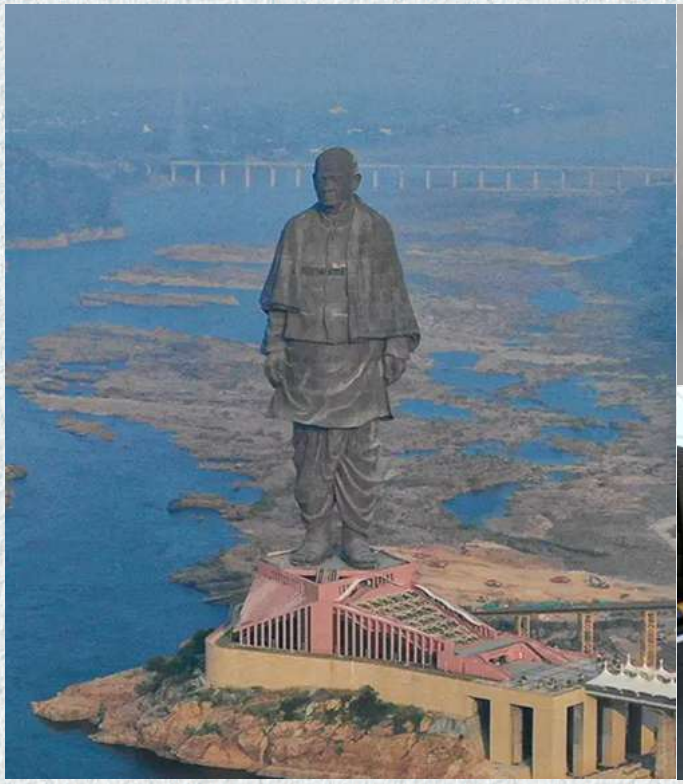
वार्षिक प्रतिवेदन ANNUAL REPORT 2025-26

सीएसआईआर
CSIR
भारत का नवाचार इंजन
The Innovation Engine of India

Recycling in Action

Towards a Sustainable Tomorrow

Natural resources like metals and materials form part of our lives in innumerable forms. We rely on these resources every day, but they are limited. Although the idea of sustainability was introduced in the 1970s, the need to promote and practice it is being felt deeply today. A few instances of successful real-world examples that show us the remarkable utilization of recycled metals and materials have been highlighted in this book.



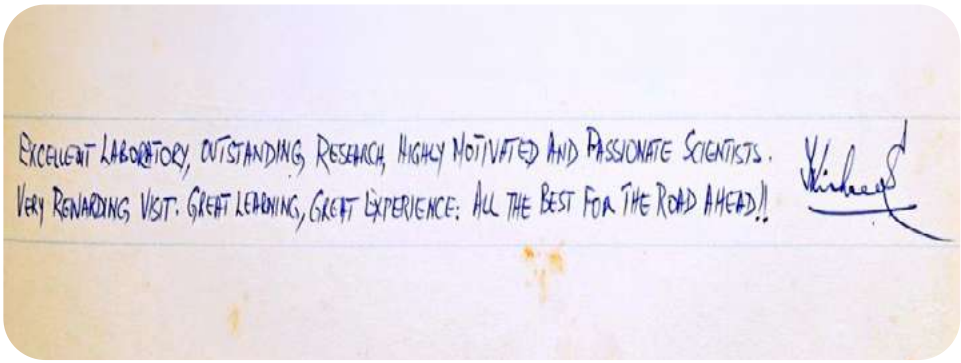




Glimpses from the book

Contents

Overview of Council of Scientific & Industrial Research (CSIR)	5
CSIR-National Metallurgical Laboratory	9
Organisation Structure	19
Research Council (RC)	21
Director's Foreword	25
Performance Targets Achieved 2025-26	33
R&D Outputs	37
Technology Profile	41
Impact Making Technology	45
Creation of New Facilities	51
Performance Targets Planned 2026-27	53
Centres of Excellence	57
Iron & Steel Making	69
Critical Metals Extraction from Primary & Secondary Resources	73
Urban Ore Recycling & Waste Valorisation	81
Alloy Development	85
Failure Analysis/Investigation and Structural Integrity Evaluation	93
Sensor & Devices	101
Minerals Processing	105
Advanced & Functional Materials	113
Services to Defence Sectors	117
Corrosion	121
AI Mission	131
Coal Characterization	133
Technical Services Rendered	137
CSIR - NML Madras Centre	139
In-house Project Support Group (i-PSG)	141
Academy of Scientific & Industrial Research (AcSIR) - NML Activities	143
Research Planning & Business Development (RPBD)	147
Information Management & Dissemination Centre (IMDC)	151
Information Communications & Technology Unit (ICTU)	153
Engineering	155
Human Resource	159
Staff News	161
Administration	163
Stores & Purchase	165
Finance & Accounts	167
Hindi Cell	169
Contributions to Society	173
CSIR - NML In News	177
Our Clientele	181
MoUs / Agreements Signed	183
Special Days & Events	187
Distinguished Visitors	207
Staff Club Activities	213
Awards and Recognitions	219
Intellectual Property Rights	237
SCI - Publications	239



"Excellent laboratory, outstanding research, highly motivated and passionate scientists. Very rewarding visit. Great learning, great experience." All the best for the road ahead."

Dr. Kishore Sreenivasan
Head, CSIR-URDIP Pune
Date: 22nd April 2025

Impressions

The Organization

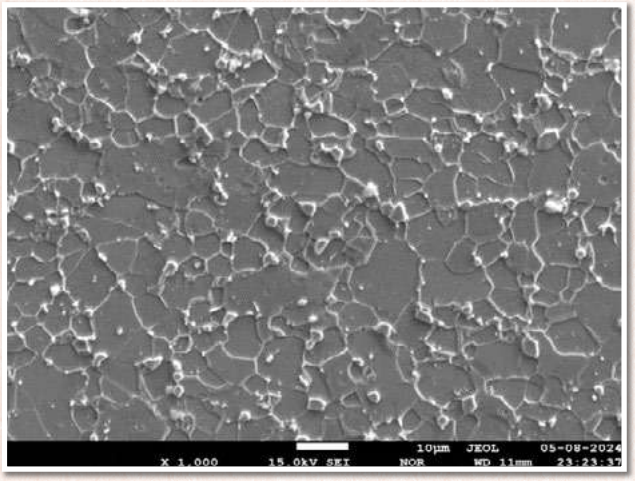
The Statue of Unity, a towering 597-foot (182-meter) statue of Vallabhbhai Patel, is constructed of bronze-coated cement and steel. Known as the **"Iron Man of India",** his statue is partially constructed of iron from recycled tools from farmers across India.



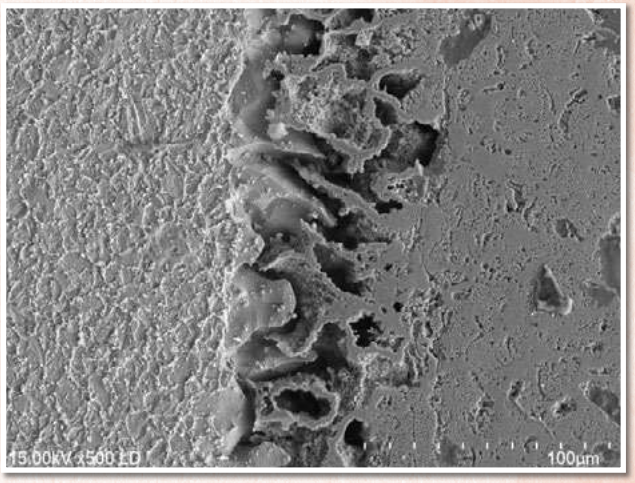
Image Source: https://statueofunitytentcity.com

www.britannica.com/topic/Statue-of-Unity

MICROSTRUCTURES



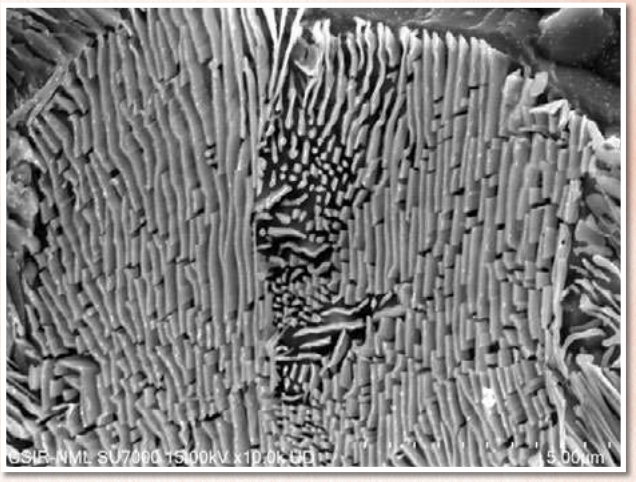
Ostwald ripening in P91 steel



Matrix/oxidation product interface in P91 steel formed after long exposure at elevated temperature



Diffraction Fringes due to crystallographic defects in austenite phase



Pearlite microstructure resembling cauliflower cut-pattern

वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद (सीएसआईआर) का अवलोकन

सीएसआईआर का विजन

"नवोन्मेषी विज्ञान और प्रौद्योगिकी, विश्व-स्तरीय प्रतिस्पर्धी अनुसंधान एवं विकास, तथा सतत समाधानों के विकास और क्षमता-निर्माण के माध्यम से, 'आत्मनिर्भर भारत' के स्वप्न को साकार करते हुए, भारत के नागरिकों के जीवन की गुणवत्ता में सुधार लाना।"

सीएसआईआर का यह विज़न भारत सरकार के अगले 25 वर्षों के 'अमृत काल' के विज़न के अनुरूप है, जब स्वतंत्र भारत 100 वर्षों का हो जाएगा।

भारत सरकार के विज्ञान और प्रौद्योगिकी मंत्रालय के अंतर्गत, वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद (सीएसआईआर) एक गतिशील अनुसंधान एवं विकास (R&D) संगठन है, जिसमें 37 राष्ट्रीय प्रयोगशालाएँ, 39 आउटरीच केंद्र, एक नवाचार परिसर और तीन इकाइयाँ शामिल हैं, जिनकी पूरे भारत में उपस्थिति है।

सीएसआईआर के पास 3400 से अधिक सक्रिय वैज्ञानिकों की एक टीम है, जिन्हें लगभग 4000 तकनीकी और सहायक कर्मियों का सहयोग प्राप्त है। सीएसआईआर विज्ञान और प्रौद्योगिकी के विभिन्न क्षेत्रों में अनुसंधान और विकास कार्यों में संलग्न है। सीएसआईआर का "विषय-आधारित दृष्टिकोण" (Thematic approach), पहचाने गए क्षेत्रों में विशिष्ट चुनौतियों को हल करने हेतु बहु-विषयक अनुसंधान और विकास को सक्षम बनाती है। ये इन क्षेत्रों में शामिल हैं: एयरोस्पेस, इलेक्ट्रॉनिक्स, इंस्ट्रूमेंटेशन और रणनीतिक क्षेत्र; नागरिक बुनियादी ढांचा और इंजीनियरिंग; पारिस्थितिकी, पर्यावरण, पृथ्वी और महासागर विज्ञान तथा जल; खनन, खनिज, धातु और सामग्री; रसायन (चमड़े सहित) और पेट्रोकेमिकल्स; ऊर्जा (पारंपरिक और गैर-पारंपरिक) और ऊर्जा उपकरण; कृषि, पोषण और जैव प्रौद्योगिकी; तथा स्वास्थ्य सेवा, पर्यावरण, ऊर्जा, भोजन, आवास, कृषि, जल आदि क्षेत्रों में सीएसआईआर के तकनीकी हस्तक्षेपों ने जीवन की गुणवत्ता को बेहतर बनाने में महत्वपूर्ण भूमिका निभाई है। इसके साथ ही, सीएसआईआर द्रव्यमान, दूरी, समय, तापमान और विद्युत धारा के मापन मानकों का राष्ट्रीय संरक्षक भी है।

सीएसआईआर के पास एक बहुत मज़बूत बौद्धिक संपदा पोर्टफोलियो, अत्याधुनिक प्रौद्योगिकियों और SCI जर्नल्स में 5800 से ज़्यादा पेपर्स हैं, जिनका प्रति पेपर औसत इंपैक्ट फ़ैक्टर 4.9 है। सीएसआईआर में सबसे नया जुड़ाव मुंबई में स्थित इसका नवाचार केंद्र है—एक अत्याधुनिक सुविधा जो नौ मंज़िलों में फैली हुई है। इसमें नवोन्मेषी स्टार्टअप, MSMEs, उद्योगों और सीएसआईआर प्रयोगशाला के लिए सुसज्जित कार्यालयों और नेटवर्किंग जगहों के अलावा, 24 "तुरंत इस्तेमाल के लिए तैयार" (ready-to-move) ऊष्मायन प्रयोगशाला भी मौजूद हैं। नवाचार केंद्र देश के स्टार्ट-अप इको-सिस्टम को और अधिक समृद्ध बना रहा है, और यह केंद्र सीएसआईआर की सुविधाओं और विशेषज्ञता के साथ, इसे और आगे बढ़ाएगा। यह सीएसआईआर वैज्ञानिकों, MSMEs, स्टार्ट-अप्स और उद्योग के हितधारकों के बीच एक संपर्क बिंदु के रूप में भी कार्य करती है। सीएसआईआर ने 'पारंपरिक ज्ञान डिजिटल पुस्तकालय' (TKDL) का निर्माण किया है और

वह इसका संरक्षक है; यह एक ऐसा साधन है जिसका उद्देश्य भारतीय पारंपरिक ज्ञान के अनैतिक व्यावसायिक शोषण को रोकना है। सीएसआईआर 'सूक्ष्मजीव प्रकार संस्कृति संग्रह' (MTCC) और 'जीन बैंक' का भी रखरखाव करती है।

सीएसआईआर, अपनी घटक प्रयोगशालाओं के माध्यम से, विज्ञान और प्रौद्योगिकी (S&T) के क्षेत्र में मानव संसाधन के विकास में भी महत्वपूर्ण भूमिका निभाती है और छात्रों को अनुसंधान कार्य करने हेतु फेलोशिप प्रदान करती है। अकादमी ऑफ़ साइंटिफ़िक एंड इनोवेटिव रिसर्च (AcSIR) छात्रों को अपनी घटक प्रयोगशालाओं से स्नातकोत्तर अध्ययन और डॉक्टोरल अनुसंधान करने का अवसर प्रदान करती है।

सीएसआईआर ने अपने कार्यक्रमों, जैसे कि सीएसआईआर-जिज्ञासा(CSIR-JIGYASA) और कौशल विकास कार्यक्रम के माध्यम से विज्ञान को युवाओं तक पहुँचाने में भी एक अहम भूमिका निभाई है, जिससे छात्रों में वैज्ञानिक सोच का विकास सुनिश्चित हुआ है। इन कार्यक्रमों का उद्देश्य युवाओं को कौशल प्रशिक्षण देना, उनके कौशल को उन्नत करना और उन्हें नए कौशल सिखाना है, ताकि उनकी रोज़गार-योग्यता में सुधार हो सके।

वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद (सीएसआईआर) ने 2025 में गर्व के साथ अपना 84वां स्थापना दिवस मनाया।



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 84th Foundation Day in 2025.



सीएसआईआर - राष्ट्रीय धातुकर्म प्रयोगशाला (सीएसआईआर - एनएमएल)

भारत का एक प्रमुख अनुसंधान संगठन है। जो खनिज, धातु और सामग्री के विभिन्न पहलुओं के लिए समर्पित है, इसका मुख्य ज़ोर इन क्षेत्रों में वैज्ञानिक अनुसंधान, प्रौद्योगिकी विकास, औद्योगिक सेवाओं और मानव संसाधन के विकास पर है। माननीय श्री सी. राजगोपालाचारी ने 21 नवंबर, 1946 को सीएसआईआर-राष्ट्रीय धातुकर्म प्रयोगशाला की आधारशिला रखी थी। 26 नवंबर, 1950 को "भविष्य में आशा और विश्वास की एक भावना के साथ" पंडित जवाहरलाल नेहरू द्वारा इसका औपचारिक रूप से उद्घाटन किया गया और देश को समर्पित किया गया। यह प्रयोगशाला सीएसआईआर की उन शुरुआती कुछ प्रयोगशालाओं में से एक है, जिन्हें देश के वैज्ञानिक और तकनीकी विकास के लिए स्थापित किया गया। सीएसआईआर-एनएमएल ने 1950 से शुरू हुई भारत की औद्योगिक क्रांति में एक महत्वपूर्ण भूमिका निभाई है, विशेष रूप से खनिज प्रसंस्करण, लोहा और इस्पात निर्माण, फेरो-मिश्र धातु और अलौह धातुओं (विशेष रूप से मैग्नीशियम) के निष्कर्षण के क्षेत्रों में। 1970 के दशक की शुरुआत में सीएसआईआर-एनएमएल में एशिया की सबसे बड़ी 'क्रीप टेस्टिंग' सुविधा भी स्थापित की गई थी, और आज भी यह एशिया की सबसे बड़ी क्रीप टेस्टिंग प्रयोगशाला में से एक मानी जाती है। अपनी स्थापना के बाद से, सीएसआईआर-एनएमएल ने अपने अनुसंधान के दायरे को कई क्षेत्रों में बढ़ाया है, जैसे कि प्राथमिक और माध्यमिक स्रोतों से महत्वपूर्ण धातुओं का निष्कर्षण, आयात-प्रतिस्थापन के लिए मिश्र धातुओं का विकास, जंग (corrosion) पर अध्ययन, धातुकर्म प्रक्रियाओं की गणितीय और भौतिक मॉडलिंग, खनिज अनुसंधान, औद्योगिक और शहरी संसाधनों से मूल्य निष्कर्षण और उनका उपयोग, उन्नत सामग्री, महत्वपूर्ण औद्योगिक घटकों की अखंडता का मूल्यांकन और सतह इंजीनियरिंग आदि।

धातुओं के संसाधन हमेशा सीमित होते हैं, और अयस्कों का शुद्धिकरण (beneficiation) अनिवार्य है। विशेष रूप से, लोहा और इस्पात उद्योगों में, धातु-लोहे के उत्पादन में वृद्धि के कारण लौह-अयस्क की भारी मात्रा खपत होती है। परिणामस्वरूप, उच्च-श्रेणी के लौह-अयस्कों का भंडार कम होता जा रहा है, और अब कम-श्रेणी के अयस्कों के शुद्धिकरण पर ज़ोर दिया जा रहा है। प्रयोगशाला ने एक ऐसी प्रक्रिया विकसित की है, जो लौह-अयस्क के शुद्धिकरण के 'बैच स्केल' पर, 1 किलोग्राम/टन 'कलेक्टर डोज़' का उपयोग करते हुए, 83.8% की प्राप्ति (yield) के साथ 2.77% Al2O3 वाला एक 'सांद्रण' (concentrate) और 43.2% Fe युक्त 'टेलिंग्स' (अवशेष) उत्पन्न करने में सक्षम है। उच्च सीमेंट ग्रेड वाले चूना पत्थर के भंडार खत्म होने के कारण, इस समय सफ़ेद सीमेंट उद्योग को सीमेंट बनाने के कच्चे माल की भारी कमी का सामना करना पड़ रहा है। इस काम के लिए आम तौर पर ऐसे उच्च-ग्रेड वाले चूना पत्थर का इस्तेमाल किया जाता है जिसमें 0.068% से कम Fe2O3 और 0.015% से कम MnO होता है। लौह और इस्पात बनाने के लिए निम्न-ग्रेड वाले लौह अयस्क के शुष्क सज्जीकरण (सूखे तरीके से शुद्धिकरण) की प्रक्रिया तकनीक विकसित करना भी इस प्रयोगशाला का एक और मौजूदा मुख्य लक्ष्य है। इस गतिविधि के तहत, दो प्रयोगशाला स्तर शुष्क सेपरेटर' और -20mm से +0.1 mm आकार सीमा वाले लौह अयस्क के प्रयोगशाला स्तर शुष्क सज्जीकरण के लिए एक 'फ्लोशीट' विकसित की गई है। लौह अयस्क के फीड का आकार घटाकर -1mm से कम करने के बाद, 'एयर

टेबल' और 'मैग्नेटिक सेपरेटर' के ज़रिए आगे की प्रोसेसिंग करने से, 62% या उससे ज़्यादा Fe (लौह) मात्रा वाली सामग्री की प्राप्ति दर (yield percent) में बढ़ोतरी हुई है। झारखंड में स्थानीय स्तर पर निम्न-ग्रेड वाले लौह अयस्क (<55% Fe) और 'नॉन-कोकिंग कोयले' (<40% F.C) की भारी मात्रा उपलब्ध है, जिन्हें पहले बेकार मानकर छोड़ दिया गया था।

लौह-युक्त सामग्री में Fe की कम मात्रा और गैंग (gangue) की अधिक मात्रा होने के कारण, इन कच्चे मालों का शुद्धिकरण करना या उन्हें मूल्य-वर्धित उत्पाद में बदलना लौह और इस्पात उद्योग के लिए एक चुनौतीपूर्ण कार्य है। इसी प्रकार, निश्चित कार्बन (fixed carbon) की कम मात्रा और केक बनाने के गुणों (caking properties) के अभाव के कारण, निम्न श्रेणी के नॉन-कोकिंग कोयले का उपयोग करना कठिन होता है, और यह अक्सर खदानों के मुहाने पर ही पड़ा रहता है। इस तरह के कम ग्रेड वाले कच्चे माल के इस्तेमाल की तकनीकी संभावनाओं पर R&D वैज्ञानिकों को खास ध्यान देना चाहिए, ताकि उन्हें एक ज़्यादा कीमत वाले उत्पाद में बदला जा सके। इसलिए, प्रयोगशाला ने क्षेत्रीय स्तर पर उपलब्ध कम ग्रेड वाले लौह अयस्क और नॉन-कोकिंग कोयले का इस्तेमाल करके DRI बनाने की एक प्रक्रिया विकसित की है।

यह प्रयोगशाला R&D (अनुसंधान और विकास) का काम भी करती है और अपनी अत्याधुनिक कोयला विश्लेषण प्रयोगशाला का उपयोग करके, रासायनिक विशेषताओं के आधार पर कोकिंग और नॉन-कोकिंग दोनों तरह के कोयले की गुणवत्ता का आकलन करती है; साथ ही यह कोयले की परत-दर-परत (band by band) और पूरी सीम (seam) का समग्र विश्लेषण भी करती है। पिछले 10 वर्षों में, सीएसआईआर-एनएमएल ने कोयले से जुड़े कई परियोजनाएं हाथ में लिए हैं, जिनमें से एक खास परियोजना है–" तेल एकत्रीकरण (oil agglomeration) विधि से वॉशरी-ग्रेड कोकिंग कोयले और ज़्यादा राख वाले नॉन-कोकिंग कोयले से राख की मात्रा कम करना"; इस परियोजना को CMPDI, रांची ने प्रायोजित किया था। इस परियोजना के तहत, एक पायलट पैमाने पर प्रक्रिया संयंत्र विकसित किया गया, जो विभिन्न प्रकार के कोयले में राख की मात्रा को 22% से घटाकर 8% तक ला सकता है। इस काम के लिए सात अलग-अलग जगहों से लाए गए कोयले का इस्तेमाल किया गया, जैसे–मगध, केडला, टोपा, राजरप्पा (झारखंड क्षेत्र) आदि। यह प्रयोगशाला CCL के विभिन्न लोडिंग पॉइंट्स– जैसे राजरप्पा, केडला, कथारा और स्वांग क्षेत्र (झारखंड) से प्राप्त 'वॉश्ड कोकिंग कोयले' की सैंपलिंग, उसे तैयार करने और उसके विश्लेषण का काम भी करती है, ताकि इस कोयले की आपूर्ति SAIL और RINL के स्टील प्लांट्स को की जा सके।

एक्सट्रैक्टिव मेटलर्जी (धातु निष्कर्षण) सीएसआईआर-राष्ट्रीय धातुकर्म प्रयोगशाला की शुरुआती गतिविधियों में से एक रही है। इस क्षेत्र में किए गए कुछ शुरुआती कामों में रोटरी भट्टी में स्पंज आयरन का उत्पादन, मैग्नीशियम धातु निकालने के लिए पिजन प्रक्रिया, समुद्री नोड्यूल्स से Ni और Co निकालना आदि शामिल हैं। देश की ज़रूरतों के हिसाब से, ये गतिविधियाँ कई बड़े कार्यक्रमों में बदल गई हैं, जैसे: प्राथमिक और माध्यमिक स्रोतों से महत्वपूर्ण धातुओं को निकालना, शहरी अयस्क खनन, ग्रीन स्टील बनाना और कचरे का सही इस्तेमाल करना। महत्वपूर्ण धातुएँ, जिनमें दुर्लभ मृदा तत्व भी शामिल हैं, देश की ज़रूरत हैं, क्योंकि रक्षा, अंतरिक्ष, मोबिलिटी और नवीकरणीय ऊर्जा जैसे क्षेत्रों के लिए उत्पादों का विकास इन्हीं पर निर्भर करता है। अभी भारत 90% से ज़्यादा महत्वपूर्ण धातुएँ आयात

करता है। 2023 में, खान मंत्रालय ने 30 खनिजों की एक सूची जारी की, जो भारत के लिए बहुत महत्वपूर्ण हैं। इन 30 खनिजों में से, सीएसआईआर-एनएमएल ने 16 खनिजों/धातुओं पर रिसर्च की है और इसे उन रिसर्च संस्थानों में से एक माना जाता है जो इस क्षेत्र में टेक्नोलॉजी दे सकते हैं। सीएसआईआर-एनएमएल ने पहली स्वदेशी सोडियम धातु टेक्नोलॉजी विकसित की है, जिसका पायलट प्रोजेक्ट किया गया था। क्रिटिकल धातुओं पर यह प्रोग्राम ◌ंगस्टन, मैग्नीशियम, सोडियम, वैनेडियम, स्कैंडियम, दुर्लभ मृदा तत्व, लिथियम, कोबाल्ट, निकेल और कई अन्य धातुओं पर केंद्रित है। इनमें से कई विकास कार्यों को उद्योगों का समर्थन प्राप्त है। सीएसआईआर-एनएमएल, 'क्रिटिकल धातुओं की मैपिंग और दोहन' पर CSIR के मिशन मोड प्रोजेक्ट में भाग ले रहा है। इसके अलावा, डिस्टिलेशन सुविधा के साथ एकीकृत संशोधित पिजन प्रक्रिया का उपयोग करके, 100 किलोग्राम/दिन के पैमाने पर मैग्नीशियम उत्पादन के लिए एक पायलट प्लांट स्थापित किया जाएगा।

शहरी अयस्क (Urban ores) दुनिया भर में सबसे तेज़ी से बढ़ने वाले द्वितीयक संसाधन हैं। कुछ महत्वपूर्ण शहरी अयस्कों में ई-कचरा, बैटरियाँ, CFL बल्ब, व्हाइट गुड्स आदि शामिल हैं। भारत ई-कचरे का उत्पादन करने वाला दुनिया का पाँचवाँ सबसे बड़ा देश है। वर्तमान में, देश में ई-कचरे से अलग-अलग कीमती धातुओं को निकालने और उसके सुरक्षित पुनर्चक्रण (recycling) के लिए कोई स्वदेशी तकनीक उपलब्ध नहीं है। फ़िलहाल, ई-कचरे के पुनर्चक्रण का काम असंगठित क्षेत्र के कबाड़ बीनने वालों (dismantlers) द्वारा ऐसे तरीक़े से किया जाता है जो पर्यावरण के लिए सुरक्षित नहीं है। इस संस्थान ने देश का पहला 'शहरी अयस्क पुनर्चक्रण केंद्र' स्थापित किया है और ई-कचरे से कीमती तथा महत्वपूर्ण धातुओं को निकालने के लिए कई प्रक्रियाएँ विकसित की हैं। इस क्षेत्र में विकसित की गई कई तकनीकों को विभिन्न उद्योगों को हस्तांतरित किया गया है। इलेक्ट्रिक वाहनों, स्मार्टफ़ोन और अन्य पोर्टेबल इलेक्ट्रॉनिक उपकरणों में रिचार्जेबल लिथियम-आयन बैटरियों के बढ़ते इस्तेमाल के कारण, निकट भविष्य में लिथियम की वैश्विक मांग में ज़बरदस्त बढ़ोतरी होने वाली है। भारत में प्राथमिक रूप में लिथियम के संसाधन बहुत कम हैं और यह पूरी तरह से आयात पर निर्भर है। चूंकि भारत स्मार्टफ़ोन और इलेक्ट्रिक वाहनों के लिए सबसे बड़े बाज़ारों में से एक के रूप में उभर रहा है, इसलिए लिथियम की मांग में और भी बढ़ोतरी होगी। इसलिए, द्वितीयक संसाधनों से लिथियम निकालने के लिए स्वदेशी तकनीक विकसित करने की गंभीर आवश्यकता है। सीएसआईआर-एनएमएल ने इस क्षेत्र में कई तकनीकें विकसित की हैं और उन्हें हस्तांतरित भी किया है। बेंच स्केल पर हाइब्रिड हाइड्रोमेटलर्जिकल विधि के ज़रिए धातुओं की रिकवरी के लिए कार की बैटरियों की रीसाइक्लिंग की व्यवहार्यता स्थापित की गई है, जिसमें इलेक्ट्रोड सामग्री मुख्य रूप से Mn-आधारित थी।

हाल ही में, लिथियम बैटरियों की रीसाइक्लिंग के लिए 1 टन/दिन की इनपुट क्षमता वाला एक पायलट प्लांट स्थापित किया गया है, जिसका उद्घाटन नीति आयोग के सदस्य डॉ. वी. के. सारस्वत ने किया। एक अन्य गतिविधि जिस पर काम किया जा रहा है, वह है सोलर पैनलों की रीसाइक्लिंग।

'रेयर अर्थ' (Rare earth) एक बहुत ही महत्वपूर्ण रणनीतिक सामग्री है, लेकिन भारत के पास इसके प्राथमिक संसाधन नहीं हैं और वह पूरी तरह से आयात पर निर्भर है। नीति आयोग ने फ्लाई ऐश और रेड मड जैसे द्वितीयक संसाधनों से 'रेयर अर्थ' निकालने की संभावनाओं का पता लगाने के लिए एक समिति का गठन किया है। हमें पायलट स्तर पर

एक व्यापक तकनीक विकसित करने की ज़िम्मेदारी सौंपी गई है, ताकि रेड मड से (जिसमें 'रेयर अर्थ' भी शामिल है) अधिकतम मूल्य निकाला जा सके और बचे हुए अवशेष का उपयोग किया जा सके।

इस कार्यक्रम में तीन अनुसंधान संस्थान और तीन उद्योग भाग ले रहे हैं। कैल्सीन्ड डोलोमाइट से प्राप्त पिजन प्रोसेस का इस्तेमाल करके मैग्नीशियम बनाने के लिए एक पायलट प्लांट सुविधा स्थापित करने का मकसद, उत्पादन का एक ज़्यादा टिकाऊ और असरदार तरीका उपलब्ध कराना है। यह प्रोसेस मैग्नीशियम बनाने के पारंपरिक तरीकों का एक पर्यावरण-अनुकूल विकल्प देता है, जिससे ऊर्जा की खपत कम होती है और कार्बन उत्सर्जन भी न्यूनतम स्तर पर आ जाता है, साथ ही संसाधनों का बेहतर इस्तेमाल भी सुनिश्चित होता है। सीएसआईआर की महानिदेशक डॉ. (श्रीमती) एन. कलैसेल्वी ने हाल ही में प्रयोगशाला के प्लेटिनम जुबली स्थापना दिवस के मौके पर इस प्लांट की आधारशिला रखी है।

हाल ही में हमने ग्रीन स्टील पर काम शुरू किया है और हाइड्रोजन-आधारित DRI का अध्ययन कर रहे हैं। फ़िलहाल, रिएक्शन काइनेटिक्स पर अध्ययन चल रहा है। इस क्षेत्र में हमने एक और काम शुरू किया है, वह है MOF का इस्तेमाल करके कार्बन को अलग करना और जमा करना; इसके लिए सीएसआईआर सीसीयू मिशन के तहत एक परियोजना शुरू किया गया है। MOF की उपयुक्तता को भोपाल की RKDF यूनिवर्सिटी में पायलट स्केल पर परखा गया है, जहाँ इसने कार्बन को अच्छी तरह से सोखने की क्षमता दिखाई है।

एक और क्षेत्र जहाँ सीएसआईआर-एनएमएल को अंतरराष्ट्रीय स्तर पर पहचान मिली है, वह है औद्योगिक कचरे का बड़े पैमाने पर उपयोग। हम स्लैग के 'हॉट स्टेज मॉडिफिकेशन' पर काम कर रहे हैं, ताकि उससे धातु के मूल्यवान तत्व निकाले जा सकें और बचे हुए गैर-धात्विक अवशेष का उपयोग सीमेंट जैसे बाइंडर के रूप में किया जा सके। इस क्षेत्र में, हम LD स्लैग के 'डीकंस्ट्रक्शन' (घटकों को अलग करने) पर भी काम करने की योजना बना रहे हैं, जिसमें स्लैग के हर घटक को धातु के रूप में अलग किया जाएगा। इसके अलावा, जियोपॉलीमराइजेशन तकनीक का उपयोग करके औद्योगिक कचरे से निर्माण और भवन सामग्री विकसित करना भी हमारे कार्यों में शामिल है। जियोपॉलीमराइज़ेशन प्रक्रिया के ज़रिए, एल्यूमिना-सिलिकेट कचरे को सीमेंट जैसे पदार्थ में बदला जा सकता है; लेकिन इस प्रक्रिया से पारंपरिक पोर्टलैंड सीमेंट की तुलना में 80% कम CO2 निकलती है, इसलिए इसे पर्यावरण-अनुकूल (ग्रीन) माना जाता है। उद्योग को तीन तकनीकें सौंपी गई हैं: फ्लाई ऐश से जियोपॉलीमर सीमेंट बनाना, विभिन्न औद्योगिक कचरे से पेविंग ब्लॉक बनाना, और फ्लाई ऐश व स्लैग के मिश्रण से सड़कों की तुरंत मरम्मत करने वाला पदार्थ तैयार करना। फ़िलहाल, यह टीम सीएसआईआर की पहली कार्यक्रम के तहत 'सेल्फ़-हीलिंग जियोपॉलीमर' पर काम कर रही है।

मिश्र धातु विकास और सामग्री इंजीनियरिंग सीएसआईआर - एनएमएल का एक और प्रमुख क्षेत्र है। इस क्षेत्र के अंतर्गत, रक्षा से लेकर बायोमेटेरियल अनुप्रयोगों तक, विभिन्न प्रकार के उपयोगों के लिए नई मिश्र धातुओं का विकास करना मुख्य लक्ष्य है। इस प्रयोगशाला ने मौजूदा सुपर मिश्र धातुओं के विकल्प के रूप में एक 'प्रेसिपिटेशन-हार्डन्ड कम्पोज़िशनली कॉम्प्लेक्स अलॉय' (CCAs) को डिज़ाइन और विकसित किया है; इसके अलावा हाइड्रोजन भंडारण के लिए 'हाई एंट्रॉपी अलॉय', उच्च बैलिस्टिक क्षमता वाला 'आर्मर स्टील', और बायोमेडिकल अनुप्रयोगों के

लिए Zr-आधारित 'बायोकम्पैटिबल अलॉय' भी विकसित किए हैं—ये उनमें से कुछ प्रमुख उदाहरण हैं। यह प्रयोगशाला उद्योगों को इंजीनियरिंग घटकों के शेष जीवन-काल के आकलन, संरचनात्मक अखंडता के आकलन, स्वास्थ्य की निगरानी और विफलता के विश्लेषण के क्षेत्र में भी उत्कृष्ट सेवाएँ प्रदान करती है। तेल, ऊर्जा, अंतरिक्ष, नौसेना, रक्षा और परमाणु जैसे कई औद्योगिक क्षेत्र इस डोमेन के अनेक कार्यक्रमों में भागीदार हैं।

देश के सामाजिक-आर्थिक विकास में इस प्रयोगशाला का योगदान उल्लेखनीय है। सीएसआईआर-एनएमएल ने समाज तक पहुँचने के लिए कई कार्यक्रम शुरू किए हैं। यह प्रयोगशाला पारंपरिक तकनीकों को उन्नत करके और धातु-सामग्री का काम करने वाले कारीगरों के लिए प्रासंगिक नवाचारों को लागू करके, देश के कारीगरों की समृद्धि और लाभ के लिए लगातार प्रयास कर रही है। सीएसआईआर-एनएमएल ने ऊर्जा-कुशल और पर्यावरण-अनुकूल, कोक-आधारित पीतल और घंटा-धातु (bell metal) गलाने वाली भट्टी विकसित की है, जिसके पारंपरिक भट्टियों की तुलना में कई फायदे हैं। प्रयोगशाला ने तांबे, पीतल और कांस्य की सतहों पर इस्तेमाल के लिए एक 'एंटी-टार्निशिंग लैकर' भी विकसित किया है, जो AMAZON जैसे ऑनलाइन मार्केटिंग स्टोर के माध्यम से 'BRASS CARE' नाम से व्यावसायिक रूप से उपलब्ध है।

इस प्रयोगशाला ने भारत सरकार के "स्किल इंडिया" मिशन में भी योगदान दिया है और यह स्कूल व कॉलेज के छात्रों, उद्यमियों और औद्योगिक सहयोगियों जैसे विभिन्न वर्गों के प्रतिभागियों को प्रशिक्षण प्रदान करती है। सीएसआईआर-एकीकृत कौशल विकास कार्यक्रम (CSIR-Integrated Skill Development Program) ऐसा ही एक कार्यक्रम है, जो विभिन्न स्तरों पर लोगों के विविध वर्गों की ज़रूरतों को पूरा करता है—जिसमें स्कूल छोड़ने वालों से लेकर किसानों, ITI डिप्लोमा धारकों और स्नातकों तक सभी शामिल हैं। इसका मुख्य उद्देश्य धातु, धातु-विज्ञान, विनिर्माण, अपशिष्ट उपयोग, सॉफ्ट स्किल्स और उद्यमिता विकास के क्षेत्रों में कौशल विकसित करना है। इस प्रयोगशाला ने एक 'ई-वेस्ट क्लस्टर' बनाने की पहल की है। इस कार्यक्रम का लक्ष्य क्षमता निर्माण और तकनीकी प्रगति पर ध्यान केंद्रित करके इलेक्ट्रॉनिक कचरे (ई-वेस्ट) की बढ़ती चुनौती का समाधान करना है। इसके प्रमुख उद्देश्यों में अनौपचारिक क्षेत्र की क्षमता का निर्माण और उसका उन्नयन करना; MSME योजना के तहत रीसाइक्लिंग क्लस्टरों का गठन करना; और ई-वेस्ट से कीमती सामग्री—जैसे धातु, प्लास्टिक और दुर्लभ मृदा तत्व (rare earth elements)—को निकालने के लिए उन्नत तकनीकों का विकास और कार्यान्वयन करना शामिल है, जिससे संसाधनों की दक्षता को बढ़ावा मिले और एक 'चक्रीय अर्थव्यवस्था' (circular economy) को समर्थन प्राप्त हो।

इस संस्थान ने भविष्योन्मुखी सहयोगात्मक, अनुसंधान एवं विकास और शैक्षणिक उद्देश्यों को पूरा करने के लिए दुनिया भर के शैक्षणिक संस्थानों के साथ सहयोग भी स्थापित किया है। संस्थान ने दीर्घकालिक शैक्षणिक आदान-प्रदान, संयुक्त अनुसंधान और एक-दूसरे की सुविधाओं तक पहुँच को सक्षम बनाने के लिए कई सहयोगात्मक MoU पर हस्ताक्षर किए हैं, ताकि धातुकर्म, पृथ्वी विज्ञान और औद्योगिक विकास के विस्तार में बेहतर सुविधाएँ प्रदान की जा सकें। IIT-कानपुर, IIT-पटना, OP जिंदल विश्वविद्यालय, IIT मद्रास, IIT रुड़की, IIT खड़गपुर, IIT बॉम्बे, कलकत्ता विश्वविद्यालय, शिव नादर विश्वविद्यालय, सत्यभामा विश्वविद्यालय, और अंतरराष्ट्रीय शैक्षणिक आदान-प्रदान के लिए यूनिवर्सिटी

ऑफ़ स्टावांगर-नॉर्वे, यूनिवर्सिटी ऑफ़ मिस्कोल्क, कोरिया मैरीटाइम यूनिवर्सिटी (KMU), यूनिवर्सिटी ऑफ़ सैंटियागो-डी-कम्पोस्टेला (जो संसाधनों के उपयोग और पुनर्चक्रण प्रौद्योगिकी के अनुसंधान और विकास का एक सहयोगात्मक कार्यक्रम शुरू करने के इच्छुक हैं), QUB, बेलफ़ास्ट; यूनिवर्सिटी ऑफ़ स्टटगार्ट ऐसे ही कुछ शैक्षणिक संस्थान हैं जिनके साथ समझौते किए गए हैं। सीएसआईआर-एनएमएल ने कई प्रमुख सरकारी संगठनों के साथ सहयोग जारी रखा है, जैसे: भारतीय सशस्त्र बल, भारतीय नौसेना, डीएई, बीएआरसी, आईजीसीएआर, एनएफडीसी, डीएसटी, डीएमआरएल, बीएचईएल, एनटीपीसी, ओएनजीसी, आईओसीएल, बीपीसीएल, सेल, एचएएल, इसरो, भारतीयरेलवे, आरडीएसओ, विभिन्न ऑर्डिनेंस फैक्ट्रियां, मेकॉन, एआरडीबी, एनआरबी, और अन्य। इसके अलावा, सीएसआईआर-एनएमएल निजी क्षेत्र की अग्रणी कंपनियों के साथ भी साझेदारी करता है, जिनमें शामिल हैं: टाटा स्टील, जेएसडब्ल्यू, कल्याणी स्टील, विजाग स्टील, एस्सार स्टील, जेएसपीएल, नाल्को, टाटा मोटर्स, वेदांता, हिंडाल्को, आदित्य बिड़ला ग्रुप, टाटा ब्लूस्कोप, आईएफबी लिमिटेड, क्वेकर केमिकल्स, एलएंडटी, जीई इंडिया, भारत फोर्ज, रामकृष्ण फोर्जिंग, अशोक लीलैंड, श्री सीमेंट, जीएसीएल, फाइजर, रिलायंस इंडस्ट्रीज और विभिन्न रिफाइनरियां, आदि।

हमारा दृष्टि वक्तव्य

"खनिज, धातुकर्म तथा अनुसंधान एवं विकास के क्षेत्र में एक वैश्विक अग्रणी और अंतरराष्ट्रीय मानकों पर खरी उतरने वाली प्रयोगशाला बनना। खनिजों, धातुओं और पदार्थों के क्षेत्र में एक आत्मनिर्भर प्रौद्योगिकी केंद्र बनना।"



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. Niti Aayog 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."



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

MANAGEMENT COUNCIL

Director
CSIR-National Metallurgical Laboratory



Dr. Sandip Ghosh Chowdhury

RESEARCH COUNCIL

R&D Divisions/Centre



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



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



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



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



Dr. Sandip Ghosh Chowdhury
Scientist G & Head
Applied And Analytical Chemistry (AAC)



Dr. M. Ananda Rao
Scientist F & Head
CSIR-NML Madras Centre (NML-MC)

R&D Support Divisions



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



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



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



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

Functionaries



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



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



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



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

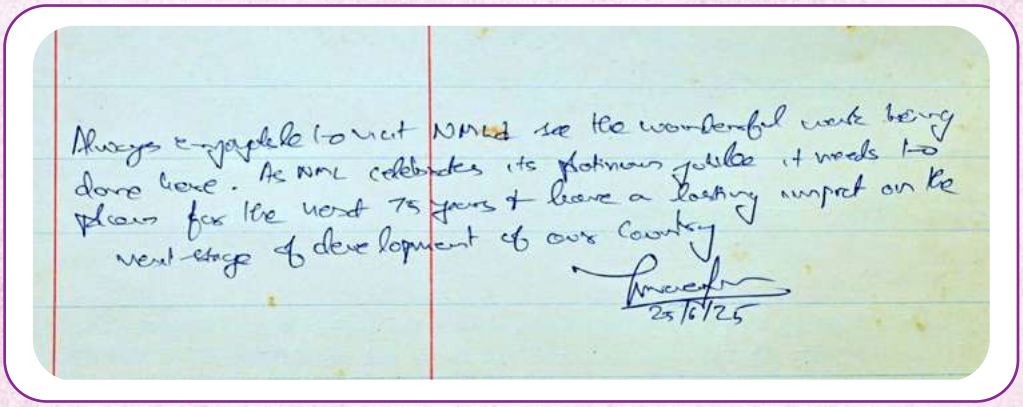


Shri. Bhola Azad
Stores and Purchase Officer (SPO)
Stores and Purchase (S&P)



Shri. Naveen Kumar Sharma
Stores and Purchase Officer (SPO)
Stores and Purchase (S&P)





"Always enjoyable to visit NML and see the wonderful work being done here. As NML celebrates platinum jubilee it needs to place for the past 75 years to have a lasting impact on the best stage of development of our country. "

T.V. Narendran
MD Tata Steel
Date: 25th June 2025

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. Rajneesh Kumar Gupta
Scientist F,
CSIR Headquarters, New Delhi



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

Impressions



NML is to be congratulated for completing 75 years of glorious service in the field of Material Science and metallurgy. I am really impressed by the quality of infrastructure particularly in the area of high temp creep testing and other testing facilities. The work in Exchange metallurgy is unique to NML, particularly the extraction of RE from Red-Mud. An air atomisation based metal powder production is also praise worthy.
I am really impressed by the passion of scientists in their respective field of work. The initiatives taken to take the technology to industry are also outstanding.
The leadership is dynamic, team work is excellent and culture of transdisciplinary and inter institutional research is prevalent.
I wish all the Scientist, staff and students the very best in all their future endeavours.
God Bless U all
V K Saraswat

"NML is to be congratulated for completing 75 years of glorious service in the field of material science and metallurgy. I am really impressed by the quality of infrastructure, particularly in the area of high testing and other testing facilities. The work in exchange metallurgy is unique for NML, particularly the extraction of RE from red-hud. An air atom-based metal powder producer is also praiseworthy." I am really impressed by the passion for materials in their respective field of work. The initiatives taken to take the technology to industry are also outstanding. The leadership is dynamic; teamwork is excellent. Research is prevalent. I wish all the scientists, staff and students the very best in all their future endeavours. God bless you all."

Dr. V. K Saraswat
Member NITI Aayog, New Delhi
Date: 02nd July-2025

The Performance

Hazira Port Steel Slag Road-World's First Port Road Using Steel Slag

Natural resources like metals and materials form part of our lives in innumerable forms. We rely on these resources every day, but they are limited. Although the idea of sustainability was introduced in the 1970s, the need to promote and practice it is being felt deeply today. A few instances of successful real-world examples that show us the remarkable utilization of recycled metals and materials have been highlighted in this book.

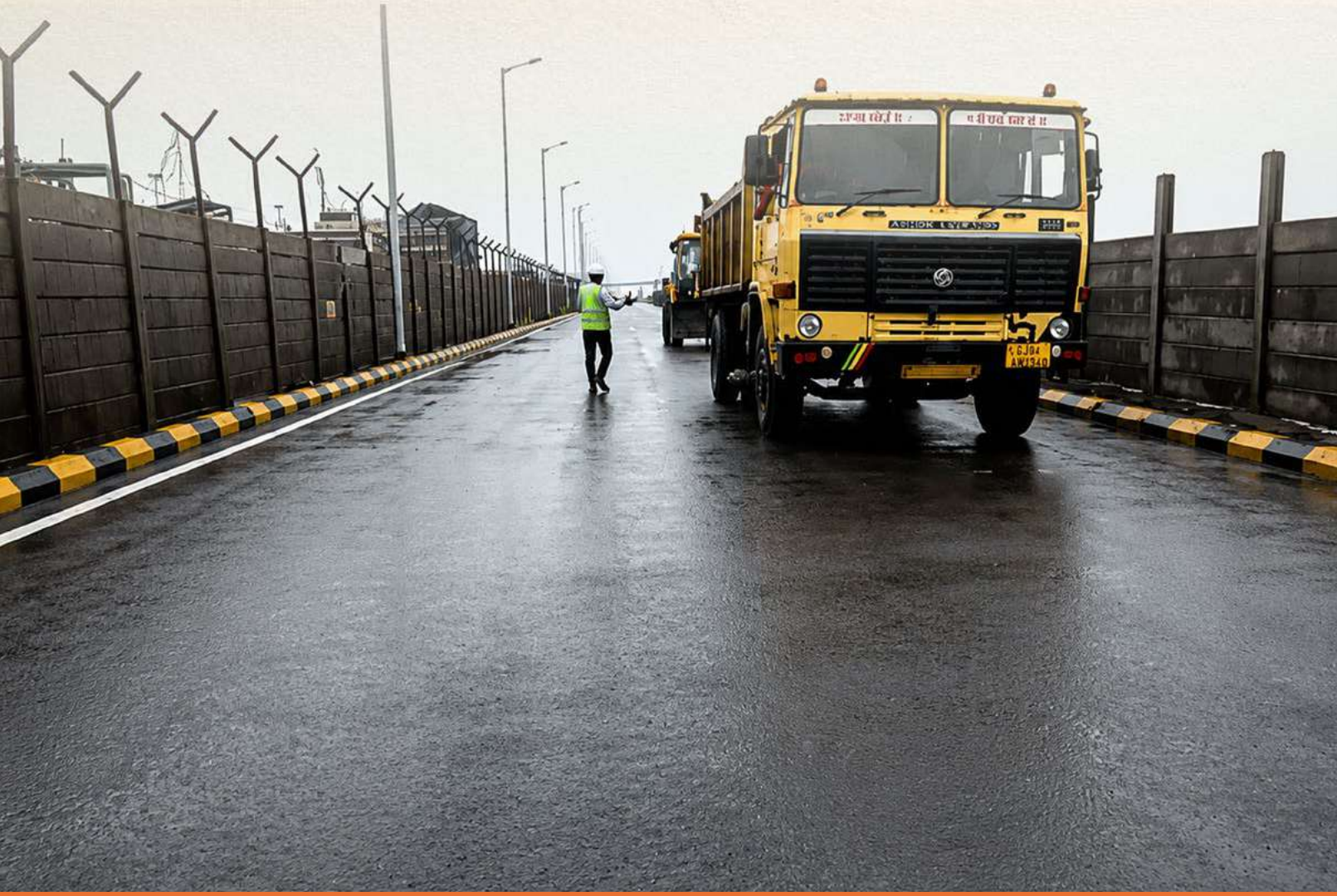


Image Source: https://www.ndtv.com

https://crridom.gov.in/en/node/2358

TURNING METAL SCRAP INTO ART







Using recycled metal minimizes mining demand, slashing carbon emissions and energy use. It diverts viable materials from landfills, fostering zero-waste, eco-friendly art practices. Beyond sustainability, scrap metal delivers a distinctive, raw, industrial aesthetic. The scratches, dents, and imperfections imbue each piece with a history and soul that new materials cannot replicate. Furthermore, found objects challenge conventional artistic methods. Instead of carving or modeling, creators must cut, weld, and assemble, transforming each sculpture into a complex puzzle.

https://aimgallery.in/how-artists-are-using-recycled-metal-for-sculptures/



निदेशक की प्रस्तावना

मुझे सीएसआईआर-राष्ट्रीय धातुकर्म प्रयोगशाला की वार्षिक रपट 2025-26 को प्रस्तुत करते हुए अत्यंत हर्ष की अनुभूति हो रही है। हमें यह अवसर खनिज, धातु और सामग्री अभियांत्रिकी के क्षेत्र में हमारे 75 वर्षों के प्रभावशाली योगदान के पूरा होने का एक महत्वपूर्ण पड़ाव है। हमारे दीर्घकालिक दृष्टिकोण पर आधारित और हमारे वैज्ञानिक, तकनीकी तथा प्रशासनिक कर्मचारियों की सामूहिक प्रतिबद्धता से प्रेरित होकर, हमने धातु, खनिज और सामग्री अभियांत्रिकी के क्षेत्र में हमने राष्ट्रीय प्रासंगिक, वैश्विक मानकों पर खरी उतरने वाली और उत्तरोत्तर आत्मनिर्भर संस्था के रूप में अपनी स्थिति को और सुदृढ़ किया है। एक तेज़ी से बदलते वैश्विक परिदृश्य में—जो कि स्थिरता की अनिवार्यताओं, संसाधन सुरक्षा की चिंताओं और तकनीकी व्यवधानों से चिह्नित है—सीएसआईआर-एनएमएल राष्ट्रीय प्राथमिकताओं और वैश्विक स्थिरता लक्ष्यों के अनुरूप, प्रौद्योगिकी-आधारित समाधान प्रदान करने हेतु अपने मिशन पर अडिग है।

वर्ष 2025-26 का विशेष महत्व है क्योंकि हम 1950 में अपनी स्थापना की प्लेटिनिम जयंती मना रहे हैं। 26 नवंबर 2024 (सीएसआईआर-एनएमएल स्थापना दिवस) को उद्घाटन किया गया साल भर चलने वाला समारोह पूरे वर्ष जारी रहा और 26 नवंबर 2025 को समाप्त हुआ। स्मारक वर्ष में संगोष्ठियों, उद्योग बैठकों, अंतर्राष्ट्रीय सम्मेलनों और तकनीकी व्याख्यानों की एक विस्तृत श्रृंखला देखी गई, जो प्रयोगशाला की जीवंतता और पहुंच को दर्शाती है। इनमें क्रिटिकल मेटल कांग्रेस (CRITMET 2025), मैटेरियल्स इंडिमैट के स्वदेशीकरण पर उद्योग सम्मेलन: रणनीतिक क्षेत्र 2025 में चुनौतियां और अवसर, 'खनिज और धातुओं के लाभ और निष्कर्षण - सतत विकास के लिए अनुसंधान, संसाधन और उद्योग को जोड़ना' पर उद्योग सम्मेलन, खनिज लाभकारी प्रौद्योगिकियों में उभरते रुझानों पर राष्ट्रीय सम्मेलन (EMBT 2025), अगली पीढ़ी के गैल्वेनाइज्ड और कलर कोटेड स्टील्स पर अंतर्राष्ट्रीय सम्मेलन (गैल्वानेक्स्ट 2026) शामिल हैं।

समीक्षाधीन वर्ष में, प्रभावकारी और अनुप्रयोग-उन्मुख अनुसंधान पर विशेष ज़ोर दिया गया है, जिससे राष्ट्रीय प्राथमिकताओं और उभरती हुई तकनीकी आवश्यकताओं के प्रति हमारी प्रतिबद्धता और सुदृढ़ हुई है। नवाचार और ज्ञान के व्यावहारिक उपयोग पर लगातार ध्यान केंद्रित करने की झलक इस वर्ष सृजित बौद्धिक संपदा में मिलती है, जिसमें 04 पेटेंट आवेदन और 03 कॉपीराइट शामिल हैं। इसके अलावा, उद्योग जगत के भागीदारों के साथ संयुक्त पहलों से उभरने वाले कई पेटेंट प्रस्ताव विचार-विमर्श के उन्नत चरणों में हैं, जो हमारे सहयोगात्मक अनुसंधान पारिस्थितिकी तंत्र की बढ़ती

परिपक्वता का संकेत देते हैं। हमारा वैज्ञानिक योगदान मज़बूत बना रहा, जिसमें SCI-इंडेक्स्ड जर्नल्स में कुल 155 प्रकाशन शामिल हैं, जो हमारे काम की गहराई और समकालीन प्रासंगिकता दोनों को रेखांकित करती हैं।

तकनीकी विकास और उसका हस्तांतरण हमारे इस मुख्य उद्देश्य के लिए बहुत ज़रूरी है कि हम प्रयोगशाला में होने वाली अनुसंधान को औद्योगिक अनुप्रयोग में उसके इस्तेमाल से जोड़ सकें। इस वर्ष के दौरान, हमने उद्योगों और MSME को 08 प्रौद्योगिकियों हस्तांतरित कीं। इनमें शामिल हैं: अपशिष्ट PCBs से Cu, Al और Au (धातुओं/लवणों के रूप में) जैसे बिक्री योग्य उत्पादों की रिकवरी - मेसर्स Eyantram Waste Management Pvt. Ltd. को; MnSO4 घोल से इलेक्ट्रोलाइटिक मैंगनीज धातु (EMM) का उत्पादन - मेसर्स Sarthi Aerospace & Defence Pvt. Ltd., हरियाणा को; GI लाइन में जिंक कोटिंग के वज़न को मापने के लिए सेंसिंग डिवाइस 'Zincometer' - मेसर्स Ajanta Refosteel Chemicals Pvt. Ltd., जमशेदपुर को; विभिन्न PCBs की रीसाइक्लिंग करके सोना, तांबा और एल्युमीनियम की रिकवरी - मेसर्स EnviroServe Technologies, नई दिल्ली को; Li, Ni, Co, Mn और दोबारा इस्तेमाल होने वाले ग्रेफाइट की रिकवरी के लिए लिथियम-आयन बैटरी - मेसर्स TerraNova Eco Management Pvt Ltd., बेंगलुरु को; इस्तेमाल हो चुके NdFeB मैग्नेट से 'Rare Earth' की रिकवरी - मेसर्स Renocell Recycling Pvt. Ltd., कोलकाता को; इस्तेमाल हो चुके मैग्नेट से 'Rare Earth' की रिकवरी - मेसर्स Shape Shift Energies Pvt. Ltd., तेलंगाना को; और 'Billet Caster' में 'Breakout' को रोकने के लिए 'Instrumented billet mould' - Ajanta Refosteel, जमशेदपुर। ये प्रयास स्वदेशी प्रौद्योगिकी के विकास, आयात प्रतिस्थापन और MSME की प्रतिस्पर्धात्मकता को सुदृढ़ करने पर दिए जा रहे राष्ट्रीय बल के साथ घनिष्ठ रूप से संरेखित हैं। इसके अलावा, अलग-अलग प्रौद्योगिकी तत्परता स्तर (TRL 5-9) पर कई प्रौद्योगिकी विकसित की गई हैं, जिनमें MgO-लाइन वाले इंडक्शन फर्नेस में स्टील से फॉस्फोरस हटाने के लिए किफ़ायती नॉन-फ्यूज्ड फ्लक्स टेक्नोलॉजी; एल्यूमिना, आयरन, रेयर अर्थ ऑक्साइड और टाइटेनिया को रिकवर करने के लिए रेड मड की पूरी रीसाइक्लिंग, जिसमें बचे हुए अवशेषों का भी इस्तेमाल किया जाता है; ज़्यादा मज़बूती, इम्पैक्ट टफ़नेस और घिसाव-रोधी क्षमता वाला हॉट रोल्ड लो अलॉय स्टील; और इस्तेमाल हो चुके मैग्नेट स्क्रैप (EV गाड़ियाँ, हार्ड डिस्क, विंड टर्बाइन, बटन मैग्नेट, स्वार्फ़, मशीनिंग स्क्रैप और MRI मैग्नेट) से ऑक्साइड के रूप में रेयर अर्थ की रिकवरी शामिल है। ये नवाचार स्थिरता, पुनर्चक्रण, रक्षा, उन्नत सामग्री और बुनियादी ढांचे के क्षेत्र में राष्ट्रीय प्राथमिकताओं को सीधे तौर पर समर्थन देते हैं। आगे बढ़ते हुए, हमारा लक्ष्य सुनियोजित औद्योगिक साझेदारियों, इन्क्यूबेशन तंत्रों और राष्ट्रीय नवाचार मंचों के साथ एकीकरण के माध्यम से इनके व्यावसायीकरण की गति को तेज़ करना है।

हमारा वित्तीय प्रदर्शन सीएसआईआर विजन 2030 में तय किए गए लक्ष्यों की ओर लगातार हो रही प्रगति को दिखाता है, खासकर बाहरी राजस्व जुटाने और उद्योगों के साथ जुड़ाव बढ़ाने के मामले में। इस वर्ष बाहरी कैश फ़्लो (ECF) 29.78 करोड़ रहा, जिसमें से 19.58 करोड़ का योगदान औद्योगिक स्रोतों से आया; यह उद्योग के लिए तकनीकी भागीदार के तौर पर हमारी बढ़ती भूमिका का एक उत्साहजनक संकेत है। हमने राष्ट्रीय और अंतरराष्ट्रीय संगठनों के साथ 56 MoU और समझौतों को औपचारिक रूप दिया, जिससे हमारे सहयोगी इकोसिस्टम को मज़बूती मिली। उल्लेखनीय अंतरराष्ट्रीय साझेदारियों में इंडियन रेयर अर्थ्स लिमिटेड टेक्नोलॉजी डेवलपमेंट काउंसिल, ओडिशा; वेदांता प्राइवेट लिमिटेड, ओडिशा; सारथी एयरोस्पेस एंड डिफेंस प्राइवेट लिमिटेड, हरियाणा; ईयंत्रम वेस्ट मैनेजमेंट प्राइवेट लिमिटेड, आंध्र प्रदेश; IISC-बेंगलुरु; CSIRO-ऑस्ट्रेलिया; टाटा स्टील लिमिटेड, जमशेदपुर; CSIR-CIMFR, धनबाद; हिंदुस्तान जिंक लिमिटेड, उदयपुर; TCS, मुंबई; ऑर्डनेंस फैक्ट्री, अंबाझरी; UNDP, नई दिल्ली; NIT, रायपुर; NALCO, भुवनेश्वर और अन्य के साथ सहयोग रूप से शामिल हैं।

हमारे प्रमुख कार्यक्रम बड़े पैमाने पर, मिशन-उन्मुख प्रभाव

डालना जारी रखे हुए हैं—विशेष रूप से उन क्षेत्रों में, जो 'आत्मनिर्भर भारत' और 'विकसित भारत 2047' के लक्ष्यों के अनुरूप हैं। सीएसआईआर-एनएमएल की मैग्नीशियम पायलट प्लांट पहल स्वदेशी प्रक्रिया विकास की दिशा में एक महत्वपूर्ण कदम है, जिसमें स्केल-अप गतिविधियाँ अर्ध-सतत संचालन की ओर अग्रसर हैं। बेहतर रिटॉर्ट तकनीक का उपयोग करके प्रतिदिन 120-150 किलोग्राम मैग्नीशियम उत्पादन के लिए डिज़ाइन किया गया यह प्रस्तावित पायलट प्लांट, रणनीतिक क्षेत्रों के लिए हल्के पदार्थों के क्षेत्र में घरेलू क्षमता को बढ़ाने में महत्वपूर्ण योगदान देने की उम्मीद है। वर्ष 2024 में आधारशिला रखे जाने के बाद, प्लांट की वर्तमान प्रगति में 150 किलोग्राम की ड्राई प्रेस ब्रिकेटिंग मशीन की स्थापना, 2TPD रोटरी भट्टी कैल्सीनेशन प्लांट को चालू करना, वैक्यूम रिडक्शन और डिस्टिलेशन प्लांट का डिज़ाइन और खरीद, तथा विभिन्न डोलोमाइट ग्रेड के लिए बेंचमार्किंग शामिल है। प्रस्तावित Mg प्लांट के 2026-27 में चालू होने की उम्मीद है। 'उच्च-दबाव वाली हाइड्रोजन गैस के अंतर्गत सामग्री मूल्यांकन केंद्र' की आधारशिला 26 नवंबर 2025 को सीएसआईआर की महानिदेशक डॉ. (श्रीमती) एन. कलैसेल्वी द्वारा रखी गई। देश में अपनी तरह की यह पहली और दुनिया में ऐसी कुछ ही सुविधाओं में से एक सुविधा—यह केंद्र—भारत सरकार के नवीन और नवीकरणीय ऊर्जा मंत्रालय (MNRE) के तहत राष्ट्रीय सौर ऊर्जा संस्थान (NISE) के सहयोग से, राष्ट्रीय हरित हाइड्रोजन मिशन (NGHM) के अंतर्गत स्थापित किया गया है। यह केंद्र उच्च-दबाव वाले हाइड्रोजन वातावरण में काम करने वाली उन्नत सामग्री मूल्यांकन सुविधाओं की मेज़बानी करेगा, जिसमें धीमी स्ट्रेन दर परीक्षण, फ्रैक्चर टफनेस (KIH) मूल्यांकन, थर्मल डिसोर्प्शन स्पेक्ट्रोमीटर और हाइड्रोजन पारगम्यता अध्ययन शामिल हैं। यह केंद्र हाइड्रोजन के भंडारण, परिवहन और संबंधित ऊर्जा अनुप्रयोगों के लिए स्वदेशी सामग्री के विकास और योग्यता को समर्थन देने में एक अहम भूमिका निभाने के लिए तैयार है। सीएसआईआर-एनएमएल, भारत के महत्वपूर्ण खनिज आपूर्ति श्रृंखलाओं को सुरक्षित करने और आयात पर निर्भरता कम करने के प्रयासों के अनुरूप, प्राथमिक और माध्यमिक दोनों स्रोतों से नियोबियम, टैंटलम और स्कैंडियम जैसी महत्वपूर्ण धातुओं को निकालने की तकनीकों के विकास में सबसे आगे रहा है। इन क्षमताओं को मान्यता देते हुए, भारत सरकार के खान मंत्रालय ने सीएसआईआर_एनएमएल को 'राष्ट्रीय क्रिटिकल खनिज मिशन' (NCMM) के तहत 'उत्कृष्टता केंद्रों' (CoE) में से एक के रूप में मान्यता प्रदान की। मुझे यह बताते हुए खुशी हो रही है कि, भारत में पहली बार, सीएसआईआर-एनएमएल ने आभूषण उद्योग में एडिटिव मैन्युफैक्चरिंग और संबद्ध अनुप्रयोगों के लिए उपयुक्त 22 कैरेट और 18 कैरेट सोने के मिश्र धातु पाउडर का उत्पादन किया। पाउडर का उत्पादन हमारे अत्याधुनिक प्रयोगशाला पैमाने पर अक्रिय गैस एटमाइज़र, AU1000-HTC का उपयोग करके किया गया था, जो भारत में अपनी तरह का पहला है। अन्य परिणामों में नरम चुंबकीय अनुप्रयोगों के लिए Fe-Si क्रिस्टलीय और FeBCPSiCrMo अनाकार मिश्र धातु पाउडर और HVOF कोटिंग्स के लिए FeCrMo-आधारित अनाकार पाउडर का विकास शामिल है। हाल ही में, मैसर्स लैटिस एयरोस्पेस, हैदराबाद के साथ एक सहयोगात्मक कार्य ने धातु योजक निर्माण के लिए उपयुक्त FeSiBC (Cr) मिश्र धातु पाउडर का उत्पादन किया।

सस्टेनेबिलिटी और नेट ज़ीरो लक्ष्यों पर आधारित राष्ट्रीय मिशनों के अनुरूप, सीएसआईआर-एनएमएल कम-कार्बन वाली धातुकर्म प्रक्रियाओं, संसाधन दक्षता और रीसाइक्लिंग के क्षेत्र में शोध और तकनीकी विकास को सक्रिय रूप से आगे बढ़ा रहा है। हाइड्रोजन-आधारित रिडक्शन, कचरे के सही इस्तेमाल और ऊर्जा-कुशल प्रोसेसिंग पर हमारी पहलें भारत के कम-कार्बन वाली अर्थव्यवस्था की ओर बढ़ने में सहायता करने के लिए बहुत ज़रूरी हैं। अपने एक महत्वपूर्ण प्रयास मेंसीएसआईआर-एनएमएल इस्तेमाल के बाद बेकार हो चुके NdFeB मैग्नेट के लिए एक सीधे, शॉर्ट-लूप रीसाइक्लिंग तरीके पर ध्यान केंद्रित कर रही है, ताकि सामग्री को कुशलतापूर्वक वापस प्राप्त किया जा सके। इस प्रक्रिया में स्क्रैप मैग्नेट को

वापस पाना, दोबारा पिघलाकर मिश्र धातु को फिर से एकसार करना, मेल्ट-स्पिनिंग के ज़रिए तेज़ी से ठोस होने वाले रिबन बनाना, और फिर हॉट-प्रेसिंग और डाई-अपसेटिंग के ज़रिए उन्हें जोड़कर एनिसोट्रोपिक बल्क मैग्नेट बनाना शामिल है। इस महत्वपूर्ण कार्य का उद्देश्य पुनर्चक्रित सामग्रियों में उच्च चुंबकीय प्रदर्शन को बनाए रखते हुए, सतत पुनर्चक्रण को बढ़ावा देना है। इसके अतिरिक्त, 'हायर-ऑपरेट-ट्रांसफर' (HOT) मॉडल के तहत स्थापित बैटरी पुनर्चक्रण पायलट प्लांट MSMEs और स्टार्ट-अप्स के लिए उपलब्ध है। अर्बन ओर रीसाइक्लिंग सेंटर (UORC) ने उन्नत ई-कचरा रीसाइक्लिंग तकनीकों के विकास में अपनी अहम भूमिका निभाना जारी रखा, जिसका उद्देश्य 'शून्य-कचरा' परिणाम प्राप्त करना और उच्च-मूल्य वाली धातुओं को पुन: प्राप्त करना है। सीएसआईआर-एनएमएल मिशन परियोजना सौर पैनल, इलेक्ट्रिकल/इलेक्ट्रॉनिक उपकरणों के एयर कंडीशनर अपशिष्ट से टिकाऊ सामग्री (सी-एसईएएस) में नोडल है, जिसमें 30 घटक और 11 भाग लेने वाली प्रयोगशालाएं शामिल हैं। इस परियोजना को क्षेत्र में "उद्योग के लिए तैयार" प्रौद्योगिकियों के विकास के लिए उच्च उम्मीदें हैं। मिशन का उद्देश्य भारत में सर्कुलर इकोनॉमी पर एक औसत दर्जे का प्रभाव पैदा करने के लिए उद्योग के हितधारकों और भागीदारों को बनाना है।

हमारे लोग हमारी सफलता की आधारशिला बने हुए हैं। हमारे वैज्ञानिकों और कर्मचारियों की उपलब्धियों को कई प्रतिष्ठित पुरस्कारों के माध्यम से मान्यता दी गई है, जिनमें भारतीय धातु संस्थान से डॉ. अम्मासी ए.-यंग मेटलर्जिस्ट अवार्ड (लौह श्रेणी), डॉ. अवनीश कुमार चंदन- इंस्टीट्यूट ऑफ इंजीनियर्स (इंडिया) से यंग इंजीनियर्स अवार्ड, इंस्टीट्यूट ऑफ इंजीनियर्स (इंडिया) से डॉ. के. एल. साहू- प्रख्यात वैज्ञानिक पुरस्कार, डॉ. प्रेम कुमार-आईएनएई यंग इंजीनियर अवार्ड, एन.एम. संपत राष्ट्रीय पुरस्कार, डॉ. रंजीत सिंह-राष्ट्रीय भूविज्ञान पुरस्कार 2024, डॉ. आशीष कुमार पांडा- भारतीय समाज की ओर से एनडीटी सिस्टम नवाचार और विकास के लिए राष्ट्रीय पुरस्कार, और डॉ. महेश वालुंज- एनएम संपत राष्ट्रीय पुरस्कार 2025 और राष्ट्रीय संक्षारण चैम्पियनशिप ट्रॉफी-2025। हमारे वैज्ञानिकों में से एक, डॉ. विनोद बेलवंशी को होमी भाभा नेशनल इंस्टीट्यूट (एचबीएनआई), मुंबई द्वारा एचबीएनआई के पूर्व छात्र राजदूत के रूप में चुना गया है। हमारी पांच महिला वैज्ञानिकों डॉ. बीना कुमारी, डॉ. मीता तराफदर, सुश्री एन. वसुमति, डॉ. प्रतिमा मेश्राम, डॉ. शर्मिष्ठा पालित सागर और डॉ. शोभना डे को सीएसआईआर-एनएएल द्वारा एसटीईएम संग्रह में सीएसआईआर महिलाओं में उपलब्धि हासिल करने वाली महिलाओं के रूप में सूचीबद्ध किया गया है। ये मान्यताएं उत्कृष्टता, समर्पण और नवाचार को दर्शाती हैं जो सीएसआईआर-एनएमएल को परिभाषित करती हैं।

जैसे ही हमने अपने प्रभावशाली योगदानों के 75 वर्ष पूरे होने का जश्न मनाया, हम आज एक ऐसे महत्वपूर्ण मोड़ पर खड़े हैं जहाँ धातुकर्म और पदार्थ विज्ञान, स्थिरता और डिजिटल प्रौद्योगिकियाँ के साथ मिलकर विनिर्माण और संसाधन उपयोग के भविष्य को फिर से परिभाषित कर रही हैं। सीएसआईआर विज़न 2030 के अनुरूप, हम मिशन-मोड परियोजनाओं, उद्योग सह-निर्माण और अनुप्रयोग अनुसंधान पर अपना ध्यान केंद्रित जारी रखेंगे। हमारी रणनीतिक प्राथमिकताओं में महत्वपूर्ण खनिज, उन्नत संरचनात्मक और कार्यात्मक सामग्री, चक्रीय अर्थव्यवस्था प्रौद्योगिकियां और कम-कार्बन प्रक्रिया नवाचार शामिल होंगे। भविष्य की ओर देखते हुए, हम 'समाज के लिए विज्ञान' और 'परिवर्तन के लिए प्रौद्योगिकी' के मार्गदर्शक सिद्धांतों के प्रति अपनी प्रतिबद्धता को दोहराते हैं। हमारे प्रयास 'विकसित भारत 2047' जैसे राष्ट्रीय मिशनों के अनुरूप रहेंगे, जिसमें धातु, खनिज और सामग्री के क्षेत्र में आत्मनिर्भरता, स्थिरता और समावेशी विकास पर विशेष ज़ोर दिया जाएगा।

स. घोष चौधुरी

(संदीप घोष चौधुरी)



Director's Foreword

It is my pleasure to present the Annual Report 2025–26 of CSIR–National Metallurgical Laboratory on the momentous occasion of completing 75 years of impactful contributions in the field of minerals, metals, and materials engineering. Anchored in our long-term vision and driven by the collective commitment of our scientific, technical, and administrative staff, we have continued to strengthen our position as a nationally relevant, globally benchmarked, and increasingly self-sustaining institution in the domain of metals, minerals, and materials engineering. In a rapidly evolving global landscape, marked by sustainability imperatives, resource security concerns, and technological disruption, CSIR-NML remains steadfast in its mission to deliver technology-driven solutions aligned with national priorities and global sustainability goals.

The year 2025-26 holds special significance as we commemorate the Platinum Jubilee of our foundation in 1950. The year-long celebrations, inaugurated on 26 November 2024 (CSIR-NML Foundation Day), continued throughout the year and culminated on 26 November 2025. The commemorative year witnessed a wide array of symposia, industry meets, international conferences, and technical lectures, reflecting the vibrancy and outreach of the laboratory. These included Critical Metal Congress (CRITMET 2025), Industry Conclave on Indigenization of Materials IndiMat): Challenges & Opportunities in Strategic Sector 2025, Industry Conclave on 'Beneficiation & Extraction of Minerals and Metals - Bridging Research, Resources, and Industry for Sustainable Growth', National Conference on Emerging Trends in Mineral Beneficiation Technologies (EMBT 2025), International Conference on Next Generation Galvanized and Color Coated Steels (GalvaNext 2026).

The year under review has been marked by a strong emphasis on impactful and application-oriented research, reinforcing our commitment to national priorities and emerging technological needs. A continued focus on innovation and knowledge translation is reflected in the intellectual property generated during the year, including 04 patent filings and 03 copyrights. In addition, several patent proposals emerging from joint initiatives

with industry partners are in advanced stages of consideration, indicating the growing maturity of our collaborative research ecosystem. Our scientific output remained robust, with a total of 155 publications in SCI-indexed journals underscoring both the depth and contemporary relevance of our work.

Technology development and transfer remain critical to our mandate of bridging laboratory research with industrial application. During the year, we transferred 08 technologies to industries and MSMEs, encompassing Recovery of saleable products of Cu, Al and Au as Metals/ salts from waste PCBs to M/s. Eyantram Waste Management Pvt. Ltd.; Production of Electrolytic Manganese Metal (EMM) from MnSO4 Solutions to M/s. Sarthi Aerospace & Defence Pvt. Ltd., Haryana; Sensing Device Zincometer for Zinc Coating Weight Measurement in GI line to M/s Ajanta Refosteel Chemicals Pvt. Ltd., Jamshedpur; Recycling of Different PCBs to Recover Gold, Copper and Aluminum to M/s. EnviroServe Technologies, New Delhi; Lithium-Ion Battery for the Recovery of Li, Ni, Co, Mn and reusable graphite to M/s. TerraNova Eco Management Pvt Ltd., Bengaluru; Rare Earth Recovery from Spent NdFeB Spent Magnets to M/s. Renocell Recycling Pvt. Ltd., Kolkata; Rare Earth Recovery From Spent Magnets to M/s. Shape Shift Energies Pvt. Ltd., Telangana; and Instrumented billet mould for the prevention of Breakout in Billet Caster" to Ajanta Refosteel, Jamshedpur. These efforts are closely aligned with the national emphasis on indigenous technology development, import substitution, and strengthening MSME competitiveness. In addition, several technologies have been developed at varying Technology Readiness Levels (TRL 5–9), including Cost-Effective non-fused Flux Technology for Dephosphorisation of steel in MgO-Lined Induction furnace; Holistic Recycling of Red Mud for recovery of Alumina, Iron, Rare Earth oxides, Titania with utilization of Final residue; Hot rolled Low Alloy Steel with High Strength, Impact toughness and Abrasion resistance; and Rare Earth recovery as oxides from spent magnet scrap (EV vehicles, hard disks, Wind turbines, button magnets, Swarf, machining scrap and MRI magnets). These innovations directly support national priorities in sustainability, recycling, defense, advanced materials, and infrastructure. Moving forward, we aim to accelerate their commercialization through structured industry partnerships, incubation mechanisms, and integration with national innovation platforms.

Our financial performance reflects steady progress toward the goals outlined in CSIR Vision 2030, particularly in enhancing external revenue generation and industry engagement. The external cash flow (ECF) for the year stood at 29.78 crores, with 19.58 Crores contributed by industrial sources, which is an encouraging indicator of our growing role as a technology partner to industry. We formalized 56 MoUs and agreements with national and international organizations, strengthening our collaborative ecosystem. Notable international partnerships include collaborations with Indian Rare Earths Limited Technology Development Council, Odisha; Vedanta Pvt. Ltd.,Odisha, Sarthi Aerospace & Defence Pvt. Ltd.,Haryana, Eyantram Waste Management Pvt. Ltd., Andhra Pradesh, IISC-Bengaluru, CSIRO-Australia, Tata Steel Ltd., Jamshedpur, CSIR-CIMFR, Dhanbad, Hindustan Zinc Limited, Udaipur, TCS, Mumbai, Ordanance Factory, Ambajhar, UNDP, New Delhi, NIT, Raipur, NALCO, Bhuwaneshwar and others.

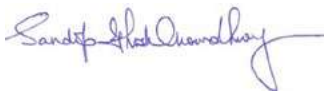
Our flagship programs continue to drive large-scale, mission-oriented impact, particularly in areas aligned with the Atmanirbhar Bharat and Vikshit Bharat 2047 goals. CSIR-NML's Magnesium Pilot Plant initiative represents a key step toward indigenous process development, with scale-up activities progressing toward semi-continuous operation. The proposed pilot plant, designed for 120–150 kg/day magnesium production using improved retort technology, is expected to contribute significantly to domestic capability in lightweight materials for strategic sectors. After the foundation stone laid in the year 2024, the present progress of the plant included installation of 150 kg dry press briquetting machine, commissioning of the 2TPD rotary kiln Calcination plant, design and procurement of vacuum reduction and distillation plants, and benchmarking for different dolomite grades. Envisaged Mg Plant is expected to be commissioned in 2026-27. The foundation stone for the 'Centre for Material Evaluation under High-Pressure Hydrogen Gas' was laid on 26 November 2025 by Dr. (Mrs.) N. Kalaiselvi, Director General, CSIR. This first-of-its-kind facility in the country and few in the world, centre is being established with support from the National Institute of Solar Energy (NISE), Ministry of New and Renewable Energy (MNRE), Government of India, under the National Green Hydrogen Mission (NGHM). The Centre will host advanced material evaluation facilities operating under high-pressure hydrogen environments, including slow strain rate testing, fracture toughness (KIH) evaluation, thermal desorption spectrometer and hydrogen permeation studies. The center is poised to play a pivotal role in supporting indigenous material development and qualification for hydrogen storage, transportation, and allied energy applications. CSIR-NML has been in the forefront of the development of technologies for extraction of critical metals such as niobium, tantalum, and scandium from both primary and secondary resources, aligned with India's efforts to secure critical mineral supply chains and reduce import dependence. Endorsing these capabilities, the Ministry of Mines, Government of India recognized CSIR-NML as one of the Centres of Excellence (CoE) under the National Critical Mineral Mission (NCMM). I am happy to share that, for the first time in India, CSIR-NML produced 22K & 18K gold alloy powders suitable for additive manufacturing and allied applications in the jewellery industry. The powders were produced using our state-of-the-art laboratory scale inert gas atomizer, AU1000-HTC, which is first of its kind in India. Other outcomes include development of Fe-Si crystalline and FeBCPSiCrMo amorphous alloy powders for soft magnetic applications and FeCrMo-based amorphous powders, for HVOF coatings. Recently, a collaborative work with M/s Lattice Aerospace, Hyderabad led to the production of FeSiBC(Cr) alloy powders suitable for metal additive manufacturing.

In alignment with national missions on sustainability and Net Zero targets, CSIR-NML is actively advancing research and technology development in low-carbon metallurgical processes, resource efficiency, and recycling. Our initiatives on hydrogen-based reduction, waste valorization, and energy-efficient processing are integral to support India's transition toward a low-carbon economy. In one of the important endeavors, CSIR-NML focuses on a direct, short-loop recycling approach for end-of-life NdFeB magnets to enable efficient material recovery. The process involves recovering scrap magnets, re-homogenizing the alloy through re-

melting, producing rapidly solidified ribbons via melt-spinning, and consolidating them through hot pressing and die-upsetting to obtain anisotropic bulk magnets. This vital work aims to support sustainable recycling while maintaining high magnetic performance in regenerated materials. Further, the Battery Recycling Pilot Plant under a Hire-Operate-Transfer (HOT) model is accessible for MSMEs and start-ups. The Urban Ore Recycling Centre (UORC) continued playing pivotal role in development of advanced e-waste recycling technologies, aiming at zero-waste outcomes and recovery of high-value metals. CSIR-NML is the nodal in the mission project Solar Panels, Electrical/ Electronic Appliances s Air Conditioner Wastes to Sustainable Materials (C-SEAS) involving 30 components and 11 participating laboratories. The project has high expectations for the development of "industry-ready" technologies in the area. The mission aims for making industry stakeholders and partners for creating a measurable impact on the circular economy in India.

Our people remain the cornerstone of our success. The achievements of our scientists and staff have been recognised through several prestigious awards, including Dr. Ammasi A.- Young Metallurgist Award (Ferrous Category) from the Indian Institute of Metals, Dr. Avanish Kumar Chandan- Young Engineers Award from the Institute of Engineers (India), Dr. K. L. Sahoo- Eminent Scientist Award from the Institute of Engineers (India), Dr. Prem Kumar- INAE Young Engineer Award, N.M. Sampat National Award, Dr. Ranjeet Singh-National Geoscience Award 2024, Dr. Ashish Kumar Panda - National Award for NDT Systems Innovation & Development from Indian Society, and Dr. Mahesh Walunj- N.M. Sampat National Award 2025 & National Corrosion Championship Trophy-2025. One of our scientists, Dr. Vinod Belwanshi has been selected as HBNI Alumni Ambassador by Homi Bhabha National Institute (HBNI), Mumbai. Five of our women scientists namely Dr. Beena Kumari, Dr. Mita Tarafder, Ms. N. Vasumathi, Dr. Pratima Meshram, Dr. Sarmistha Palit Sagar, and Dr. Shobhana Dey, have been listed as Women Achievers in the CSIR Women in STEM Compendium by CSIR-NAL. These recognitions reflect the excellence, dedication, and innovation that define CSIR-NML.

As we celebrated 75 years of impactful contributions, we stand at a pivotal juncture where metallurgical & materials science, sustainability, and digital technologies are converging to redefine the future of manufacturing and resource utilization. In alignment with CSIR Vision 2030, we will continue to strengthen our focus on mission-mode projects, industry co-creation, and translational research. Our strategic priorities will include critical minerals, advanced structural and functional materials, circular economy technologies, and low-carbon process innovations. Looking ahead, we reaffirm our commitment to the guiding principle of 'Science for Society' and 'Technology for Transformation'. Our efforts will remain aligned with national missions such as Viksit Bharat 2047, with a focus on self-reliance, sustainability, and inclusive growth in the field of metals, minerals and materials.



Sandip Ghosh Chowdhury

Performance Targets Achieved 2025-26

Sl. No.	Objectives	Planned	Achieved
1.	Total External Cash Flow (ECF)	30.0 Crores	**29.78 Crores**
2.	Industrial ECF (a part of ECF)^	18.0 Crores	**19.58 Crores**
3.	SCI Publications	160	**155**
4.	Non-SCI Publication	30	**24**
5.	Patents Filed	12	**4**
6.	Copyrights	5	**3**
7.	Technologies Developed*	5	**4**
8.	Technologies Transferred#	5	**8**

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

***Technologies Developed:**

- Cost-Effective'non-fused Flux Technology for Dephosphorisation of steel in MgO-Lined Induction furnace. (TRL 6)
- Holistic Recycling of Red Mud for recovery of Alumina, Iron, Rare Earth oxides, Titanis with utilization of Final residue. (TRL 6)
- Hot rolled Low Alloy Steel with High Strength, Impact toughness and Abrasion resistance (upgradation of TRL of existing Technology.) (TRL 7)
- Rare Earth recovery as oxides from spent magnet scrap (EV vehicles, hard disks, Wind turbines, button magnets, Swarf, machining scrap and MRI magnets)

#Technologies Transferred:

- Technology to recover saleable products of Cu, Al and Au as Metals/ salts from waste PCBs to M/s. Eyantram Waste Management Pvt. Ltd.
- Technology for Production of Electrolytic Manganese Metal (EMM) from MnSO4 Solutions to M/s. Sarthi Aerospace & Defence Pvt. Ltd., Haryana
- Technology for a Sensing Device Zincometer for Zinc Coating Weight Measurement in GI line to M/s Ajanta Refosteel Chemicals Pvt. Ltd., Jamshedpur
- Technology for Recycling of Different PCBs to Recover Gold, Copper and Aluminum to M/s. EnviroServe Technologies, New Delhi
- Technology for Lithium-Ion Battery for the Recovery of Li, Ni, Co, Mn and reusable graphite to M/s. TerraNova Eco Management Pvt Ltd., Bengaluru
- Technology for Rare Earth Recovery from Spent NdFeB Spent Magnets to M/s. Renocell Recycling Pvt. Ltd., Kolkata
- Technology for Rare Earth Recovery From Spent Magnets to M/s. Shape Shift Energies Pvt. Ltd., Telangana
- Instrumented billet mould for the prevention of Breakout in Billet Caster" to Ajanta Refosteel, Jamshedpur.

Major Technological & Scientific Targets Planned and Achieved in 2025-2026

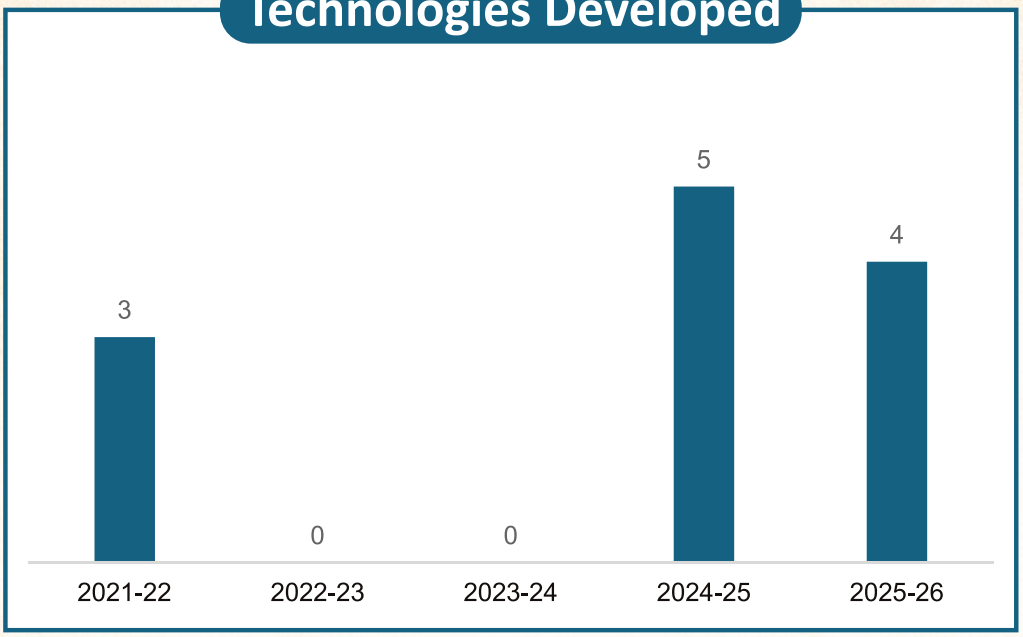
Planned for 2025-2026	Achieved in 2025-2026
Applied & Analytical Chemistry	
1. Assessment of coking coal quality concerning the active component present in coking coal.	1. Ongoing. The project on assessment of coking coal quality with respect to active components is in progress with systematic sample evaluation and data generation.
2. Chemical & mineralogical analysis of coal and non-coal samples from CMPDI.	2. Ongoing. Chemical and mineralogical characterisation of coal and non-coal samples received from CMPDI is being carried out under continuing project activities.
3. Value-added chemicals/materials from coal, industrial waste, low-value precursors, and low-value products (Target: 03 SCI publications).	3. Activity could not be initiated in the reporting period.
4. Metal oxide/sulphide/phosphate for electrochemical application (Target: 02 SCI publications).	4. Achieved. More than 02 SCI publications were successfully published in the area of electrochemical materials including metal oxide/sulfide/phosphate systems.
5. Chemical characterization and analysis of coal from various industries and subsidiaries of Coal India Ltd.	5. Achieved. Extensive chemical characterisation of coal samples from industries and subsidiaries of Coal India Ltd. was carried out, contributing significantly to divisional revenue generation through testing and consultancy services.
6. 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)	6. Manuscript under review at the Journal of Environmental Analytical Chemistry.
7. Assessment of Refuse Derived Fuel (RDF) characteristics and its impact on the clinker quality at high Thermal Substitution Rate (TSR) (Target: 01 SCI publication)	7. Manuscript under preparation
8. Evaluation of cement quality by blending of high MgO content limestone (Target: 01 SCI publication)	8. Manuscript under preparation
Materials Evaluation	
1. Hot forging, hot rolling followed by salt bath heat treatments of alloy steels	1. The external and in-house projects requiring processing and heat treatment of alloy steels have been successfully carried out.
2. Development of high Mnwear resistant steel	2. Laboratory scale development of high Mn wear resistance steel for TAKRAF is close to completion.
3. Process development for making ultra-thin foil from complex alloy steels	3. Ultra-thin foils of ALLEIMA supplied alloys steel were successfully produced by cold rolling and annealing
4. 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	4. A tri-partite agreement has been signed among the said entities envisaging services to Indian railways and, transport industries and sustainable logistics.

5. Technical audit of product/ metallurgical process – rail manufacturing at Bhilai Steel Palnt	5. Technical audit of rail manufacturing process at Bhilai steel plant completed and necessary suggestions have been given for improved product quality.
6. Implementation of LTCC based eddy current sensor for real time creep damage monitoring in one of the power plant.	6. The LTCC Eddy Current sensor has been successfully deployed in the NTPC power plant at North Karanpur for performance evaluation.
7. Performance evaluation of Ultrasonic Flowmeter in the space environment.	7. Currently the flowmeter is under fabrications using space qualified components to meet the flight worthiness requirement.
8. Transfer of FOBOP: Breakout detection of Billet Mould Technology	8. Technology has already been transferred to M/s. Ajanta Refosteels.
9. Development of AI-based model for welding parameter optimization to achieve defect-free weld joints.	9. Laser locking thermography based model has been developed for weld defect detection and identification.
10. Development of GUI for 'Automated estimation and reporting of the debonding area in Connecting rods using Ultrasonic testing and image analysis'	10. GUI has been developed and being implemented for the project as well as other components.
11. Development of Pulse Eddy Current probe to detect corrosion under insulation	11. The project is still under consideration for feasibility study.
12. Evaluation of AM components for aero engine applications	12. The project is on-going and most of the data has been generated.
13. High temperature fatigue behavior of Ni base super alloys	13. Study of LCF behavior of IN625 was published in SCI journal, which led to external funding from ARDB.
Metals Extraction & Recycling	
1. To set up a 100 kg/day magnesium metal production capacity pilot plant under the CSIR-funded CSPS project	1. The infrastructure development has been under progress and will be completed by May 2026. PO for equipment's has been released and few equipment's already received.
2. To initiate the research activities on the extraction of high-purity silicon metal by recycling of solar panels	2. A project on "Recovery of high purity grade silicon from EOL solar PV panels" has been started under CSIR Mission Mode project C-SEAS.
3. To complete the project 'holistic utilization of red mud' at 100 kg scale and release the completion report through Niti Aayog	3. Successfully completed. A MoU with NALCO signed to set up 10 tpd pilot plant at their site.
Minerals Processing	
1. Reduction of silica in dolomite and limestone for utilization in iron & steel making.	1. Silica content of less than 3% was achieved from feed assay of 7.5 to 5% from typical dolomite and limestone of Chhattisgarh.
2. Feasibility study of dry beneficiation of non-coking coal by FGX dry coal separator.	2. The coal sample of MCL having 40 -44% ash infield after single stage dry beneficiation, was reduced to 30 – 33%.
3. To carry out a Process audit of the installed fine coal circuit at 5.0 MTPA Patherdih NLW Coal Washery, BCCL.	3. The process audit was successfully carried out and various bottle-necks were identified to achieve the desired throughput of 980 TPH.

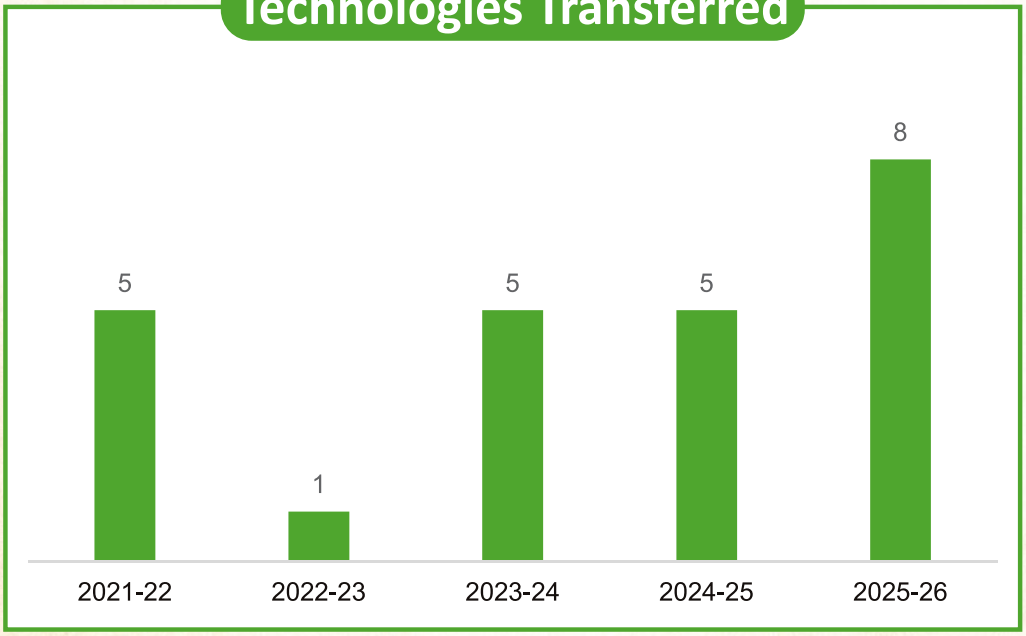
4. Extraction of vanadium from dune sand. 5. Process Audit of the Existing Copper Beneficiation Plant at Malanjkhand to study the feasibility of capacity enhancement. 6. Dry silica sand beneficiation for utilization in glass making. 7. Low-grade iron ore beneficiation. 8. Beneficiation of copper ore using column flotation. 9. Rare Earth Mapping from coal overburden. 10. Selective flotation of iron minerals from Ferruginous Manganese Ores.	4. The project could not be taken up due to fund non-availability from NMET. 5. Process audit was successfully carried out and necessary process upgradation suggestions were provided to HCL to achieve 3.0 MTPA (Target capacity). 6. The work was completed successfully, to achieve target silica removal efficiency >99.5%. 7. The work is in progress; till date bench scale process flow-sheet has been developed. 8. The project completed successfully. 9. This work is under progress. 10. 10.The project could not be taken up.
Advanced Materials & Corrosion	
1. Implementation of "MagStrics" sensor for health monitoring of thermal power plant • Colorized GI wires and their process • Development of molten salt corrosion-resistant microstructure 2 Development of additive manufacturing grade soft magnetic powders	1. Implementation of 'Magstrics sensor' at NTPC power plant is in progress and ongoing • It is completed and process developed for colour GI wire • Novel microstructure is developed for molten salt corrosion resistance 2. Additive manufacturing grade powder is developed at 6Kg scale using Gas Atomizer i) Silicon Steel powder: Fe-4.5Si and Fe-6.5Si ii) Metallic Glass Alloy powder: FeBSiPCCrMo ii) TRL : 4; 70% powders are below 100µm range.
NML Madras Centre	
1. Feasibility studies on the beneficiation of secondary phosphate ore 2. Feasibility study on the beneficiation of tailings from an industrial beneficiation plant 3. Metallurgical failure analysis of low-pressure (LP) steam turbine blades	1. Completed and Report submitted to the sponsor 2. Completed and Report submitted to the sponsor 3. In Progress
Information Management & Dissemination Centre	
1. Purchase of books as per the requirements of the library users 2. Recruitment of a librarian having a degree in Library Science in consultation with HRG 3. To organize eleven Skill Development Training programs with 140 nos. of participants 4. To increase the participation of students under the Jigyasa program up to 1100 nos.	1. In progress 2. In progress 3. Organised 11 Skill development program with 239 Particopants 4. Total participants increased to 2893 with 50.24% girl participation

R&D Outputs

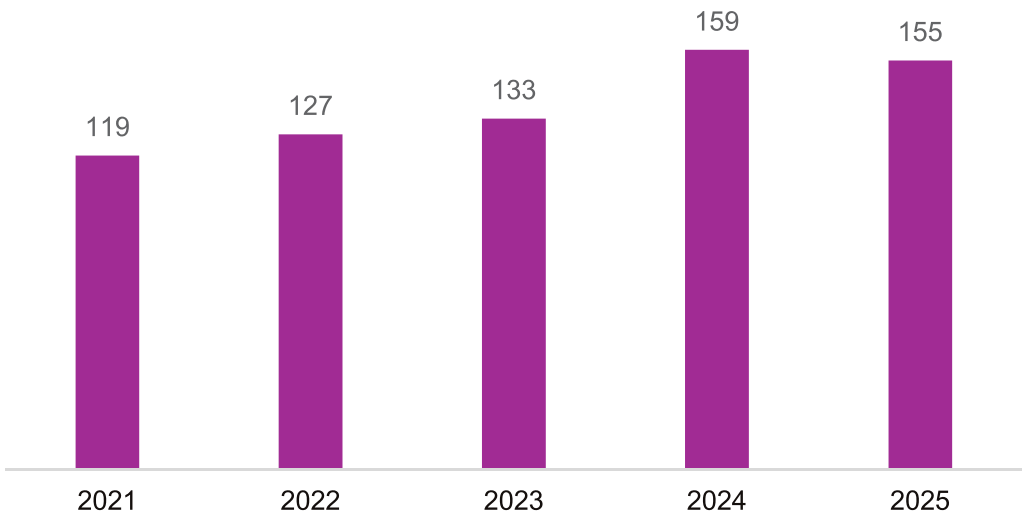
Technologies Developed



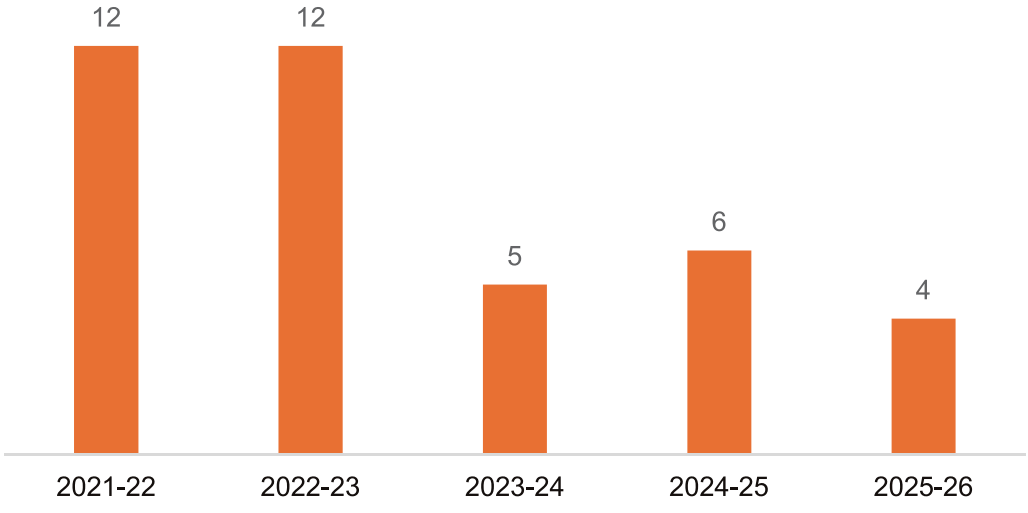
Technologies Transferred



Publication in SCI Journals



Patents Filed



Technology & Impact

Rio 2016 Olympic Games

first time in Olympic history recycled materials were used: The silver and bronze medals were produced using 30 per cent recycled materials while the ribbons were made from 50 per cent recycled PET. Meanwhile, the gold medals were completely free of mercury.





CSIR's First Battery Dismantling & Metal Extraction Pilot Scale Facility



Atomiser Facility

Technology Profile

Technologies Developed in 2025-26:

Cost-Effective Non-Fused Flux Technology for Dephosphorisation of steel in MgO-Lined Induction furnace. (TRL 6)

Approximately 35% of India's steel (around 50 million tons) in FY 2023–24 was produced via the induction furnace (IF) route, predominantly for structural applications such as TMT rebars, angles, and channels. However, steel produced through this route typically contains elevated phosphorus levels (0.08%–0.11%), which results in inferior grade products. To address this challenge, CSIR-NML has developed a cost-effective non-fused flux and process methodology for phosphorus reduction in steel produced via MgO-lined induction furnaces. This innovation enables the reduction of phosphorus content to 0.03%–0.04%, well within the BIS specifications (IS 1786:2008), without the need for expensive refining infrastructure such as ladle refining furnaces (LRF).

Merits:

- Compatible with standard MgO-based ramming mass linings in induction furnaces.
- Achieves phosphorus reduction from 0.09%–0.11% down to 0.03%–0.04%.
- Requires 3–4 wt% flux addition to the molten steel.
- Treatment must be performed under oxidizing conditions; the carbon content in the bath should not drop below 0.15% to avoid excessive reactivity.
- No additional refining infrastructure (like LRF) required — refining is carried out directly in the induction furnace.
- Lower capital and energy requirements compared to conventional LRF-based steel refining.





Figure 1: (a) Mixing in a Conical mixture for Flux preparation Figure1: (b) Prepared flux (Non-fused)



Figure 1: (c) Flux treatment in MgO-lined induction furnace



Figure 1: (d) Deslagging after flux treatment

Hot rolled Low Alloy Steel with High Strength, Impact toughness and Abrasion resistance (upgradation of TRL of existing Technology) (TRL 7)

India has been importing high-performance wear-resistant steel grades due to lack of indigenous technology. Typically, the material with high abrasion resistance is hard and brittle, therefore, leads to early failure from generation of cracks during sudden impact loading. Thus, there is a need to develop new grade of material which is highly resistant to abrasion together with good impact toughness. Therefore, a research team at CSIR–National Metallurgical Laboratory (CSIR-NML), Jamshedpur, in collaboration with Tata Steel Ltd Jamshedpur has indigenously developed a novel lean-alloy steel composition along with its energy-efficient processing technology. The novel multiphase microstructure in the developed steel is highly resistant to abrasion (over 2.5 times) and exhibit excellent impact toughness at subzero temperatures, while having tensile properties comparable to existing imported grades. Further, steel has been produced at Tata Steel Kalinganagar with 300 Tonnes capacity to promote In-house manufacturing of mining component from developed steel, leading to leveraging of the Indian industries from a global perspective.

Rare Earth recovery as oxides from spent magnet scrap (EV vehicles, hard disks, Wind turbines, button magnets, Swarf, machining scrap and MRI magnets) (TRL 6)

This is a circular economy technology focused on securing India's Rare Earth Element (REE) supply chain. By targeting "urban mining" from Neodymium-Iron-Boron (NdFeB) magnets, this process addresses a critical vulnerability in the green energy transition. Strategic Context: India currently imports 100% of its Nd-Pr demand. With the Nd-Pr oxide market projected to grow from 1,100 MT (2020) to 18,600 MT by 2030, this technology provides a domestic alternative to volatile global supply chains. The Resource for the technology is spent magnets containing ~30% REEs, making them far more concentrated than primary ores (which often contain <1% REE). With respect to the technical efficiency a hybrid approach is followed. The combination of pyro-metallurgical (likely roasting/thermal treatment) and hydrometallurgical (leaching/ solvent extraction) routes enables the processing of diverse scrap types, from contaminated swarf to large MRI magnets. Achieving >99.5% purity for Mixed Rare Earth Oxides and Fluorides makes the output suitable for industrial re-entry into magnet

manufacturing. The conversion of impurities into marketable by-products—such as Iron salts and Ni-Cu-Co sulphides—improves the project's internal rate of return (IRR) while meeting environmental standards. There are several operational advantages as well. Using locally produced, commercial-grade chemicals (such as Sulphuric acid and Oxalic acid) ensures the process is cost-effective and does not rely on specialised imported consumables. The current 10–100 kg batch scale is a solid "Proof of Concept" / Pilot phase. Transitioning to a 1 KL leaching reactor indicates a design ready for medium-scale industrial deployment. To operationalise this technology at the 100 kg scale, the setup requires:

- Pre-treatment: Ball mills and sieve shakers for size reduction.
- Chemical Processing: 30-stage mixer-settlers are crucial for the precise separation of Neodymium and Praseodymium from the iron matrix.
- Thermal Processing: A rotary furnace for the final calcination of oxalates into oxides.

This technology is a high-value proposition for stakeholders in the Electric Vehicle (EV) and Renewable Energy sectors looking to fulfil "extended producer responsibility" (EPR) mandates.



PILOT SCALE FACILITY FOR PROCESS VALIDATION AT 0.5TPD SCALE

Leaching and Precipitation



Roasting operation



Figure 2(a): Mixed rare earth oxides and oxalates recovered from mixed grade NdFeB magnet scraps from EV/Hard disks/Wind turbines; (b) Pilot Scale Facility for Process Validation at 0.5 TPD Scale

Holistic Recycling of Red Mud for recovery of Alumina, Iron, Rare Earth oxides, Titanis with utilization of Final residue. (TRL 6)

CSIR-NML in association with industrial partners (NALCO, HINDALCO and VEDANTA) developed a 200kg process for holistic processing of bauxite residue/red mud 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 200kg 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 by NALCO and VEDANTA to scale-up to 10ton per day demonstration plant. NALCO has signed an MOU in this regard to scale-up the process, as well as to extract REEs as individual oxides, on 5th Jan 2026.





Impact Making Technology

Technologies Transferred to Industries:

Instrumented billet mould for the prevention of Breakout in Billet Caster to M/s. Ajanta Refosteel.

The present technology offers a real-time, temperature sensing system for monitoring the cold face temperature of a billet mold along its length and to predict breakout in a live billet caster well in advance. This technology uses Fibre Bragg Grating (FBG) as a temperature sensor. Multiple sensors were written on a single optical fiber and embedded along the length of a billet mold. The "interrogation" of these sensors allowed for temperatures to be obtained along the length of the mold from a single strand of the optical fiber. In addition to the development of the packaged FBG sensor array, its installation in the harsh conditions (high temperature, high pressure, restricted space) of an operating caster has called for considerable engineering ingenuity. This too has been accomplished. Technology has already been implemented at one of the casters in the renowned steel industry, and a breakout has been successfully detected in one strand in a live caster.

- Strand of an array of FBG sensors in a fibre
- Proper encapsulation of fibre with an array of FBGs
- Installation of encapsulated fibre on the machined Cu- mold
- Test of output signals from the sensors on the fixing of the mould in the caster.
- Software for analysing data to detect a breakout and creating an alarm before the breakout.

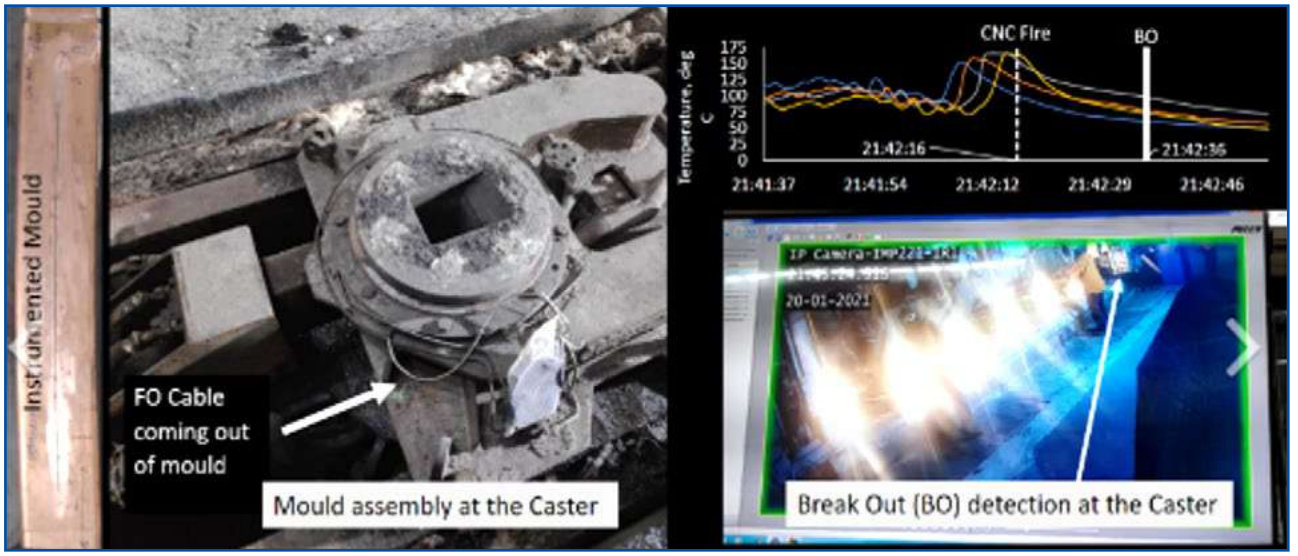


Figure 1: (a) Mould Assembly; (b) BO Detection at the Caster

Technology for a Sensing Device Zincometer for 5-channel Zinc Coating Weight Measurement in GI line to M/s Ajanta Refosteel Chemicals Pvt. Ltd., Jamshedpur

In-situ monitoring and control of zinc coating weight are critical to the galvanization of steel (GI) wires, as they ensure optimal corrosion protection, structural integrity, and cost efficiency by preventing excessive zinc consumption. Precise control of coating weight in the hot-dip galvanizing (HDG) process is particularly challenging due to the dynamic and nonlinear nature of the process, often leading to non-uniform coatings. CSIR–NML has

developed an advanced eddy current sensor–based smart manufacturing system integrated with ML-driven automation and IIoT-enabled architecture to address these challenges and promote sustainable manufacturing practices. The system enables in-situ monitoring and control of thin zinc coatings (~50–150 GSM) on GI wires. The indigenously developed solution is low-cost, reliable, and capable of serving as an effective import substitute for conventional zinc coating weight control systems. Status: The integrated system has successfully been installed on a commercial production line at M/s Tata Steel Ltd., where it has been in continuous operation since October 2023. The technology has been transferred to M/s Refosteel Instruments, Jamshedpur. Subsequently, an order for a five-channel integrated sensing device has been received from M/s Tata Steel Ltd. Owing to its demonstrated industrial performance; the technology has generated significant interest and enquiries from multiple user industries for large-scale implementation.

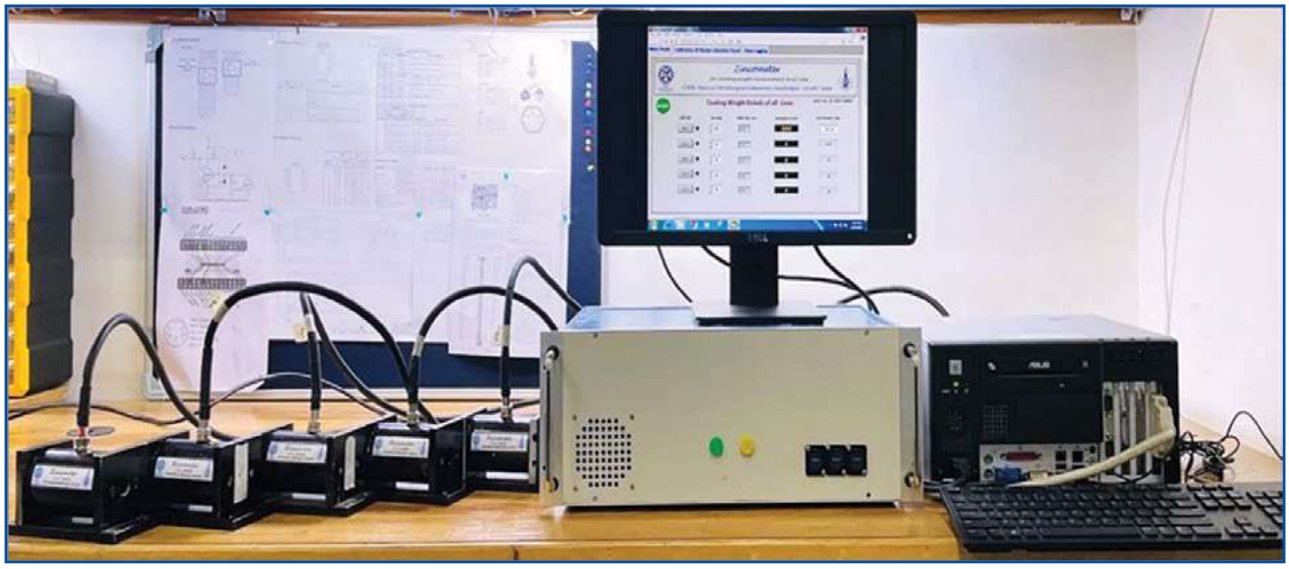


Figure 2: Zincometer

Technology for Rare Earth Recovery from Spent NdFeB Spent Magnets to M/s. Renocell Recycling Pvt. Ltd., Kolkata and M/s. Shape Shift Energies Pvt. Ltd., Telangana

The technology has been transferred to two industries in the reporting year. The technology provides a domestic alternative to volatile global supply chains for Nd-Pr oxide. The Resource for the technology is spent magnets containing ~30% REEs, making them far more concentrated than primary ores (which often contain <1% REE). With respect to the technical efficiency a hybrid approach is followed. The combination of pyro-metallurgical (likely roasting/thermal treatment) and hydrometallurgical (leaching/ solvent extraction) routes enables the processing of diverse scrap types, from contaminated swarf to large MRI magnets. Achieving >99.5% purity for Mixed Rare Earth Oxides and Fluorides makes the output suitable for industrial re-entry into magnet manufacturing. The conversion of impurities into marketable by-products—such as Iron salts and Ni-Cu-Co sulphides—improves the project's internal rate of return (IRR) while meeting environmental standards. There are several operational advantages as well. Using locally produced, commercial-grade chemicals (such as Sulphuric acid and Oxalic acid) ensures the process is cost-effective and does not rely on specialised imported consumables. The current 10–100 kg batch scale is a solid "Proof of Concept" / Pilot phase. Transitioning to a 1 KL leaching reactor

indicates a design ready for medium-scale industrial deployment. To operationalise this technology at the 100 kg scale, the setup requires:

- Pre-treatment: Ball mills and sieve shakers for size reduction.
- Chemical Processing: 30-stage mixer-settlers are crucial for the precise separation of Neodymium and Praseodymium from the iron matrix.
- Thermal Processing: A rotary furnace for the final calcination of oxalates into oxides.

This technology is a high-value proposition for stakeholders in the Electric Vehicle (EV) and Renewable Energy sectors looking to fulfil "extended producer responsibility" (EPR) mandates.



Figure 3: Agreement Signing with M/s. Renocell

Technology for Lithium-Ion Battery for the Recovery of Li, Ni, Co, Mn and reusable graphite to M/s. TerraNova Eco Management Pvt Ltd., Bengaluru

CSIR-National Metallurgical Laboratory (CSIR-NML) has developed a patented, holistic hydrometallurgical process for recycling spent Lithium-ion batteries (LIBs), achieving (>96-99%) purity recovery of Lithium (Li), Nickel (Ni), Cobalt (Co), Manganese (Mn), and reusable graphite from mixed chemistries. This process provides high-purity metal salts and recovers graphite, offering a sustainable, indigenous technology for the battery industry. M/s. TerraNova Eco Management Pvt Ltd., Bengaluru, established in 2022, is a licensed and approved facility to have become a premier destination for the recycling of e-waste & batteries, precious metal recovery, metal refining, data destruction & wiping services, and Telecom towers sites operations. With CSIR-NML technology, they aim to create a recycling facility to process 1 ton of scrap batteries per day, for the extraction of Lithium, Nickel, Cobalt and Manganese. The company shall be erecting its plant in Ranipet, Tamil Nadu.

Technology for Recycling of Different PCBs to Recover Gold, Copper and Aluminum to M/s. EnviroServe Technologies Pvt. Ltd., New Delhi

CSIR-NML entered into an agreement with M/s Enviro Serve Technologies Pvt. Ltd., New Delhi, for the transfer of technology to recycle different PCBs to produce value-added products of gold, copper and aluminium as metals/salts.CSIR-NML has already transferred similar technologies to various recycling plants for commercial exploitation under the aegis of Urban Ore Recycling Centre. The recycling plant M/s Enviro Serve Technologies Pvt. Ltd., will be soon operational for the production of saleable products of Cu, Al and Au from PCBs based on CSIR-NML technology. Based on the developed and proven technology at CSIR-NML, technology in the closed-loop design for the recycling of different PCBs to recover gold, copper and aluminium from different printed circuit boards (PCBs) has been developed. A hybrid metallurgical process comprising mechanical pre-treatment, physical beneficiation, hydrometallurgical advanced separation and/ or electro has been used for this technology to recover Cu, Al and Au as value-added product (metal/ salts). Characterisation and chemical analysis of PCBs was done using AAS/ICP. Subsequently, a hydrometallurgical process flow-sheet to recover Cu, Al and Au as metals/salts, from spent PCBs was fine-tuned using the waste PCBs supplied by M/s Enviro Serve Technologies Pvt. Ltd., New Delhi. The party may scale-up/ pilot and commercialise the technology as per the technology of CSIR-NML using their own/ hired engineering.



Figure 4: Technology Transfer ceremony between CSIR-NML & M/s Enviro Serve Technologies Pvt. Ltd., New Delhi

Technology for Production of Electrolytic Manganese Metal (EMM) from MnSO4 Solutions to M/s. Sarthi Aerospace & Defence Pvt. Ltd., Haryana

The CSIR-National Metallurgical Laboratory (NML) provides technical know-how for producing electrolytic manganese metal (EMM) by treating low-grade manganese ore. The key technical steps for NML-EMM production process are: (1) Leaching of crushed low-grade manganese ore in sulfuric acid to form a manganese sulfate solution, (2) Purification to remove impurities like Fe, Ni, Co, Cu, Cd etc to produce a qualified electrolyte and (3) Electrolysis of purified solution in an electrolytic cell. A direct current is applied to deposit Mn metal on a stainless-steel cathode and using lead anodes. The final product is high purity manganese metal flakes (99.7%–99.9%), useful in alloys and chemical manufacturing.

Benefits of the NML Technology:

- Capable of processing low-grade manganese ore and waste slag.
- Optimized electrolytic cells (using divided cells with diaphragms) ensure high recovery rates and high-purity metal deposition.
- Includes steps from Ore Preparation and Leaching to purification, electrolysis, and final product handling.

Transfer of technology know-how for the "Magnetoimpedance (MI) Based Array Sensing Device for Detection of Carburisation and Defective Welds: MagRays"

A Magnetoimpedance (MI) Based Array Sensing Device was developed by CSIR-National Metallurgical Laboratory (NML), Jamshedpur as per NML's technical input and fabricated by M/s. Accelor Microsystem, Chandigarh. The device coined the name as "MagRays", can be used for assessment of carburization and defective welds. In the current project the device will be used for detection of carburization in SS 321 and steels used in typical applications of petrochemical, thermal power plant units. The operating parameters of the said device will be optimized to get enhanced MI signals.

The objective of the activity was to detect carburisation in steel and also defective weld in austenitic steels using Magnetostrictive sensing device MagRays. The as-carburised samples of SS 321 were further subjected to heat-treatment at 800OC for different durations upto 244 hrs for

controlled diffusion of carbon and consequent carbide formation. Each of the heat treated plates was scanned using MagRays and sensor output of all the samples are shown in fig-1. It was observed that with enhanced carburization, the MagRays signal output increased.

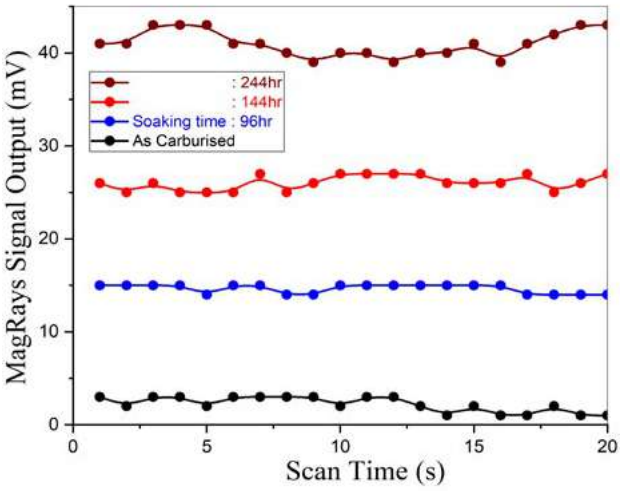


Figure 5: MagRays scan data obtained from as-carburised (As-carb) and heat-treated 321SS plates

Technologies Commercialised by Industry:

Technology to recover saleable products of Cu, Al and Au as Metals/ salts from waste PCBs to M/s. Eyantram Waste Management Pvt. Ltd., Visakhapatnam

CSIR-NML signed an agreement with M/s Eyantram Waste Management Pvt. Ltd., Visakhapatnam, for the transfer of technology to recover saleable products from e-waste. The recycling plant M/s Eyantram Waste Management Pvt. Ltd. based on CSIR-NML's Technology, was inaugurated on the 9th of September 2025 at the AMTZ Campus in Visakhapatnam, Andhra Pradesh. This auspicious occasion was graced by the presence of Padma Shri Prof. Ajay Kumar Sood, the Principal Scientific Adviser to the Government of India, as well as a renowned physicist and Dr. Jitendra Sharma, MD & Founder CEO AMTZ. In India, CSIR-NML, Jamshedpur, is a pioneer for the development of various recycling technologies. Since last 20 years CSIR-NML is working for the development of process to recycle various e-wastes to recover valuable metals and materials. The developed processes are fully indigenous, economically feasible, less energy intensive and have received high value of metal and materials. In order to carry out scale-up and pilot scale trials, a centre dedicated to the development of feasible technologies to recover non-ferrous, precious and rare earth metals from secondary resources has been established. The transfer of technologies contributes towards the "Swachhata Abhiyan" and "Atmanirbhar Bharat" initiative taken by the Government of India.





Figure 6: (a) Technology Transfer Ceremony; (b) Inauguration of M/s Eyantram Waste Management Pvt. Ltd., Visakhapatnam

Creation of New Facilities

Double Beam Atomic Absorption Spectrophotometer
Semi-Continuous MG Distillation System
Vacuum Induction Melting Furnace
Press Briquetting Machine
Slurry Jet Erosion Tester
PTFE Leaching Reactor
Ni-Cr Alloy Vacuum Retort Tube
Laser Source for Locks in Thermography
Bain-Thin Geo
Electrochemical Workstation
Horizontal Fluidised Bed Reactor – Iron Ore Fines Reduction
Microwave Ultraviolet Ultrasonic Sythesis
Microwave Digestion Extraction System
Omni - Directional Programmable Planetary Ball Mill
Rebar Corrosion Detector & Resistivity Meter
Hydraulic Ram Press
Portable Multi-Gas Analyzer



Double beam atomic absorption spectrophotometer



PTFE Leaching Reactor





Horizontal Fluidized Bed Reactor

Performance Targets Planned 2026-27

Performance Targets planned for 2026-27

	Objectives	Planned
1.	External Cash Flow (ECF)	35.0 Crores
2.	Industrial ECF (a part of ECF)	20.0 Crores
3.	SCI Publications	160
4.	Non-SCI Publications	30
5.	Patents	10
6.	Copyrights	5
7.	Technologies to be Developed	6
8.	Technologies to be Transferred	8

Major Technological & Scientific Targets Planned for 2026-2027

Applied & Analytical Chemistry

- Advanced assessment of coking coal quality with special emphasis on petrographic and reactive component analysis.
- Continued chemical and mineralogical characterisation of coal and non-coal samples from CMPDI and other industrial clients.
- Expansion of external collaborative projects with national and industrial partners such as CMPDI, QCI, KCS, and Inspectorate Griffith.
- Revenue Generation Target: ₹ 2.5–2.8 Crore through consultancy, testing, and collaborative research services.
- 06 SCI publication on the electrochemical application of Metal oxide/sulfide/phosphate and coal derived hard carbon.
- Upgradation and modernization of analytical facilities with two new ICP-OES installation, including purchase of a new ICP–MS and thermal analysis systems (GCV, TGA).
- Commercialization of developed ceramic powder materials, including scale-up, industry validation, and technology transfer to industrial partners.
- Focused efforts will be made towards technology translation through self-healing coating systems, aiming at industry deployment and revenue generation.
- Commercialization of self-healing coating technology, including performance validation, pilot-scale demonstration, and transfer/licensing to industry.
- Certified Reference Material(CRM) Development targets for CRM service applications
- Development of 0.4% Carbon Steel (turning sample) CRM – 100 bottles.
- Development of Disk CRM of Stainless Steel Grade 304 and Stainless Steel Grade 316 – 50 pieces each
- Development of Low alloy steel (turning sample) -100 bottles
- Development of Limestone (SMS Grade) and (BF grade) CRM – 100 bottles each
- Addition of external customers for chemical analysis of Ores, Minerals and Metals. Targeted ECF >50 lakhs for the FA 2026-27.
- 01 SCI publication on Chemical analysis of mineral samples by using spectroscopic techniques.
- Undertaking the project work on "Establishment of SI Traceability through National Standard of CSIR-NPL for Metrology in Ores & Minerals Technical Services of CSIR-NML" with collaboration with CSIR-NPL, Delhi.

Materials Evaluation

- Characterization of sub-structures and precipitate morphology for advanced Nickel based superalloys manufactured through additive manufacturing in liquid engines
- Root cause analysis of failure of Bogie Bolster

- Development of superior grade tool steel for profiling and cutting of iron nails
- Atomistic Simulation of Hydrogen Embrittlement in Steel
- To develop and validate a rejuvenation protocol for the first stage turbine blades of GTG 1250-2E of INS Eksila
- To understand the role of thermal management on properties of wire arc additively manufactured IN625 plates.
- Metallurgical Failure investigation support to strategic sectors (defence, power, railways & others)
- Development of high Mn wear-resistant steel: Plant trial at TAKRAF
- Pilot/Plant upscaling of Armour grade steel followed by Ballistic evaluation
- Artificial Intelligence based model development for wear-resistant steels: Collection and analysis of literature data for prediction of wear rate
- Development of lean alloy steel (alternate to maraging steel) for rocket motor casing
- Optimisation of alloy composition and processing parameters for a modified A356 Al-alloy for high strength alloy wheel (01 patent)
- Optimized alloy chemistry and processing parameters for obtaining the TS/YS ratio in the range of 1.15 – 1.25 TMT bars (01 patent / 01publication)
- Optimization of alloy chemistry and corresponding processing routes for 27CG120 and 27CG140 grade Electrical Steels (1 patent/1 publication)
- Development of low core loss and high strength CRNO steel for high frequency application in Electric Vehicle's traction motors
- Residual Life Assessment of GTG 1250-2E Reduction Gear Assembly Components
- Thermo-mechanical processing services for in-house R&D as well as sponsored projects

Metals Extraction & Recycling

- Establishing the technology of magnesium metal production by pilot plant trials
- To initiate activities on "Magnet to Magnet", where end of the life magnet will be used to extract Neodymium and Praseodymium from EOL magnet and to prepare permanent magnet using the extracted materials.
- To initiate activities on decarbonization of steel and efforts to establish a CoE in this area
- Technology transfer in the area of battery, PCB and Magnet recycling

Minerals Processing

- To develop a complete dry beneficiation protocol at pilot scale for solar panel/electronic wastes.
- To develop beneficiation and purification process flow-sheet in pilot scale for production of high pure graphite (Cg>99%) from natural low grade resources.
- Simulation analysis of fluorspar beneficiation plant at kadipani mines of GMDC.
- Development of lead from lead middling from Rampura-Agucha Pb-Zn beneficiation plant,
- Flotation recovery of copper and other metal values from the old slag dump of HCL, Ghatshila.
- Evaluation of gravity separation technique for beneficiation of Pb-Zn ore of SK mines of Vedanta.
- Beneficiation flow-sheet development of slime, DRI fines and blend.
- Statistical evaluation of flotation reagents for copper flotation.
- Iron removal from quartz sand for glass making.

Advanced Materials & Corrosion

- Superhydrophobic galvannealed coating in one step novel route
- Corrosion resistance Zn-coating through HVOF process for railways tracks
- Stealth coating for aerospace/defense applications
- Production of high purity (>95%) Ti_2AlC and V2AlC MAX phases and their corresponding MXenes
- Development of Magnetocaloric alloys (Heusler) and composites (Heusler & Amorphous alloys) developed
- Heat treatment process for the improved SCC resistance of Aluminum alloys

NML Madras Centre

- Process Development for Recovery of Graphite from Spent Li-Ion Battery Black Mass using 75 mm Dia-Laboratory-scale Flotation Column
- Metallurgical Failure Analysis of wind mill bearings
- Metallurgical Failure Analysis and condition assessment of boiler tubes from TGV SRAAC, Kurnool
- Consultancy on "Technical evaluation of tender for Monazite enrichment and Separation of REEs.

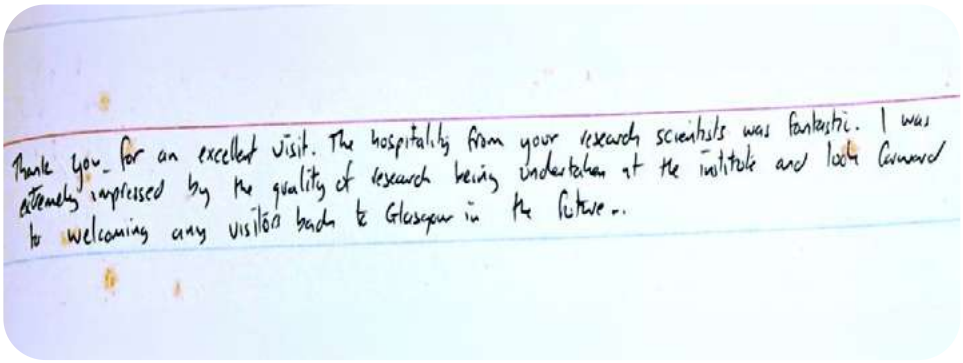
Research & Development

Olympic Games Tokyo 2020's Recycled Medals

30.3kg of gold, 4,100kg of silver and 2,700kg of bronze were recycled from a total of 78,985 tons of discarded devices ncludingapproximately 6.21 million used mobile phones, along with digital cameras, handheld games and laptops.



https://www.olympics.com


Thank you for an excellent visit. The hospitality from your research scientists was fantastic. I was extremely impressed by the quality of research being undertaken at the institute and look forward to welcoming any visitors back to Glasgow in the future..

"Thank you for an excellent visit. The hospitality from your scientists was fantastic. I was extremely impressed by the quality of research being undertaken at the institute and look forward to welcoming any visitor to Glasgow in the future."

Giles Hammond
School of Physics and Astronomy,
University of Glasgow, UK.
Date: 13th August 2025

Centres of Excellence

Establishment of a centre of innovation & a manufacturing eco-system for sensors (CIMES) in industrial 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 center of innovation & a manufacturing eco-system for sensors (CIMES) for Industrial IoT (IIoT) in Kolkata, West Bengal. The project is being 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 and other industry partners and stakeholders. The centre is being developed by pooling the complementary competencies of five CSIR laboratories that excel in sensor development and field applications in geotechnical and structural health monitoring and industrial process control instrumentation, with well-defined application domains as demanded by stakeholders and industry partners. The vision of the proposed centre would be to:

i. Enable a start-up and innovation ecosystem in the country as a solution provider in the sensor and instrumentation for industrial IOT.

ii. Create a knowledge and resource centre for Indian industries and

iii. Place India in the global market of sensors and instrumentation in the domain of geotechnical and structural health monitoring and industrial process control instrumentation.

CIMES is a consortium comprising five CSIR laboratories (CSIR-CGCRI, NML, SERC, CRRI, CIMFR), with CSIR-CGCRI serving as the nodal laboratory. The process for establishing the Centre is currently underway. Several technologies like *'Zincometer: A device for Coating Weight measurement in Galvanised wire lines', 'FOBOP technology for billet caster'* developed under the consortium have already been transferred to MSME companies for commercialisation, reflecting the translational potential of the research and its relevance to industrial applications.

Centre of excellence (CoE) on wear and corrosion resistant coating technology

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

Ongoing R&D Projects under the Centre:

Electroplated zinc–iron intermetallic alloy coating as an alternative to hot-dip galvanizing or galvannealing

Electroplated zinc–iron (Zn–Fe) intermetallic alloy coatings provide a promising alternative to conventional hot-dip galvanizing and galvannealing for corrosion protection of steel. In *acidic pulse electroplating bath technology* (**Figure 1**), pulsed current is applied to control nucleation and growth of the Zn–Fe deposit, producing fine-grained coatings with improved uniformity, better adhesion, and enhanced corrosion resistance. Pulse parameters such as duty cycle, frequency, and peak current density regulate iron incorporation and coating microstructure. In contrast, *alkaline direct current electroplating bath technology* (**Figure 2**) operates under steady current conditions and offers simpler bath chemistry, good throwing power, and stable deposition on complex geometries. The alkaline bath-based electroplating process also produces uniform and ductile coatings and is considered a cost-effective approach for further scale-up. Both processes enable the formation of desired phases and Fe compositions in the coating, comparable to those found in hot-dip galvanized and galvannealed steels. These electrodeposition approaches therefore provide controllable, energy-efficient, and environmentally favorable alternatives to traditional thermal galvanizing processes.

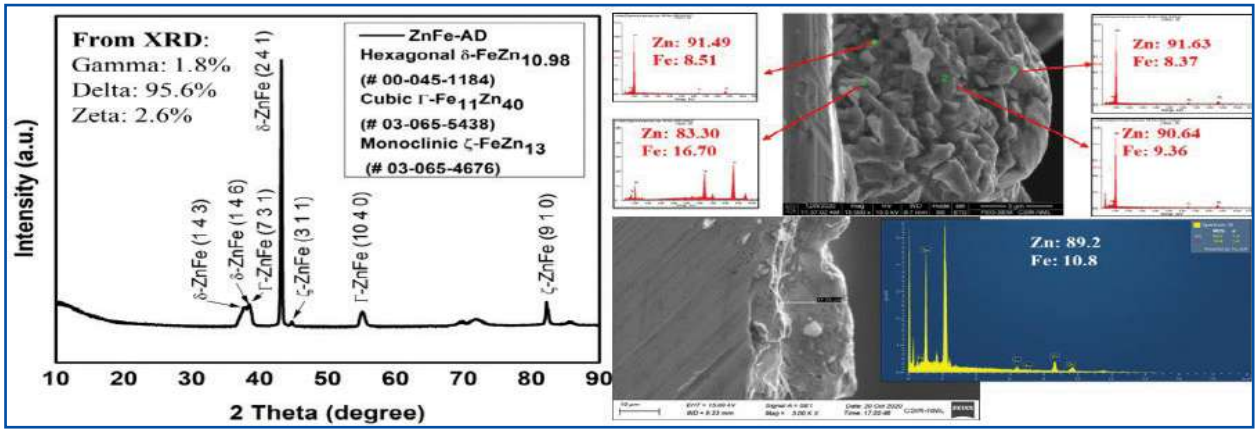


Figure 1: XRD pattern and EDS line mapping of the cross-sectional area of as-electroplated Zn–Fe from acidic pulse electroplating bath.

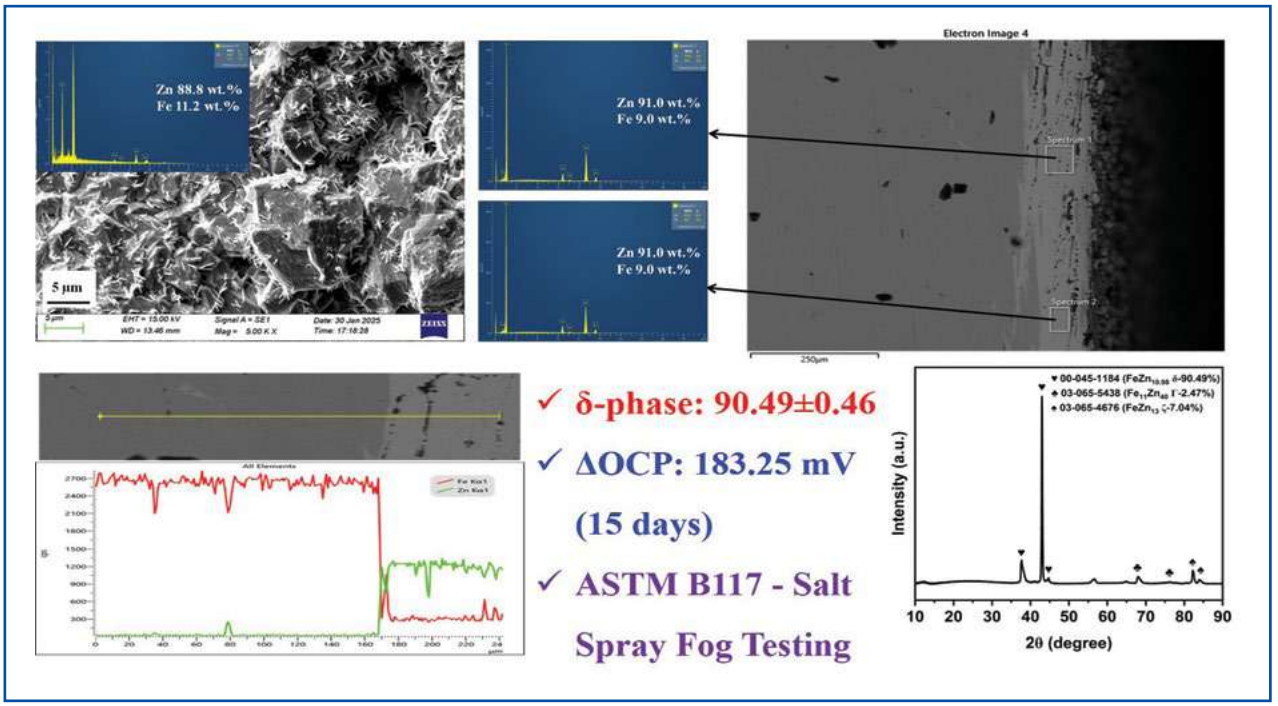


Figure 2: SEM, EDS line mapping of the cross-sectional area and XRD pattern of as-electroplated Zn–Fe from alkaline direct current electroplating bath.

Rust converter ceramic primer and self-healing anticorrosion coating for corrosion protection of structural steel

Corrosion of mild steel structures is a major challenge faced in the industry, transport, and infrastructure sectors. There is an urgent need to develop anti-corrosion coatings suitable for direct application on rusted steel structures, eliminating the tedious, expensive and time-consuming surface preparation steps. This will facilitate the maintenance of existing corroded steel structures and enhance longevity. CSIR-National Metallurgical Laboratory, Jamshedpur, has formulated a rust converter ceramic primer (**Figure 3**) suitable for direct application on rusted steel with minimal surface preparation. The active component of the ceramic primer reacts with rust and converts it to a ceramic coating. A self-healing anti-corrosion coating has also been developed, which self-heals autonomously in the presence of water to prevent the initiation of corrosion in the crack area. At CSIR-NML, the ceramic primer and self-healing coating production process has been scaled up to 200 litres/batch scale. The technology has been transferred to M/s Asianol Biotech Pvt Ltd, Kolkata, for commercial production (**Figure 4**). CSIR-NML has achieved a major breakthrough in rust converter and self-healing coating technologies by inventing a simple, scalable, and economical process. The rust converter ceramic primer formulation uses chemically bonded phosphate ceramic (CBPC) chemistry to create a ceramic coating on the rusted steel surface, eliminating the need for removal of rust (surface preparation) prior to paint application. The self-healing coating formulation involves blending of commercially available, low-cost, epoxy polymer resin, and inorganic powders. The developed coatings are suitable for application on metal surface using conventional paint application processes like brushing, rolling, or spraying, followed by curing in ambient conditions. Upon formation of a crack in the coating, water or moisture triggers autonomous self-healing of the crack/scratch. The developed coating passes 1000 hours of salt spray test (ASTM B 117) without the formation of red rust at the cut area. The performance of the coating has

been evaluated both in laboratory conditions and in real-life environments. The ceramic primer and self-healing coating can be utilised for the maintenance-free corrosion protection of existing and new mild steel structures in infrastructure, transport and industry sectors. This will increase productivity, reduce accidents, and enhance the service life of steel structures.



Figure 3: Application of ceramic primer at haldia met coke plant site, haldia.



Figure 4: Signing of technology transfer agreement with M/S Asianol Biotech Pvt Ltd., Kolkata

Colorized hot dip galvanizing coating

The hot-dip galvanised 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 galvanising coatings exhibits the typical silvery-white shade from the surface. Therefore, an attempt has been made to develop the advanced Hot Dip Galvanizing Coating which will show the colorized surface. CSIR-NML developed an advanced hot dip colourized galvanising coating (~35 µm) at industrial process parameters using Hot Dip Process Simulator (HDPS) at CSIR-NML (Figure 5 & Figure 6). Hot Dip Colourized Galvanising Coating provides different colourised shades with an easy process feasible to the batch-type as well as continuous type hot dip galvanising steel industries. The property of the cathodic corrosion protection and the resistance to change in surface chromaticity remains intact in the colorized GI coating. Various applications include:

- Construction, agriculture, automobile, wire fencing, aesthetic and decorative
- 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.

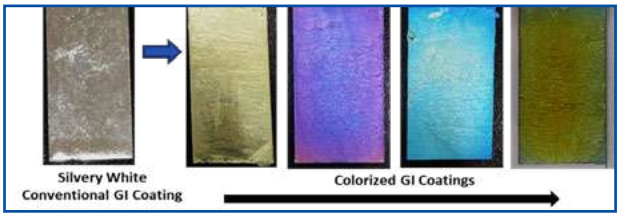


Figure 5.: Photographic images of colourised GI coated steel sheets

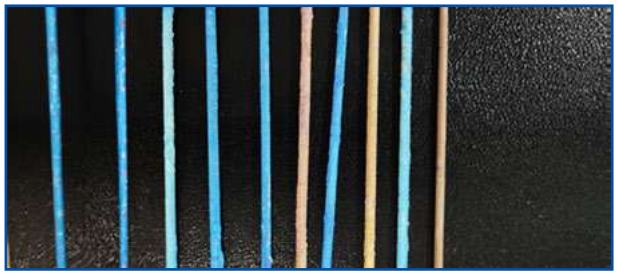


Figure 6: Photographic images of colourised GI-coated steel wires

Mitigation of erosion damage of hydro turbine components in a cost-effective manner

Ensuring the long-term sustainability of the mining industry is difficult due to component degradation. About 40% of mining energy is used to address friction and wear. Commercial pre-alloyed carbo-

boride surface coatings of Ni, Co, Cr, and W, although highly costly, provide extra protection to wear plates and structural steel. There is a need for a more affordable, durable coating with high hardness and toughness to reduce wear. In view of this, a Fe-based amorphous alloy was explored as a wear/erosion- and corrosion-protective coating material, also sought for industrial applications in precision gears, advanced robotics, surface coatings, etc., in the offshore environment. Current wear- and corrosion-resistant Fe-based amorphous alloys often contain expensive transition metals, such as Zr, Hf, and W, as well as rare-earth elements. However, the developed Fe-amorphous alloy excludes rare-earth elements and costly heavy metals such as W, Zr, Hf, Nb, and Ta, making it more commercially viable. A durable Fe-amorphous alloy-based composite coating with excellent hardness (~1200 Hv) and high wear and erosion resistance has been developed on steel using the High Velocity Oxy Fuel (HVOF) deposition technique. A performance comparison of the developed Fe-based amorphous coating with commercially used WC-Co-Cr coating is shown in **Figure 7**.

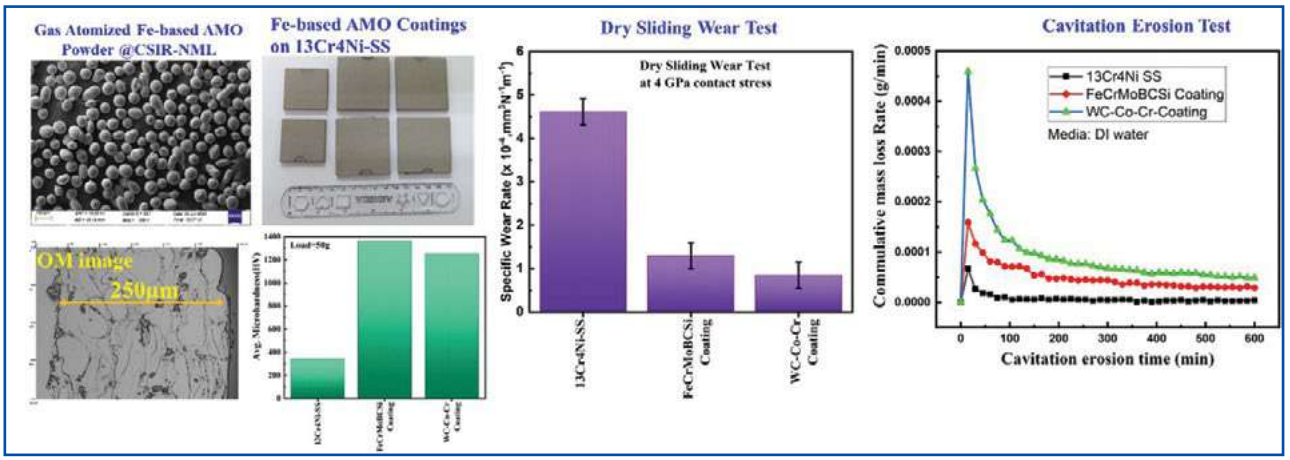


Figure 7*:* Performance (Hardness, Wear, and Erosion) comparison of the developed Fe-based amorphous coating with commercially used WC-Co-Cr coating under similar conditions.

Development of wear and corrosion-resistant metallic coatings for boiler components in coal-fired thermal power plants

In this work, high-hardness and low-porosity Ni-Cr-CrC-SiC coatings have been developed on Type 304 and 401 stainless steel substrates through HVOF-sprayed coatings. The phase composition, cross-sectional microstructure, roughness and micro-hardness of the coatings were analysed using optical microscopy, SEM-EDS, EPMA, and 3D-optical profilometry. Micro-hardness results show that the micro-hardness of the HVOF-sprayed coatings is significantly higher (~ 800-900 $HV_{0.1}$) than that of the substrate (~ 200-250 $HV_{0.1}$), due to the presence of embedded carbides (especially CrC and SiC) in the coatings. The findings will contribute to the improved design and development of highly erosion-resistant coatings for boiler components that are frequently exposed to severe erosive environments. To further assess the performance of the developed coatings, comprehensive evaluations including hot corrosion, erosion, and thermal conductivity measurements are required.

Development of novel microstructure to combat molten chloride salt corrosion in concentrated solar power plant

This work evaluates the impact of grain boundary engineering (GBE) on the corrosion behaviour of Type 316L austenitic stainless steel when exposed to molten chloride salts. The GBE microstructure was achieved by optimising 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. 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. This disruption was confirmed by the higher fraction of low Σ-coincident site lattice (CSL) boundaries in the GBE samples. To further increase the population of low-Σ CSL boundaries in the microstructure, a small-strain iterative thermomechanical processing route will be implemented, which is expected to further enhance resistance to molten salt corrosion.

Oxidation and hot corrosion behaviour studies of micro-arc oxidation (mao) coated Ti_2AlNb alloy

Advanced aerospace propulsion systems require lightweight materials capable of withstanding high mechanical loads and resisting oxidation at elevated temperatures. Among emerging candidates, Ti_2AlNb-based alloys have attracted significant attention for high-temperature structural applications in jet engines, gas turbines, and other aero-engine components. These alloys are considered potential alternatives to conventional Ni-based superalloys, which possess relatively high densities ($\rho \approx 8–8.5$ g/cm³). In comparison, Ti_2AlNb alloys offer several advantages, including lower density, high specific strength, good plasticity, excellent fracture toughness, and superior creep resistance at elevated temperatures, making them attractive for next-generation aerospace systems. To improve oxidation resistance, several approaches have been explored, including alloying, pre-oxidation treatments, and protective coatings. Among these, micro-arc oxidation (MAO) is a promising surface modification technique capable of producing dense and adherent ceramic oxide coatings on titanium alloys. Therefore, this study aims to investigate the oxidation and hot corrosion behaviour of MAO-coated Ti_2AlNb alloys in the temperature range of 600-1000 °C for exposure durations of 100-1000 hours, in order to understand oxidation mechanisms and evaluate the effectiveness of MAO coatings for high-temperature applications. The objectives of the project are: Preparation of Ti-24Al-6Nb alloy, Development of MAO coating on Ti-24Al-6Nb alloy, Oxidation, hot corrosion studies on Ti-24Al-6Nb alloy with or without MAO coatings, Post exposure characterization of specimens and oxide scales subjected to oxidation & hot corrosion tests and Evolution of possible degradation mechanisms. The achievements under the project are: Prepared Ti-24Al-6Nb alloy at CSIR-NML Jamshedpur, Oxidation studies on prepared Ti-24Al-6Nb alloy at 600- 800 oC in air for 100 hours are completed, Post oxidation characterizations of Ti-24Al-6Nb alloy, using XRD, SEM and Raman spectroscopy for 600-800 oC for 100h exposures is completed, Preparation of Ti-50Al-6Nb alloy at CSIR-NML Jamshedpur is in progress, Oxidation & Hot corrosion behaviour of Ti-24Al-6Nb & Ti-50Al-6Nb alloys are in progress. (Figure 8). Oxidation behaviour investigations of Ti-24Al-6Nb alloy at 600-800 oC for 100 hours suggest that these materials are suitable for aerospace applications. This will reduce low-pressure turbine blade failures caused by oxidation/hot corrosion, enhance fuel efficiency, and contribute to India's aim of self-reliance in the aerospace sector.

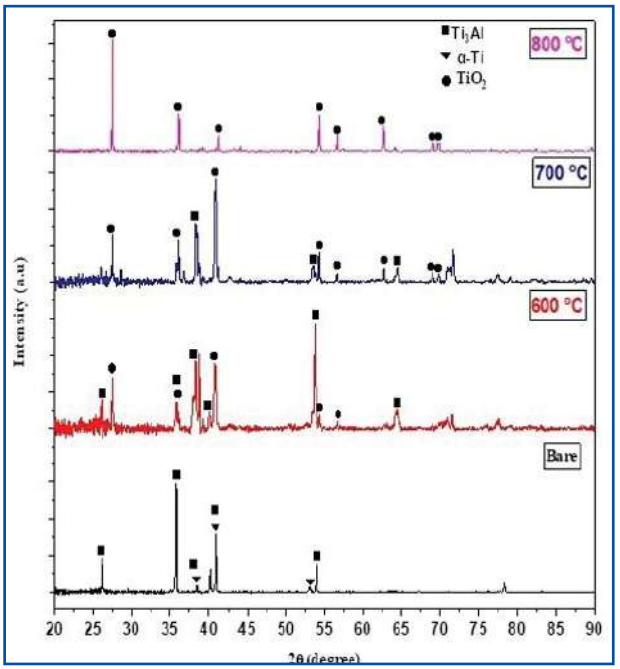


Figure 8: XRD plots of Ti-24Al-6Nb alloy showing different oxides formed during oxidation at 600-800 °C for 100 h

Development of wear and corrosion-resistant coatings for railway tracks

This project aims for the development of cost-effective, corrosion-resistant zinc-based protective coatings through high velocity oxy-fuel (HVOF) method for railway tracks by optimising alloying elements such as aluminium, magnesium, and selected rare earth elements. The railway tracks are continuously exposed to harsh environmental conditions, including moisture, chlorides, industrial pollutants, and cyclic wetting & drying, which accelerate corrosion and reduce the service life of rails and associated fasteners. Conventional zinc coatings provide basic sacrificial protection but often suffer from limited durability under aggressive field conditions. Therefore, the present project focuses on developing advanced Zn-based alloy coatings with enhanced corrosion resistance, improved adhesion, and extended service life suitable for railway infrastructure. The work carried out so far includes preparation of zinc-based coatings through the HVOF method, incorporating varying concentrations of Al & Mg elements. Laboratory-scale coating development and deposition trials have been performed, followed by microstructural characterisation using optical microscopy, scanning electron microscopy (SEM), electron probe microanalysis (EPMA), along with energy dispersive spectroscopy (EDS) & wavelength dispersive spectroscopy (EDS) to evaluate coating morphology and elemental distribution. Further, the phase distribution has been evaluated through X-Ray diffraction (XRD) technique. The mechanical properties, such as hardness and adhesion strength has been determined through micro-hardness and pull-off adhesion tester, respectively. The corrosion performance of the developed coatings has been evaluated through electrochemical techniques, including open circuit potential (OCP), potentiodynamic polarization (PDP) and electrochemical impedance spectroscopy (EIS) in 3.5% NaCl solutions environments, along with the long-term OCP & EIS monitoring in similar environments. Preliminary results indicate that the addition of aluminium and magnesium significantly enhances the corrosion resistance and stability of the zinc coatings. The optimized coatings have demonstrated substantially lower corrosion rates compared with conventional zinc coatings and commercial zinc. An overview of morphological characteristics and electrochemical corrosion behavior of developed coatings is shown in Figure 9. The project is currently progressing toward optimization of compositions and coating parameters, along with evaluation of coatings for wear properties in dry conditions and with long-term durability evaluation through accelerated salt spray exposure tests in 5% NaCl fog environment. The expected outputs include development of a durable and economically viable protective coating technology, technical guidelines for industrial implementation, and potential intellectual property (IP) generation related to optimized coating compositions and processing parameters. Future work will focus on demonstrating coating on 1-feet long railway track, and technology transfer to railway and coating industries to enhance the durability and reliability of railway infrastructure.

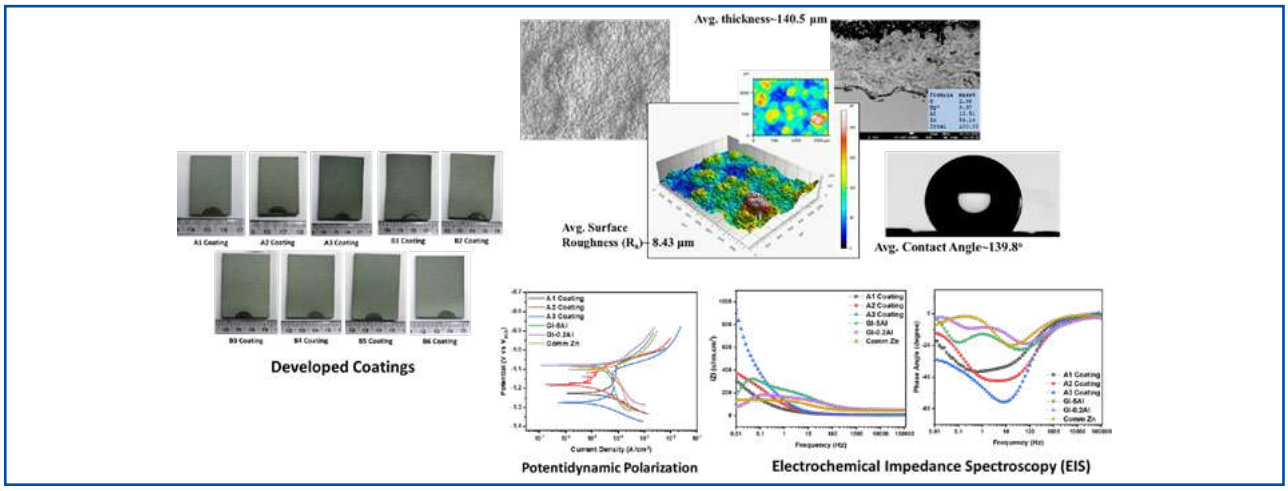


Figure 9: As-developed zinc-based protective coatings through high velocity oxy-fuel (HVOF) method, 3D-prfilogram, cross-sectional SEM, potentiodynamic polarization and electrochemical impedance spectroscopic analysis.

Global centre of excellence for steel decarbonisation of iron & steelmaking industries

The conventional Blast Furnace – Basic Oxygen Furnace route (BF–BOF) remains the dominant pathway for global steel production. However, it is also one of the most energy and carbon intensive industrial processes. This route relies heavily on coal and coke to achieve high temperature reduction reactions, resulting in substantial greenhouse gas emissions. The iron and steel sector contributes nearly 7–8% of global energy related CO_2 emissions, making it a critical focus area in international climate mitigation strategies. Global steel demand has risen sharply from about 550 million tons in 1970 to nearly 1.75 billion tons at present and projected to reach 2.3–2.5 billion tons by 2050. Such rapid growth will further intensify environmental pressures across the steel value chain. A significant challenge also arises from upstream iron ore mining and beneficiation. Producing one ton of steel requires approximately 1.6 tons of run-of-mine iron ore, in which nearly 40–45% treated as waste during processing. These wastes include tailings, slimes and low-grade rejects that accumulate in large volumes, leading to land degradation, water contamination and risks of tailings dam failures. Conventional steelmaking requires around 550–600 kg of coke per ton of steel, which enhance the coal demand and associated emissions. Coal mining alone releases nearly 52 million tons of methane annually, an intoxicating greenhouse gas. In downstream, BF–BOF route emits roughly 2.2 tons of CO_2 per ton of steel and without immediate intervention; global emissions is estimated to exceed 4–5 gigatonnes of CO_2 annually by 2050**.** Implementation of technological advancement and operational strategies can reduce emissions. These include improving blast furnace efficiency through advanced optimization models, reducing coke consumption by injecting alternative reductants such as pulverized coal, natural gas, hydrogen or biomass and using high-quality sinter or pellets to enhance furnace productivity. Utilization of agricultural residues, bamboo and other biomass resources to produce biofuels, syngas etc. will also significantly reduce emissions. Digital technologies, including AI-based process control and real-time monitoring can further optimize fuel consumption and minimize operational losses. Additionally, integrating Carbon Capture, Utilization and Storage (CCUS) can help to capture and manage CO_2 from furnace gas streams. In view of this, CSIR–NML proposes to submit a project proposal to DST in collaboration with BHP

Australia under the initiative titled 'Global Centre of Excellence for Steel Decarbonisation', with the following core objectives:

- To develop, deploy, evaluate and accelerate Decarbonisation Technologies such as energy efficient BF–BOF process, low carbon iron making and steelmaking technologies utilizing biomass derived fuels and hydrogen for reduction, utilizing wastes and selective CO_2 separation and regeneration system.
- Establish and operate pilot-scale facilities in collaboration with industry to validate emerging green steel technologies and facilitate their adoption at commercial scale.
- Provide training, skill development and technical assistance to industry personnel, policymakers and researchers with the competencies needed for the transition to low-carbon steelmaking.
- Create a platform for international collaboration among research organizations, steel producers, technology providers and government bodies to accelerate the global green steel transition through techno-economic assessment and emissions benchmarking.

This integrated framework aims to accelerate technology development, support industry transition and facilitate global cooperation for a sustainable, low-carbon steelmaking future. Figure 9 captures the challenges of conventional steelmaking and the strategic objectives of the proposed Global Centre for Excellence on Decarburization of Iron & Steelmaking Industries.



Figure 10: Global Centre for Excellence

Marine corrosion research station (MCRS) 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 issues regarding the degradation behaviour of materials and coatings in actual saline environments, 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.

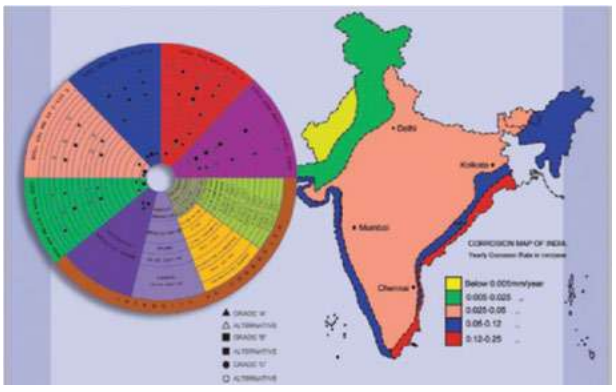


Figure 11: First Corrosion Map of India (1975)

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 the strict government regulations for the proper treatment of these electronic scraps, only 20% are recycled in an organised manner by the formal sector. In developing countries, there is a lack of a proper collection system, and mostly illegal recycling is carried out in the informal sector in an unorganised 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, e-waste recycling 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 contain 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 to 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 UORC banner, CSIR-NML has transferred e-waste recycling technologies to various industries for the recovery of 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 12: Urban ore recycling centre

Centre of Excellence in Critical Minerals and Metals (COECMM)

The Ministry of Mines has established Centres of Excellence (CoEs) under the National Critical Mineral Mission (NCMM) to boost domestic capabilities in critical minerals, aimed at research, technology development, and recycling. Among the 9 COEs, CSIR-National Metallurgical Laboratory, Jamshedpur is one of the designated CoEs to work on a hub-and-spoke model to strengthen India's critical mineral supply chain.

The Centre of Excellence in Critical Minerals

and Metals (COECMM) is conceptualised with the mission to "Advent, Practise, Promote and Commercialise" research & development in critical mineral processing and critical metal extraction spanning from exploration to recycling, and act as a catalyst in powering the clean & green economy for Viksit Bharat. The COE is operating with the vision to envisage novel cross-disciplinary approaches via integration of traditional, allied, and independent disciplines and expertise to maximize the benefits of cooperation among the spokes & stakeholders, which should result in manifold enhancement of critical mineral processing and metal extraction via sustainable pathways in utilising primary, secondary & tertiary resources. The certificate of CoE is given in Figure 13.

The COE with CSIR-NML as hub is attached to 16 spokes, spanning from 8 Industries/PSUs, 5 Academic Institutions, 2 CSIR Labs to CEEW as the policy advisor as displayed in Figure 14.

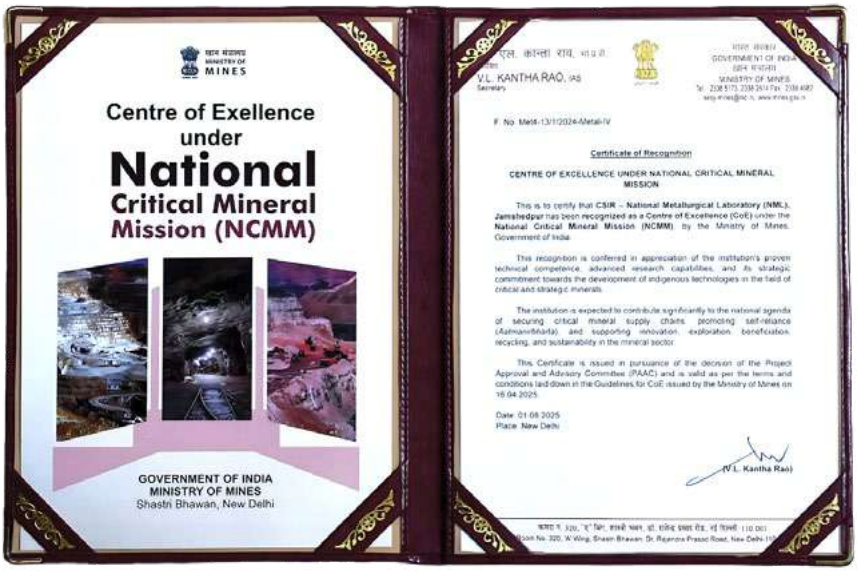


Figure 13: (a) COE Certificate

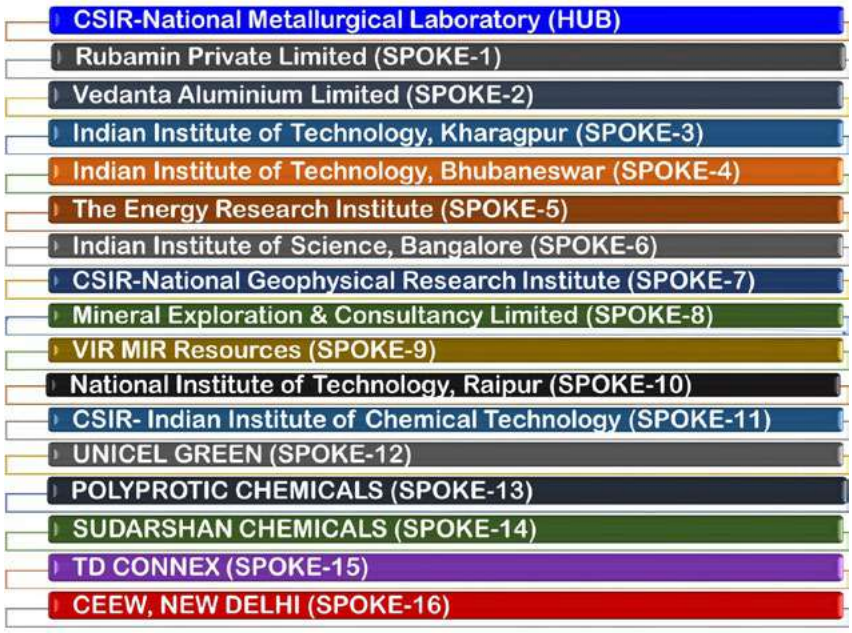


Figure 13: (b) COE Constitution with Hub and Spokes

Iron & Steel Making

Investigation on the preparation of DRI from the magnetite precipitate generated from VTM and ilmenite in CSIRO's Ti/V extraction process

CSIRO, Australia, has developed an innovative process to recover vanadium (as V_2O_5) and titanium (as TiO_2) from vanadiferrous titanomagnetite and vanadium-bearing ilmenite through hydrochloric acid leaching. In this process, iron is obtained as ultrafine magnetite (Fe_3O_4) as a by-product. These ultrafine magnetite particles can potentially be used as feedstock for the production of Direct Reduced Iron, but they must first be agglomerated to achieve a suitable size and strength for handling and processing. Pelletization is considered a suitable agglomeration technique because magnetite pellets oxidise during induration, producing in situ heat that assists pellet sintering and reduces external energy requirements. However, pelletizing ultrafine magnetite is difficult due to its extremely high surface area and tendency to form excessive nuclei. To investigate this challenge, CSIR-National Metallurgical Laboratory, Jamshedpur, in collaboration with CSIRO, initiated studies on palletization and reduction behavior of magnetite precipitates. The precipitated magnetite fines were received from CSIRO, pulverized, homogenized, and sampled using the cone and quartering method. Characterisation of magnetite precipitates, particle size, chemical composition, phase identification, microstructure analysis etc. was carried out for further processing of raw material. Particle size analysis revealed that more than 50% of the particles were below 1 µm, indicating a very high surface area and requiring high moisture for pellet formation. Pelletization experiments were conducted using a disc pelletizer with 0.2% bentonite as a binder. During pelletization, ultrafine magnetite required 25 – 28% moisture, which resulted in excessive nucleation and particle sticking, preventing proper pellet growth. To overcome this issue, coarser hematite ore fines (100–150 µm) were added. The addition of 10% hematite slightly improved pellet growth but remained inadequate. Increasing hematite to 20% improved nucleation but still failed to produce spherical pellets. However, with 30% hematite addition, pelletization improved significantly, reducing moisture requirement and enhancing green and drop strength. Further optimization is ongoing and expected to be completed in the coming quarter.

Process for production of bio sponge iron utilising bio-wastes and lean-grade ferruginous materials

India generates about 620–680 million tons of agricultural and forestry bio-waste annually, along with nearly 62 million tons of urban organic waste. While a portion of this waste is utilized for animal feed, composting, and energy generation, a significant amount is either burned or left to decompose, leading to environmental pollution. Similarly, nearly 49% of ferruginous wastes, such as iron ore slime, sludge, and mill scale generated in an integrated steel plant, remain unutilized. These wastes create serious environmental and disposal challenges and result in the loss of valuable minerals and materials. In view of this, it is envisaged to develop a process for the production of bio-sponge iron using biowaste as a reductant and ferruginous wastes such as iron ore slime, LD sludge, and mill scale as sources of iron-bearing materials. Pellets were prepared from the above ferruginous wastes using a disc pelletizer. The air-dried pellets were arranged with alternate layers of premixed biowaste fines and bio-desulphurization agent in a weight ratio of 1:2 inside a reactor. The reactor was heated in a temperature range of 900–1200°C for 20–180 minutes in a muffle furnace to facilitate the reduction of pellets. After the reduction process, the reduced pellets, known as Bio Sponge Iron (BSI) were separated from the by-product biochar, referred to as By-product

Biochar (BBC). The produced BSI and BBC were characterized for percentage metallization and calorific value, respectively. It is interesting to note that the BSI produced exhibited a metallization in the range of 88–92%, making it suitable for steelmaking in BOF, EAF, and induction furnaces (IF) as a substitute for scrap. It is also worth mentioning that the BBC obtained from wood char possesses a calorific value of 6882kcal/kg and can be further utilized as a reductant. Experimental photographs and the corresponding results are given in **Figure 1**. Based on the laboratory-scale findings, a patent has been filed entitled *"An Apparatus and a Process for the Preparation of Highly Metallised Low-Sulphur Bio Sponge Iron"*. Furthermore, a high-value project proposal for conducting commercial trials has been submitted to BHP, Australia, under the Global Centre of Excellence for Steel Decarburization scheme.

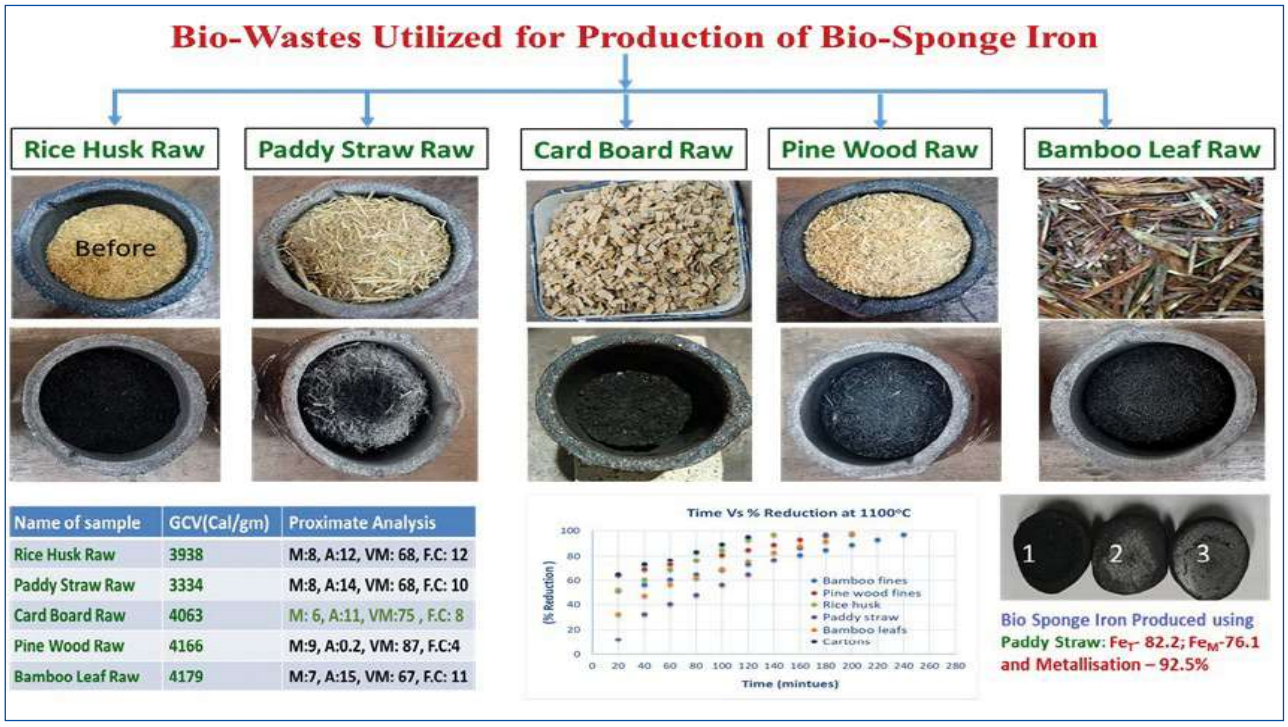


Figure-1: Experiments and results.

Upgradation of Lean Grade Ore/ Slimes through Reduction Roasting to Develop Blast Furnace Grade Pellet

Conventional beneficiation of lean-grade iron ores and slimes (<55% Fe) is constrained by complex mineralogy and the need for ultra-fine liberation, necessitating alternative upgrading routes to utilize India's vast low-grade resources and support the targeted 300 MT steel production by 2030. In this approach, lean-grade iron fines are ground and subjected to hydrogen-based reduction roasting (400–600 °C) in a Vertically Stacked Fluidized Bed(VSF)/Fluidized Bed Reactor(FBR) to convert hematite to magnetite partially. The roasted product is upgraded by low-intensity magnetic separation to obtain magnetite concentrate, which is subsequently pelletized and indurated to produce Blast Furnace or Direct Reduced Iron-grade pellets-grade pellets with reduced induration energy demand and lower carbon footprint. The schematic process flow of the developed process is shown below. The most important results obtained are: Hydrogen-based reduction roasting at 550 °C for 60 min, followed by low-intensity magnetic separation (774 gauss), successfully upgraded lean iron ore fines of two different grades. The 58% Fe Barajamda ore was enriched to ~66% Fe with a high yield of 93.35% and iron recovery of 97.29%, while the 48% Fe BHQ

ore was upgraded to ~63.5% Fe with 81.4% yield and 94.9% recovery. The magnetite concentrates were effectively pelletized at 1250 °C (30 min) with a basicity of 0.3, producing pellets suitable for DRI-grade (66% Fe) and BF-grade (63.5% Fe).

Decarburisation of high-carbon ferro manganese for the preparation of low-carbon ferro manganese

Decarburisation of liquid high-carbon ferromanganese (HCFeMn) was investigated using carbon dioxide (CO_2) gas as a decarburising agent to develop an alternative route for producing low-carbon ferromanganese (LCFeMn). Molten HCFeMn containing 6.27 wt% carbon was treated at 1425 ± 10 °C using a non-consumable lance for CO_2 injection. Process parameters, including temperature, treatment time, gas flow rate, lance immersion depth, and addition of MnO-rich synthetic slag, were systematically optimised to maximise carbon removal while minimising manganese oxidation losses. Carbon content was successfully reduced from 6.27 wt% to 3 wt%. A comparative techno-economic analysis indicates that the proposed process requires 3.74 kWh/kg, significantly lower than the 8.96 kWh/kg required in the conventional aluminothermic route, resulting in an energy saving of 5.22 kWh/kg. Furthermore, CO_2 emissions are estimated at 0.5–0.6 kg CO_2/kg LCFeMn for the proposed route, compared to 8–10 kg CO_2/kg in the aluminothermic process, resulting in a substantial reduction in the carbon footprint.



Figure 2: Bottom purging reactor (20-50 kg) for CO_2 treatment

Reduction of Manganese Ore using Elemental Sulphur

The project aims to find a suitable agglomeration process and pre-reduction of manganese ore using Sulphur at a 10 kg scale in the production of Ferromanganese. a The scope of the project are, establishing the suitable agglomeration process for Sulphur infused of manganese ore and Pre-reduction of manganese ore-Sulphur composite pellets at 10 kg scale followed by Production of ferro manganese in 5 kg scale SAF. For making of pellets, 1% Boric acid, 5% Bentonite, and 5% Lime was used as binder which ensured minimum strength requirements. Reduction Index (RI), Reduction Degradation Index (RDI), Tumbler strength, and Abrasion resistance etc.. Optimization of Particles Size, Binder, and Smelting parameters has been done. Mechanical & Metallurgical Properties of Briquette/pellet and Pre-Reduced Briquette/pellet has been measured. has been optimized . . 6)

ScaleUp: Successful prereduction at batch scale of 13-15 kg pellets.7) SmallScale Trials (~1.5 kg batch): Lower basicity and longer holding time significantly improved metallic yield. Prereduction study at 1.5 kg/ batch and in 13-15 kg/batch has been carried out and achieved 43.3% yield . At lower basicity (0.24), maximum yield obtained was 34%.

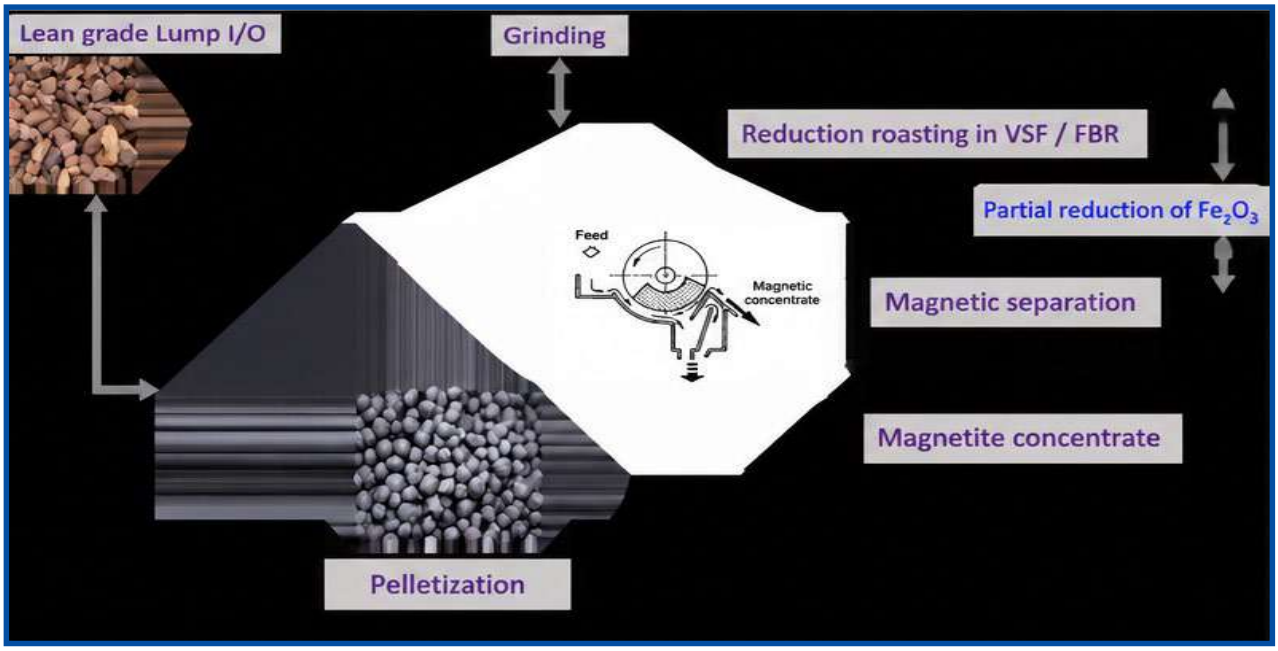


Figure 3: Flow sheet of the pre-reduction and smelting of manganese ore to produce ferro-manganese and sulphuric acid

Design and Development of a novel innovative reactor for the production of Magnetite powder from iron oxide fines

The project aims to develop a process at 10 kg scale using H_2 /Syn gas in an innovative reactor for the production of Magnetite powder from Iron oxide fines. 10 kg scale process using hydrogen gas / syn gas with an improved design reactor has to be developed, which will effectively reduce iron oxide fines to magnetite powder. The reactor has been designed, fabricated and installed in our laboratory . Now, the experiments are going on to optimise the process parameters. Four trial runs have already been taken.



Figure 4: Innovative Reactor

Critical Metals Extraction from Primary & Secondary Resources

Potash fertilizer recovery from indigenous silicate minerals K-feldspar with simultaneous production of valuable by-products

The project is sponsored under mission mode (tapping of critical minerals). Potassium (K) is one of the key macronutrients, essential for the healthy growth and development of crops with no substitute to date. Currently, the major sources for 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 fertiliser. India is currently importing 100% potash (>5 million tonnes) by spending $1.45 billion dollar per annum and is projected to increase further in the future if no indigenous production comes up. Therefore, the objective of this work is to utilise our own natural resource (K-feldspar) for the production of different potassium salts as well as other valuable by-products like silica powder and ferrosilicon. The process is developed at a scale of 20 kg. The developed indigenous process could be helpful to reduce imports 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 own natural resources.

Recovery of Metal Values from Spent Lithium-Ion Batteries and Fabrication of New Lithium-Ion Batteries

[A Circular Economy Approach-Battery to Battery (B2B)]

CSIR-NML in the B2B project focuses on the recovery of metal values from spent lithium-ion batteries and the fabrication of new lithium-ion batteries. The project broadly outlines the following targets for CSIR-NML: a) Sourcing of tonnage volume spent/scrap/waste Lithium-Ion Batteries (LIBs) by CSIR-NML and processing at CSIR-NML; b)Recycling all available chemistries of spent lithium-based batteries (LCO-Lithium Cobalt Oxide; NMC- Nickel Manganese Cobalt; NCA- Nickel Cobalt Aluminium; LMO- Lithium Manganese oxide; LNA-Lithium Nickel Aluminium; LFP- Lithium Iron Phosphate, for extraction and separation of highly pure (approx. 90%) materials of Li, Mn, Ni, Co as carbonate/sulfate and synthesis of mixed metal oxide precursors. CSIR-NML has been able to generate the product with NMC 622 chemistry and supplied to CSIR-CECRI for battery making. The pure salts shall be upgraded to desired levels by CECRI to make new batteries, and tested by GODI Energy and Tata Chemicals.



Figure 1:Processing of Lithium based Batteries at NML (From warehouse scrap to leaching)

Recycling Of Graphite From Spent Lithium-Ion Batteries for High-Energy Li-Ion Capacitors In Association with IISER, Tirupati

This project is funded by the Waste Management Division of DST, and operated in the close-knit association of IISER-Tirupati, NML Jamshedpur, and Industrial Partner. The project is based on the objectives of recovery and purification of graphite from spent **Lithium-Ion Battery** (LIB) followed by production of high-energy and power LIC (>150 Wh kg–1). Mechanical separation was employed to obtain electrode material, which was leached in acid to obtain a metal-rich solution and residue. The chemistry of LIBs and the quality of graphite used have a very close correlation. LMO batteries contain high amount of graphite. The residue was further processed by low-acid leaching to obtain graphite. The chemical analysis of graphite shows >95% purity. The high-purity graphite synthesised at CSIR-NML has been tested by IISER, Tirupati, to fabricate a high-performance LIC. The RG half-cell exhibited an excellent specific capacity of 302 mAh g–1 even after 75 charge-discharge cycles with a coulombic efficiency of >99%, in 300 cycles with high stability and reversibility.

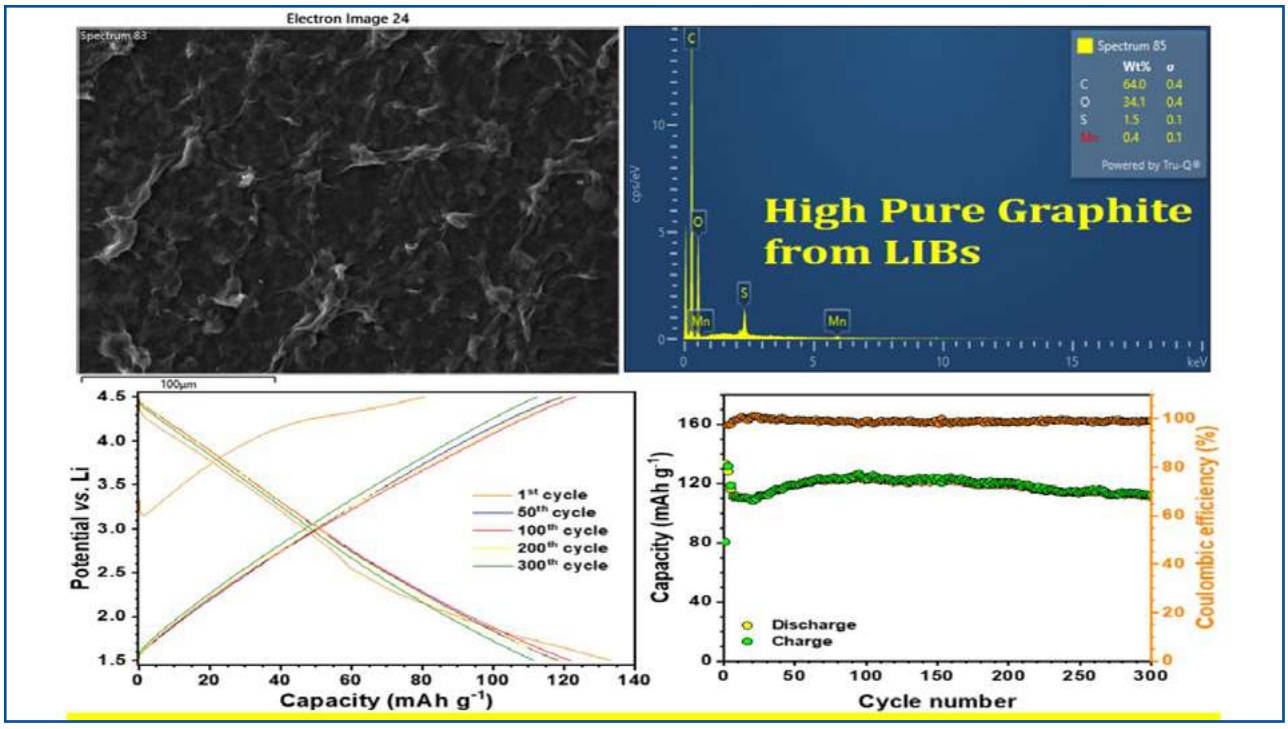


Figure 2: Electrochemical performance of high surface area carbon from spent LIB in half cell configuration

Development of Process for Synthesis of Copper and Nickel Metal Powders from Waste Electric and Electronic Equipment (WEEES) For Additive Manufacturing

WEEEs are a rich source of Cu (35% wt) and Ni (5-60%), which can be converted to high-quality metal powders using hydro-cum-electro-metallurgical methods. With India's current vision of indigenous technologies in additive manufacturing by 2030, a technological intermediation is required for a cheaper process from less costly raw material. Using copper wire scrap post dismantling and hydro-metallurgical processing, the dissolved copper was processed by solvent extraction as well as reduction to make copper salts, metallic copper, and copper powders, respectively. The copper powder was analysed to be 99.999% Cu with a particle size (d_{80}) of <45 µm.



Figure 3: a) Processing of Wires, b) Leaching of Copper, c) Cu Metal Foil, d) Copper Powder

Recovery of Lithium from Potential Indian Primary Resources for Battery Applications

[CSIR Fast Track Mission Mode Project]

The demand for lithium is projected to increase three times by 2030, while India is deficient in high-grade resources of lithium. In view of this, CSIR-NML, under a Fast Track Mission Mode Project, took up the studies on characterization, beneficiation, and extraction of lithium values in a marketable form from a few potential Indian deposits. 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) Degana in Rajasthan, and (iii) Amareshwar in Karnataka. The a**chievements under the project are**: a) **Lithium carbonate from** Spodumene from Amareshwar, Karnataka: 99.98% Li Carbonate; b)**Lithium Hydroxide from** Zinnwaldite from Degana, Rajasthan: 99% LiOH; and c)**Lithium Carbonate Equivalent Product from** Laterite from Reasi, Jammu: 98% Mix of LiOH + Li Carbonate.

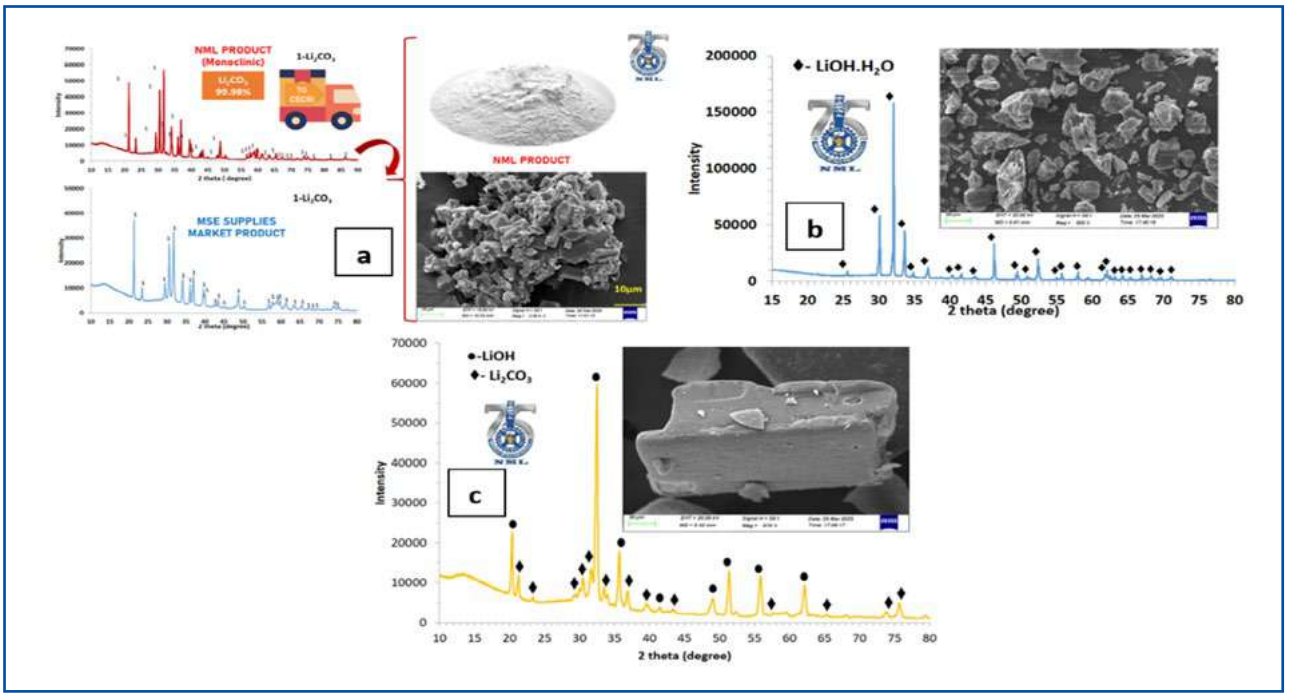


Figure 4:a) Lithium carbonate from Spodumene (XRD in Red for NML Sample, XRD in Blue for Commercial Product; SEM of the Product); b)Lithium Hydroxide from Zinnwaldite; c) Lithium Carbonate Equivalent Product from Reasi Jammu ore

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

This project focuses on scaling up the vacuum distillation process from a 1.5 kg batch capacity developed in earlier work to a larger 5–6 kg batch scale. End-of-life magnesium scrap from automotive and die-casting sources is processed by vacuum distillation to recover >99.9% pure magnesium, leaving aluminium and zinc-rich residues. This process involves melting the crude magnesium in the upper crucible. The liquid magnesium then falls into the bottom vaporisation crucible. It is basically a two-zone heating system with a vacuum retort and accessories to monitor and control. This semi-continuous facility is planned to integrate an increased-size refined Mg crucible with condenser-vacuum controls to carry out experiments at the targeted scale of 5-6 kg. All the campaigns at a 5–6 kg scale were conducted using gearbox scrap (containing ~91% Mg, 7–8% Al) and die-casting scrap (containing ~94% Mg, ~5% Al), and the residue from these experiments is re-distilled. Residues were re-distilled under preset conditions (980–1000 °C, 5–12 mbar, connector >920 °C, condenser 300–600 °C). Mg was recovered as dendrites, droplets, and ingots with ~100% recovery at ~1 kg/hr. Single-stage distilled Mg shows a purity of 99.90–99.95%. Fe content is well controlled, while Al content is ~60 ppm. Residual Al and other impurities appear as a greyish powder. A second-stage distillation will be conducted to evaluate Al variation in the final ingot. Required standards, glassware, and chemicals have been procured, and graphite-based wetting components and consumables have been fabricated for trials. The raw material and distilled Mg were characterized using ICP-OES to determine chemical composition, while SEM and EDS analyses were employed to examine the structural features and elemental composition of leafy dendrites and magnesium droplets.

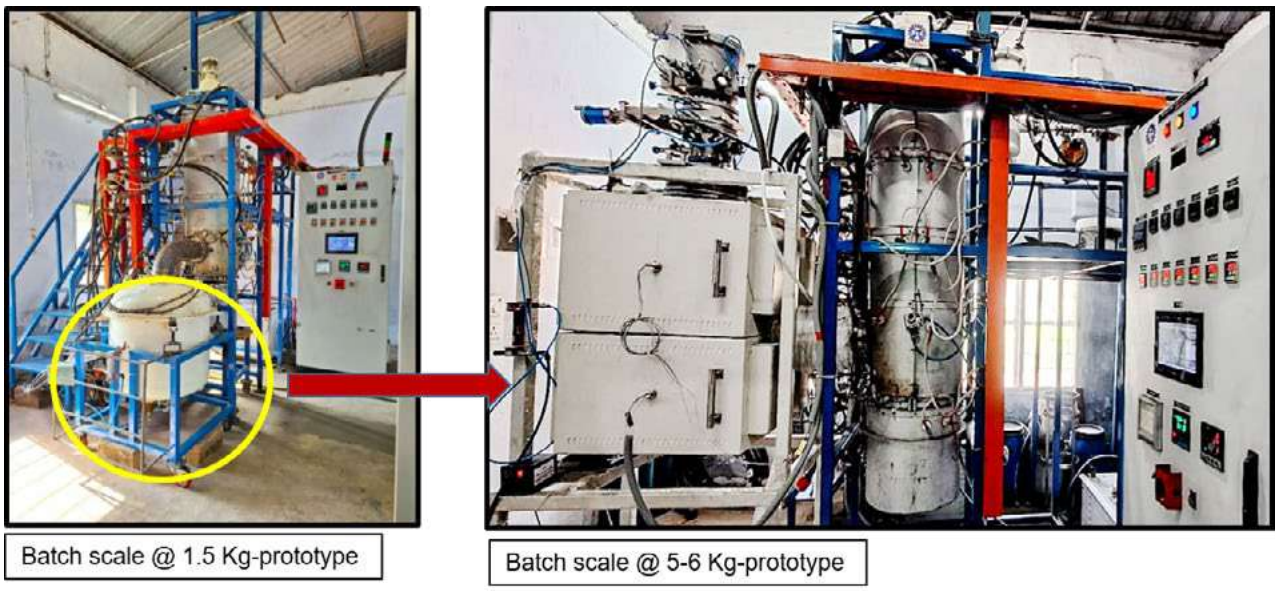


Figure 5: Semi-continuous Magnesium Distillation Pilot Plant (capacity-6kg)

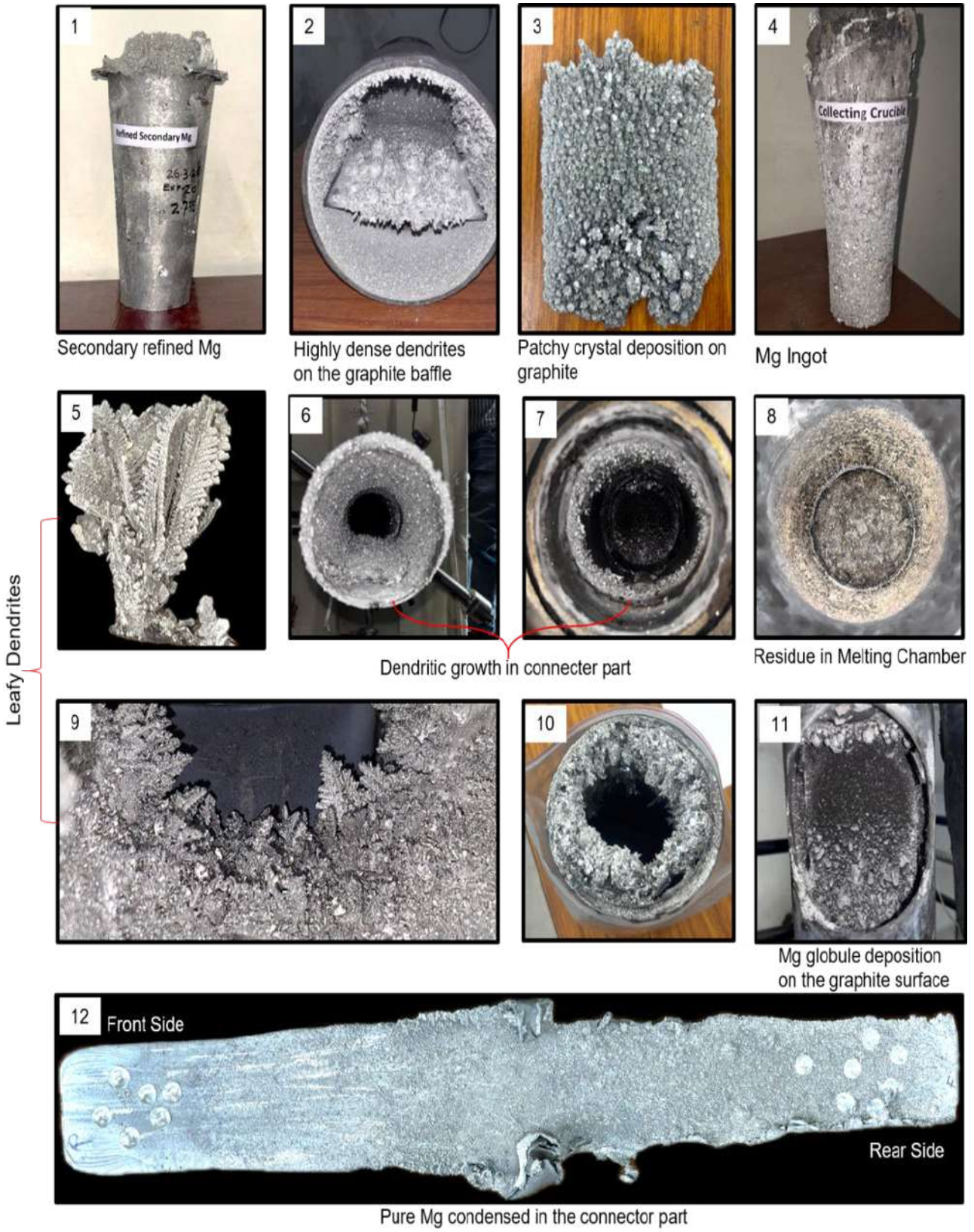


Figure 6: Pictures of experimental deposition, such as Dendrites, globule primary and secondary Refined Mg.

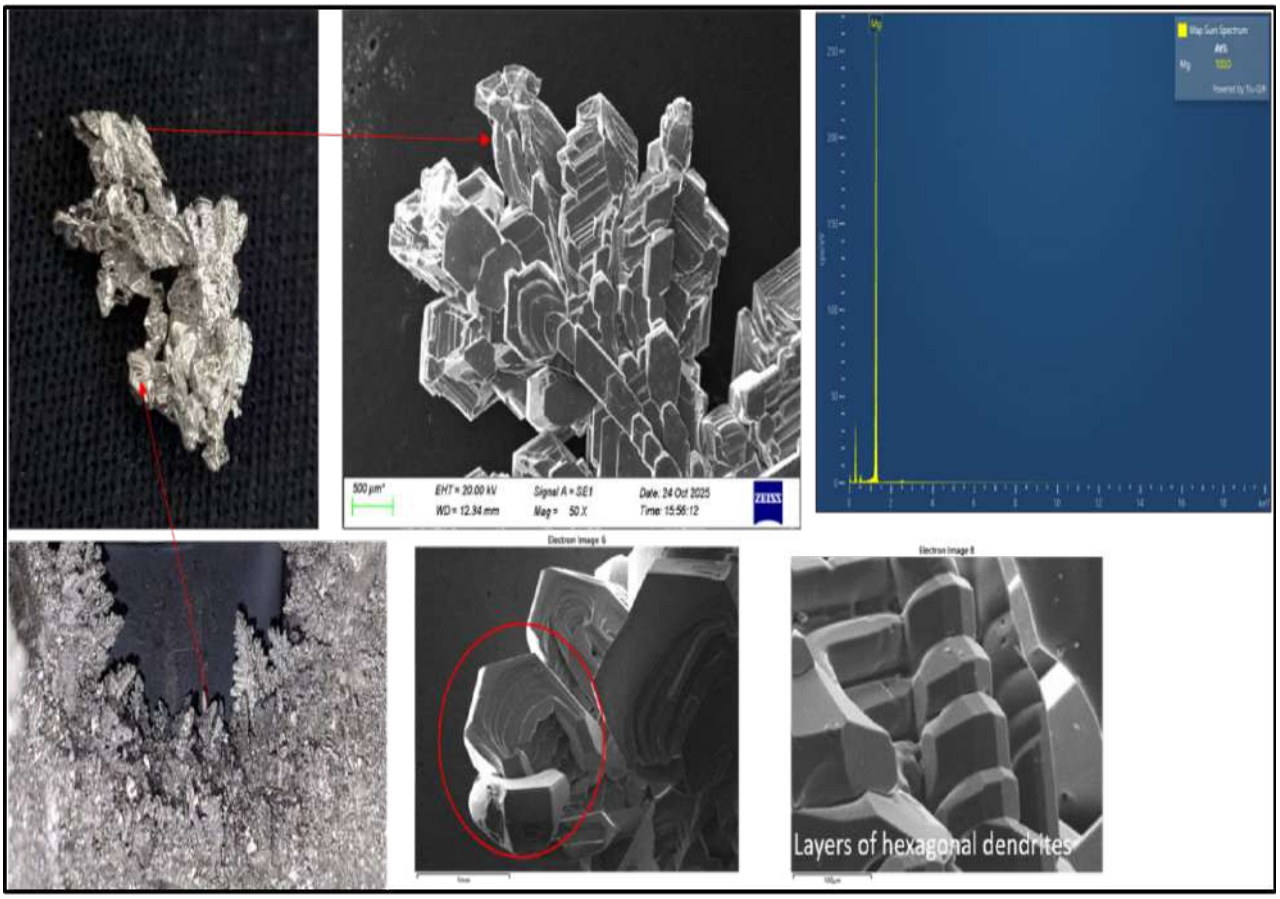


Figure 7: SEM EDS and the hexagonal structure of the highly pure Mg dendrites

Process technology for the recycling of waste Crystalline silicon photovoltaic (C-Si PV) modules.

The objective of the project is the development of methodology/processes for the recovery of valuable materials, Ag, Si, and the development of glass ceramics from waste PV glass. End of life photovoltaic (EOL PV) modules are procured and subjected to disassembly and downsizing to separate the crystalline silicon and glass fractions. Initial characterization studies of c-Si solar cells and glass have been done. 99.9% quantitative leaching of silver from crystalline silicon solar cells is achieved. Successfully separated silver from multi-metal leach solution through cementation or chemical precipitation. Silver chloride (90% purity) and silver (90% purity) from the cemented product have been produced. Silicon with 99% purity from crystalline silicon solar PV cells has been recovered. Glass ceramics produced at a range of sintering temperatures with enhanced mechanical properties meet the targeted strength. Physical property assessment has been done. XRD studies done corroborate well with the achieved properties. Both qualitative and quantitative analyses (Rietveld) have been done. The Degree of amorphisation/crystallinity has been calculated at each temperature. Quantitative XRD analysis reveals the highest crystallinity and maximum pyroxene phase development at the sintering temperature, where maximum compressive strength has been attained. Structure-property correlations has also been developed in this study.

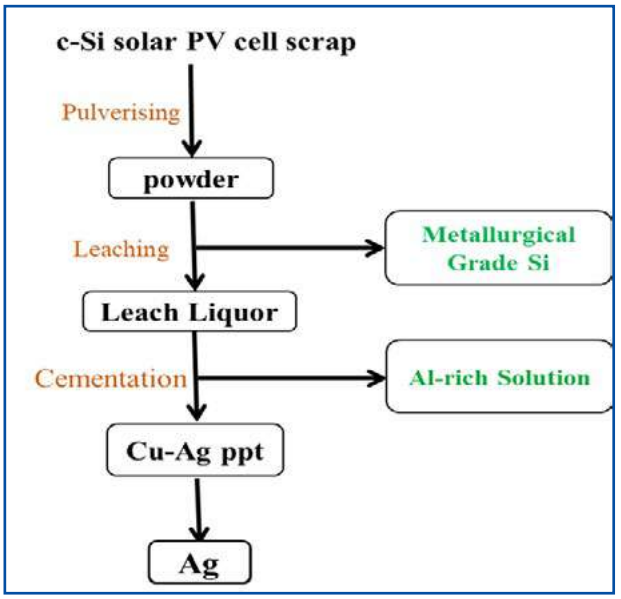


Figure 8 : A detailed flowsheet of the proposed process

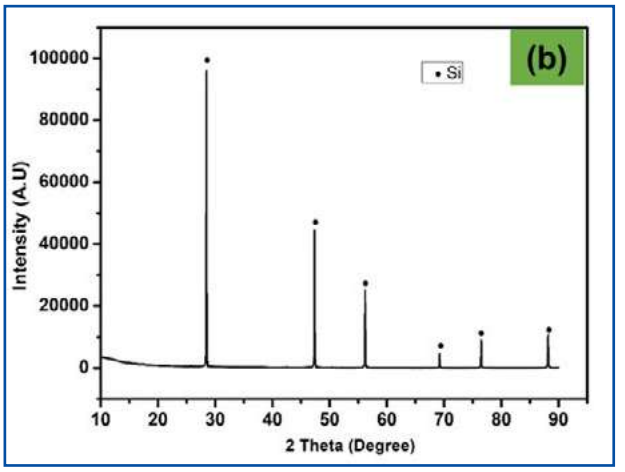


Figure 9: (a) Photograph of pure silicon powder. (b) XRD pattern of the produced silicon



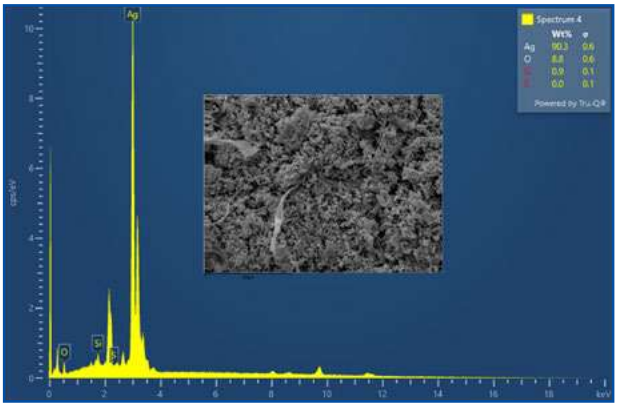


Figure 10: SEM-EDS of silver powder

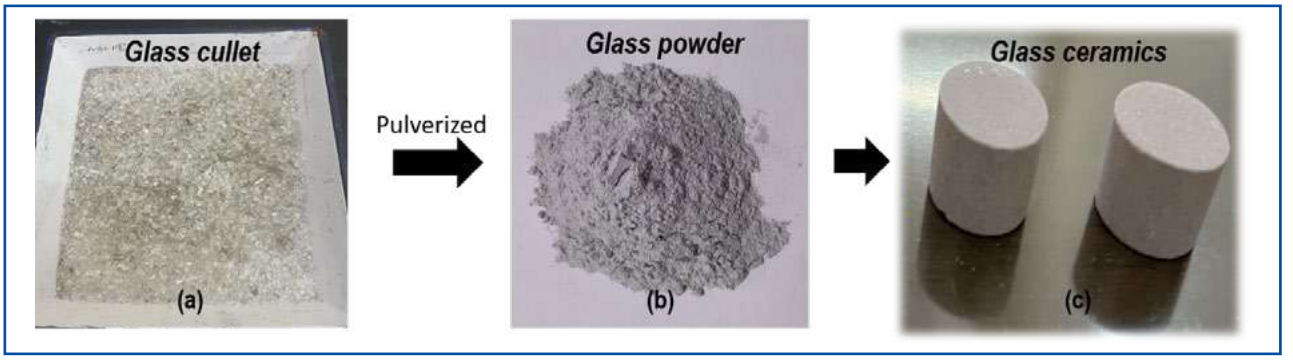


Figure 11: (a) Glass cullet obtained from waste solar glass, (b) glass powder pulverised to obtain the final products, (c) glass ceramics prepared at a particular sintering temperature

Impressions

Alleima

To,

Date: 20/06/2025

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

Respected Sir,

I would like to express gratitude and appreciate for timely completion of our project work on cold rolling of our stainless-steel strip samples to 0.1mm thickness at NML. It required careful planning of reductions and multiple intermediate annealing in inert atmosphere without damaging the material.

Mr. A. P. Murugesan's knowledge, willingness and efforts to achieve the so far never tried thickness in cold rolling mill set up at NML has been instrumental in the project. His work puts us in good position to demonstrate NML's capability to our global research colleagues and explore opportunities for collaborative research efforts.

We are also thankful to **Dr M. M. Humane** for guidance and supporting staff at NML for successfully delivering the work.

Yours faithfully,

Narendra Girase
R&D Manager,
Alleima India Pvt Ltd,
Pune, Maharashtra.

Alleima India Private Limited ★ Pune ★

Urban Ore Recycling & Waste Valorisation

Technology Development for Extraction 0f Critical Metals (Niobium, Tantalum, Scandium) from Secondary Resources/ Potential Wastes

CSIR-NML has developed a technological flowsheet that caters to the extraction and separation of Niobium, Tantalum, and Scandium, as pure oxide salts from secondary resources like tin slag, Waste Electrical And Electronic Equipment (WEEE) capacitors, to name a few. Since India is 100% import dependent on these metals, and with the stringent requirement of these metals for clean energy applications, it was envisaged to target a few resources and develop a flowsheet in association with the Ministry of Steel, Ministry of Mines, and CSIR.

- Tin slag is a potential resource of Niobium (Nb), Tantalum (Ta), and other critical metals like Sc. It contains 8-10% Ta_2O_5, 14-18% Nb_2O_5, along with 8% TiO_2 and 79ppm Sc. The feed material has been subjected to mineral liberation analysis and flotation circuits. The concentrate samples have been subjected to hybrid extractive metallurgical processes to generate 55% ferroniobium and salts of Niobium and tantalum. The work is still in progress for the separation of Sc among Rare Earth Elements.
- Ta-based capacitors contain Tantalum (Ta), and silver (Ag) along with manganese. In a project under Mission Waste-to-Wealth of CSIR, a process was developed to process these capacitors (SMD and Multilayer Ceramic Capacitors), to extract and separate Ta as 99% pure salt/oxide at NML, which was converted to tantalum metal jointly with CSIR-NIIST.

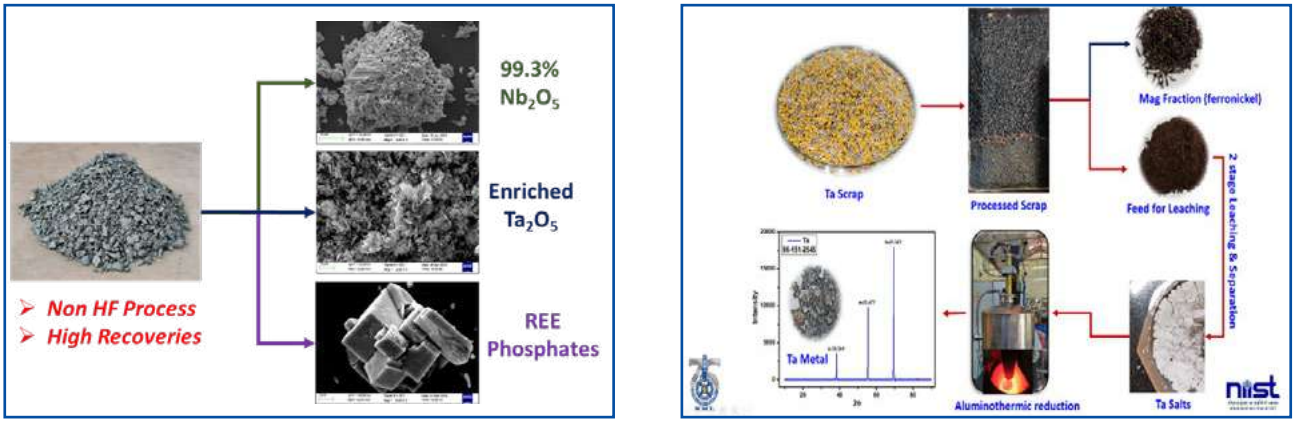


Figure 1: Processing of secondary resources of tantalum (a Tin Slag, B Capacitors)

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) have also 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. The steel industry significantly contributes to GHG emissions, producing approximately 2.6 billion tons of CO_2 in 2020 for a global steel

production of 1.86 billion tons. This contributed to an estimated 7%–9% of global GHG emissions. 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, in order to understand the fundamentals that affect the CC and MC processes. Selective CO_2 capture from coal-fired boiler flue gas is performed using single and blended amine solvents in a pilot plant at industry under anMoU with CSIR-NML. In the scope of this project at CSIR-NML, we investigate carbon sequestration through mineral carbonation (MC) using Linz-Donawitz (LD) slag, a steelmaking by-product, to understand the fundamentals that affect the CC and MC processes and their potential use as a sustainable material demonstrated as a paver block and in OPC composite cement. The carbonation efficiency achieved 19% by optimisation of parameters. Product properties are also optimised for composite cement and M-35 and M-45 paver blocks for light to medium traffic applications, with subsequent property testing at the CSIR-NML facility.

Recovery of valuables from Spent Stainless Steel Pickle Liquor

During continuous pickling operation, the activity decreases with increasing dissolved metal concentration and is rejected as spent pickle liquor (SPL) containing dissolved metal salts of iron, chromium, nickel, manganese, etc. Normal practice of neutralisation and dumping of the sludge containing valuable metals is not only hazardous to the environment, but it also incurs huge loss of revenue. Therefore, the project was sponsored by Jindal Stainless Ltd. (JSL) with an objective (i) to develop a flow-sheet for the recovery of Ni, Cr, Mn from spent stainless steel pickling liquor in the form of saleable products (ii) fixing the toxic component of process residue and assessment of environmental impact using Life Cycle Assessment (LCA).

Iron in the pickle liquor is about 75-80% of the total metallic content and creates difficulty during the recovery of valuable metals. Two flowsheets were developed for the recovery of valuables from SS pickle liquor. In the 1st flowsheet, the fluoride present in the liquor was recovered as high-purity fluorspar, and the fluoride-free liquor was subsequently treated to remove iron for easy recovery of Ni and Cr. A selective 2-stage partial precipitation method is optimised to produce hydroxide/oxide sludge with a high Cr: Fe ratio, which can further be smelted to produce Fe-Cr alloy. In the 2nd flowsheet, Fe is removed completely by solvent extraction, followed by recovery of Cr and Ni by selective precipitation.

Along with stainless steel pickle liquor, pickling sludge was also collected from JSL for developing a flowsheet for the recovery of metal values and fixing the toxic components. The sludge containing 0.75% Ni,1.6% Cr, and 9.45% Fe was leached in sulphuric acid to selectively dissolve Ni and Cr. Under optimised conditions of leaching, a counter-current leaching (CCL) method was adopted to maximise Ni and Cr dissolution. A set of CCL experiments was done to generate sufficient leached residue for further stabilisation study. The treated metal-depleted residue was sent to BITS Pilani for a fixing experiment, where it was utilised to produce eco-friendly high-strength pavement tiles with a strength up to 30 MPa by mixing it with cement, river sand, and fly ash.

Process validation was done through up-scaling and under optimised conditions; a preliminary economics of the whole process was also calculated.

Development of a process to recover Al, Sn, Ni and Fe as value added products from scrap turning and industrial waste powder

CSIR-NML signed an MoA with M/s Makaney Metals, Mumbai for a joint sponsored project to develop a comprehensive hydrometallurgical treatment process to recover valuable metals such as Al, Sn, Ni, Fe from industrial waste, enhancing the value of waste by transforming it into marketable metals/ salts. Industry has planned the execution of the commercial exploitation of Al, Ni, Sn and Fe salts/ metals from these industrial wastes.

The project will not only address the efficient recycling of metal waste but also mitigate the environmental impacts associated with waste disposal. The deliverables include a complete process flow-sheet aimed at commercial viability.



Figure 2 : MoU signed between CSIR-NML & M/s Enviro Serve Technologies Pvt. Ltd., New Delhi

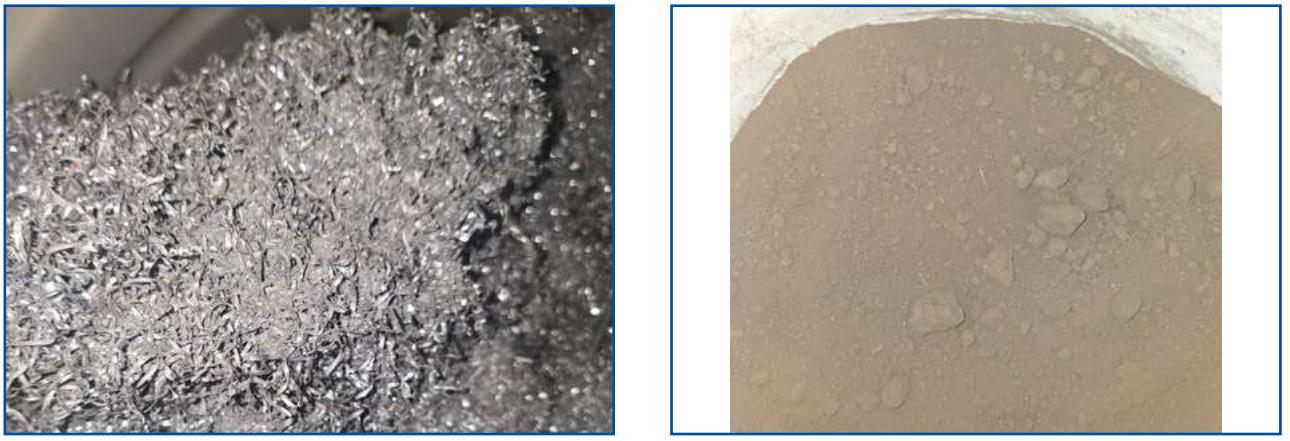


Figure 3 : Industrial waste supplied by Makaney Metals, Mumbai



Figure 4 : Various Metal Salts Produced by CSIR-NML

Impressions

Gnano
GLOBAL NANOTECH
The Innovators

405, B-wing, 4th Floor,
Jaswanti Allied Business Center
Ramchandra Lane Extn, Kanchpada, Malad (W)
Mumbai - 400064 • Mob. +919619035525
Email : globalnanotechnology@gmail.com

To Whom It May Concern

Dear Sir,

We are pleased to share a brief update and express our continued appreciation regarding the technology titled "Transfer of Know-How/Technology for the Development of Ti3AIC2 MAX Phase", which was transferred to us by CSIR-NML.

Following the successful development of high-purity batches using NML's technology, and after receiving highly positive feedback from various professors and research laboratories, we are delighted to inform you that we have commenced the gradual supply of Ti3AIC2, MAX phase and Ti3C2 MXene materials to several premier Indian research institutes including IITs, IISERs, and many universities The feedback from these laboratories has been positive and encouraging. We are also happy that we are now making these materials indigenously in India with the support of NML's technology, and stopped importing it from China, aligning with the vision of MAKE IN INDIA.

At present, these materials are primarily being utilized for research and development purposes, as large-scale commercial applications are still under exploration. However, global research on MXenes is expanding rapidly, with notable contributions from the United States, China, UAE, South Korea, India, Poland, and Canada. This growing international interest strongly indicates that the demand for advanced MAX and MXene materials will rise significantly in the coming years, driven by their potential applications in energy storage, sensors, and biomedical devices.

We have published relevant information about these materials on our official website, https://gnanoworld.com/, and are also planning to make them available on Amazon, thereby improving accessibility for the broader research community.

We once again extend our sincere thanks to CSIR-NML and also looking forward for further collaborative opportunities.

Mr. Jinesh Shah
Global Nanotech, Mumbai

For GLOBAL NANOTECH
J. S. Shah
Proprietor.

Alloy Development

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

The project aim: 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; Large-scale thermomechanical controlled processing and heat treatment optimization; Microstructure engineering for assessment and optimization of mechanical behaviour (tensile, Charpy impact, ballistic, etc.), weldability, bendability, etc. Currently the project has completed fine-tuning of lab-scale optimized composition and process schedule, reproducibility, and mechanical performance evaluation at various thicknesses. Under the project, a customized muffle and salt bath setup has been designed, procured, and installed for in-house pilot scale heat treatments (Design patent under progress). The findings of the project mitigated the impact of the lack of indigenous technology to produce ultrahigh-strength armour-grade steel with reduced and economically competitive alloying addition, elimination of energy-intensive heat treatment steps, better welding, fabrication, and other post-processing capabilities, etc. The outputs achieved under the project were: Pilot scale optimized alloy composition and energy-efficient process technology (under progress); designed medium carbon low alloy steel to eliminate import of Co, Ni, and Mo for steel making; developed an energy-efficient process technology (Figure 1) to achieve ultra-high strength combined with good ductility (Figure 2), impact toughness, and fracture toughness. One Patent is filed by CSIR (An energy-efficient process for ultrahigh strength steel with excellent toughness, Application No. 202411058888). The future plan is to conduct a plant trial and commercial production of steel to manufacture armour vehicles with better safety.

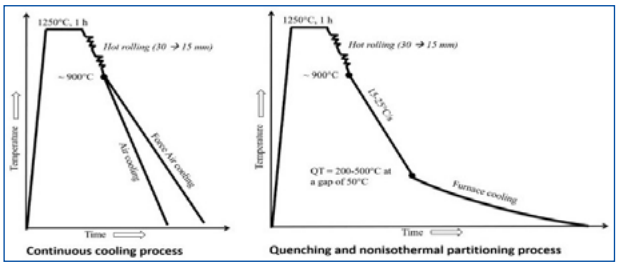


Figure 1: An energy-efficient process technology

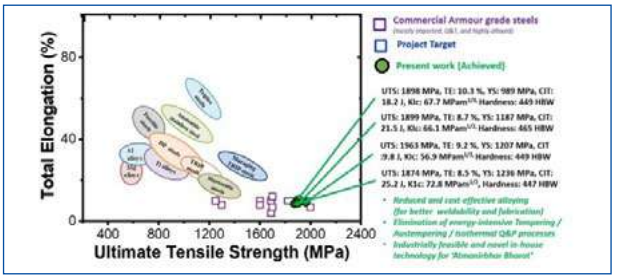


Figure 2: Ultra-high strength combined with good ductility

Feasibility study on lean steel composition and its process schedule for rocket motor casing

The main objective of the project was the identification of the extent of reduction in alloying elements and the process technology capable of delivering mechanical properties at par with the C-300 grade maraging steel. Currently, the detailed literature review and patent search to identify white space are completed, and the design of 04 new alloys with reduced alloying addition based on thermodynamic and kinetic simulations is undergoing. The study is of high significance as it reflects a) High Concentration of strategically imported alloying elements like Co, Ni, Mo, and Ti, leads to foreign dependency and high cost; b) Stringent carbon and impurity restrictions necessitates dual-stage remelting (VIM + VAR or ESR) and high-cost raw materials; c) Conventional and energy-intensive aging heat treatment; d) Limited Open domain information, i.e. minimal and largely ineffective attempts to lower alloying element content. The design of novel alloy composition has been achieved. A low alloy steel to eliminate

import of Co, Ni, Mo, and Ti, for steel making has also been designed. A collaborative project has also been accepted for funding by ISRO-VSSC. Further, the project will take up steel making and processing in theoretically designed parameters, followed by microstructure and mechanical properties evaluation.

Forging, hot rolling and salt bath heat treatment of different grades of high carbon steels

The project focused on developing and optimising thermomechanical processing routes for different grades of high-carbon steels using ingots of varied compositions supplied by the sponsor. The work involved controlled hot forging, hot rolling, and salt bath heat treatment to establish suitable process parameters for industrial applications. Processing trials were carried out with controlled deformation schedules and thermal cycles to ensure process stability and repeatability across different steel grades. Systematic variation of forging, rolling, and heat treatment conditions enabled the identification of robust processing windows. The project was centred on process optimisation, and no characterisation activities were included within the scope, with all evaluation and testing carried out at the sponsor's end. The trials were completed, and baseline as well as optimised processing parameters were established for different grades. The project was executed as per the planned schedule with effective utilisation of available infrastructure and resources. The outcomes provide a reliable process framework for industrial implementation, directly supporting sponsor's manufacturing requirements.

Development of wear-resistant steel for segment of coal sizer

Under the project, the following activities were taken up: a) characterization and evaluation of raw materials and existing segment material, b) establishment of suitable lab scale wear test method to simulate the industrial sizing and crushing operation, c) design and development of novel and economic alloy composition and its process technology, d) supervision of modified segment manufacturing, data analysis and suggestion on further areas of improvements. Currently, the lab-scale development has been completed for subsequent plant trials in the industry. The project has been able to address the issue of higher wear rate of high-Mn Hadfield steel for a better life of the segment of coal sizes. Till now, the lab. scale alloy composition and energy-efficient process technology have been optimised. Problem-specific composition & process design were done based on an in-depth review of scientific literature, patents, and thermodynamic simulations. Identified novel steel composition and energy-efficient process technology to achieve up to 85% improvement in hardness and 36% reduction in material loss due to wear with comparable tensile strength and Charpy impact toughness. The future plan includes making of segments based on CSIR-NML technology and its field trial.

Hot rolling and cold rolling followed by salt bath heat treatment of high strength steels

The project focuses on developing and optimising thermomechanical processing routes for high-strength steels using materials supplied by Tata Steel. The work involves controlled hot forging, hot rolling, and cold rolling, followed by salt bath heat treatment under varying temperature and holding conditions to establish suitable process parameters for industrial applications. During the reporting period, initial trials have been successfully carried out to define processing windows for deformation and heat treatment. Rolling and heat treatment sequences have been executed with controlled parameters to ensure process stability and repeatability. The project is primarily centred on process optimisation, and no characterization activities are included within the scope, with all evaluation to be carried out at the sponsor's end. The work is progressing as per schedule, and further efforts will focus on refinement and standardisation of rolling and heat treatment parameters for industrial implementation.

Multistage processing of high strength steels: from forging to rolling and salt bath heat treatments to annealing treatment

The primary objective of the project is to develop and optimise multistage thermomechanical processing routes for advanced high-strength steels using materials supplied by the sponsor. The scope of work is focused exclusively on the processing of the supplied steel ingots/billets through controlled hot forging, hot rolling, cold rolling, salt bath heat treatment, and annealing operations to establish suitable process parameters for industrial applications. During the reporting period, initial batches of sponsor supplied materials have been successfully processed through forging and rolling using controlled deformation schedules. Preliminary trials have been carried out to establish suitable forging temperatures, rolling reductions, and process sequences. Salt bath heat treatment and annealing trials have also been initiated to define appropriate thermal cycles for phase transformation and process stability. The work has primarily focused on establishing robust and repeatable processing parameters across different stages of deformation and heat treatment. No characterisation activities are undertaken under this project scope, and all evaluation and testing are expected to be carried out at the sponsor's end. The key outcomes achieved so far include the successful execution of multistage processing routes, identification of critical processing windows for deformation and heat treatment, and establishment of baseline parameters for further optimisation. The project is progressing as per the planned schedule with effective utilisation of available infrastructure and resources. The major challenges encountered include optimisation of process parameters for varying material compositions, maintaining process consistency during high-temperature operations, and ensuring repeatability of salt bath heat treatment conditions. The next phase of work will focus on further refinement and standardisation of processing parameters, optimisation of cold rolling schedules, and finalisation of heat treatment cycles to ensure industrial applicability. The project is on track to deliver a comprehensive process optimisation framework for high-strength steels, which will be of direct relevance to sponsor's manufacturing operations.

Unravelling the fundamental correlation of the transformation pathway with the mechanical and corrosion properties of multicomponent nano-pearlitic steels

The major objective of the proposed project was to provide a well-validated sequential thermodynamic → kinetic → mechanical/corrosion behaviour framework, which can be used to map a given steel composition along with its undercooling/ transformation temperature and holding time to its corresponding transformation mode, post-transformation partitioning extent, mechanical and corrosion properties. Some of the salient achievements and observations from the work are a) Unified Interaction Parameter Formalism (UIPF) based Local Equilibria (LE) framework has been used for predicting pearlite formation behaviour (i.e. whether pearlitic transformation will be associated with substitutional component partitioning or not) in multicomponent high carbon steels, b) Thermodynamic simulations adopting UIPF have been done to predict metastable austenite/ferrite and austenite/cementite phase boundaries for Fe-C-Mn and Fe-C-Cr alloys after assessment and compilation of necessary interaction parameters, c) Based upon partitioning and non-partitioning regime demarcation of phase diagrams via thermodynamic simulations, Fe-C-Mn and Fe-C-Cr alloys have been cast and heat treated for validation of the predicted transformation mechanism/pathway, d)Transmission Electron Microscopic analysis of partitioning/non-partitioning behaviour during pearlite formation in the designed alloys has been carried out for validation of the thermodynamic model's predictions (Figures 3) Another set of alloys with predicted non-partitioning led pearlite formation have been cast, hot forged, hot rolled,

recrystallized, re-austenitized and heat treated isothermally for different times at temperature below equilibrium eutectoid temperature to allow varying extent of post-transformation partitioning between pearlitic ferrite and cementite, f) Post transformation partitioning kinetics predicted through diffusion simulation adopting DICTRA have been validated with STEM-EDS composition profile, thereby establishing the efficacy and accuracy of DICTRA in predicting post transformation enrichment/depletion extent, once non-partitioned pearlite has formed g) Local compositional profiles adjacent to ferrite/cementite interface evolved during post-transformation partitioning have been correlated with yield strength of the steels and dependency on average Cr content within 10nm of ferrite for interface has been unveiled (Figure 6), h) Although significant differences in potentiodynamic polarization or electrochemical impedance spectroscopy were not observed within varying extents of post transformation partitioning, yet long term immersion tests in 3.5 wt.% NaCl solution unveiled lesser dissolution of solute elements for the lesser extents of post-transformation partitioning as compared to greater extents of post-transformation partitioning (Figure 4).

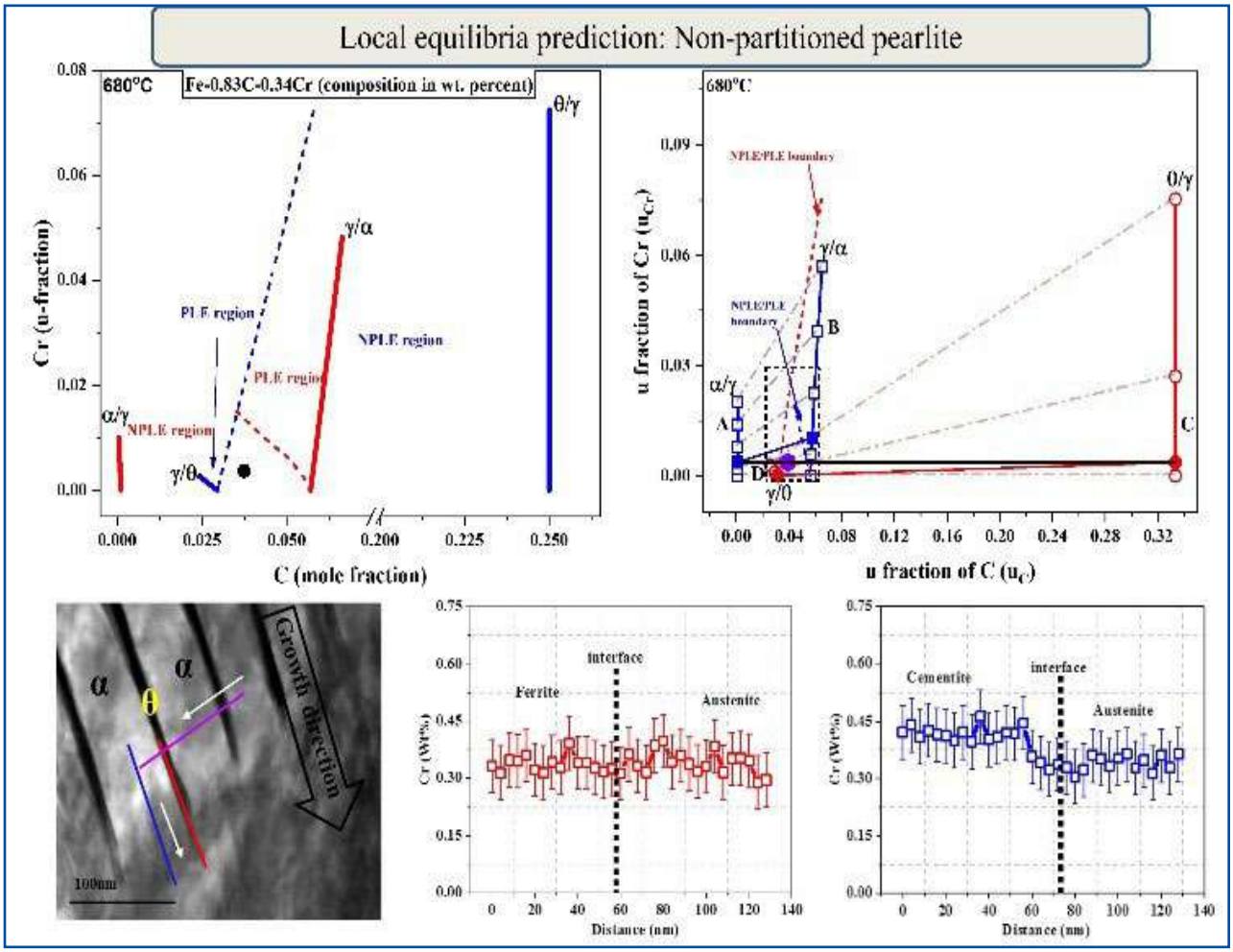


Figure 3: Experimental validation of predicted transformation pathway for a Fe-0.83C-0.34Cr system

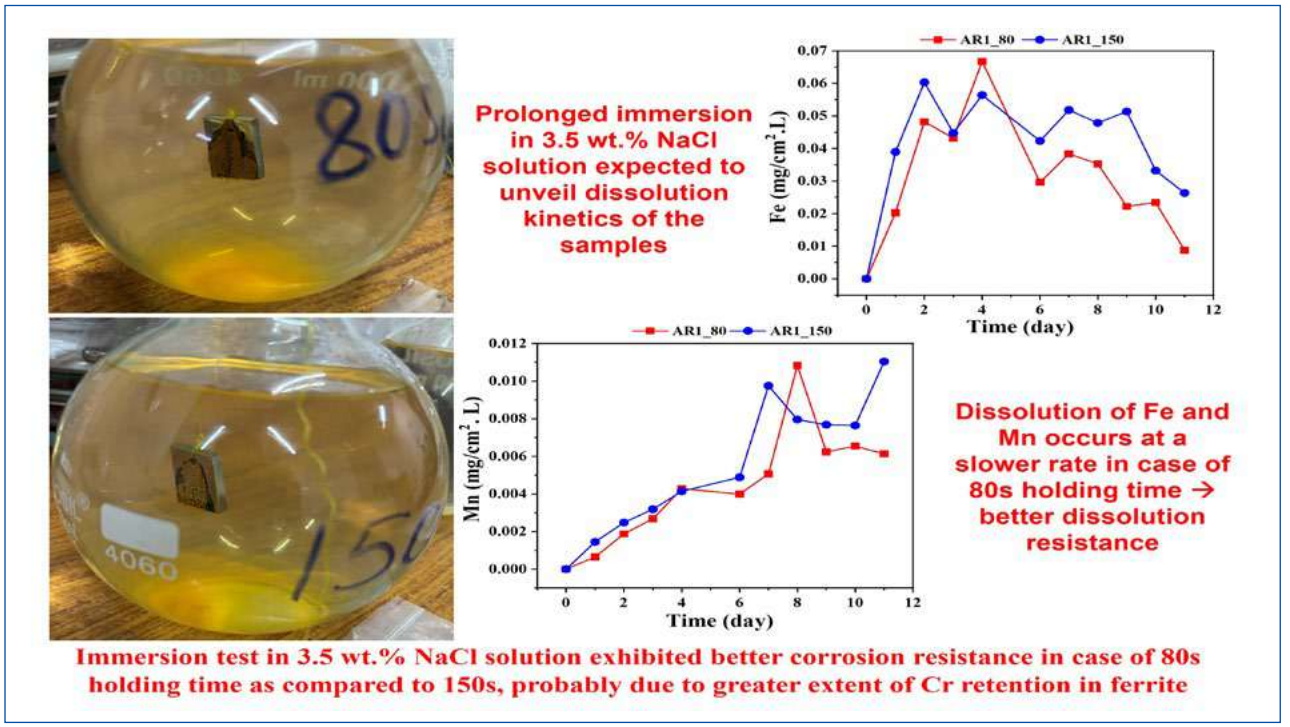


Figure 4: Dissolution behaviour of 80s and 150s isothermally heat-treated Fe-0.6C-1.02Mn-1.05Cr alloy (which formed non-partitioned pearlite) in 3.5wt.% NaCl solution

Development of high temperature low sag Al-Alloy conductor

The Indian power sector is growing rapidly both on the supply and demand sides. This has given unprecedented pressure on power transmission capacity building, reducing the transmission and distribution (T&D) losses, increasing ampacity and lowering sagging. In order to answer these issues, a new generation of high-performance conductors (HPC), including high temperature (HT) and high temperature low sag (HTLS), has been explored and recommended to be necessary to mitigate the limitations of the presently used conductors. Commercially, the HTLS grades are made up of thermal resistant Al-Zr alloys, where the reasons behind choice of Zr as a solute element are its potential to strengthen Al through fine coherent precipitates and the diffusion driven coarsening of those fine precipitates, which owing to the slow diffusivity of Zr in Al is delayed leading to delay in the softening of the structural components (and hence sagging of overhead conductors). However, the major advantage of Zr (sluggish diffusion in Al matrix) in delayed precipitate coarsening also is an impediment in the precipitate evolution process during ageing. As reported earlier by various researchers, the durations required for ageing of Al-(0.1-0.2 wt.%) Zr alloys span from 120 – 192h at temperatures in the range of 400°– 450°C, which imposes serious challenges for techno-economic viability. In light of this, the major objective of this project was to develop a suitable Al-alloy chemistry and an optimised processing schedule to possess: adequate strength (170-190 MPa), 90% retention of strength (after annealing at 280°C for 1 hour) – high temperature resistance, economical viability *vis-à-vis* commercial counterpart, reduced ageing time (by 40-50%), high conductivity (~ 60 % IACS). Summarily, the following points laid down the philosophy behind alloy design: a) Al_3Zr precipitation in metastable $L1_2$ structure is sluggish due to slow Zr diffusion; b) enhancing the precipitation kinetics requires overcoming of nucleation barrier (heterogeneous sites) and

diffusion barrier of Zr; c) overcoming diffusion barrier of Zr also implies increased susceptibility towards precipitate coarsening during service; d) nucleation barrier can be overcome by alloying additions which segregate easily in Al matrix (Fe, Si, Sn), or form solute-vacancy (Si)/solute-solute (Sn) clusters, or form intermetallic compounds (Sc) that can serve as site for Al_3Zr precipitation; e) solutes exhibiting attractive binding energy with Zr can aid in overcoming diffusion barrier (Sn, Sb, Si). Following the aforesaid philosophy, apart from Al-0.25 wt.% Zr alloy (A1), Al-0.25wt.% Zr-(0.1 – 0.25) wt.% Si (A2, A3) and Al-0.25wt.% Zr-(0.025 – 0.01) Sc alloys (A4 – A7) were designed and developed along with their corresponding ageing parameters which could lead to attainment of 60% IACS conductivity within 48h of ageing as opposed to ~ 120 – 144h of ageing in Al-Zr alloy. Figure 5 shows the comparison between the hardness of all the alloys after subjecting them to their respective ageing treatment within which 60% IACS conductivity was achieved. Detailed TEM analysis established the fact that in Si added alloys, Si-Vacancy clustering as well as Si-Zr clustering favours the initial nucleation phenomena after which Si is pushed towards the periphery of the precipitate (as confirmed by energy filtered transmission electron microscopic analysis shown in Figure 6). Similarly, in case of Sc added alloys, Al_3Sc type cores form first upon which Al_3Zr precipitates heterogeneously forming a shell Wires of 3mm were prepared out of the designed alloys which could achieve strength levels greater than 170 MPa (target set in objective section) in the as drawn condition and were also able to retain more than 90% of strength after heat resistance test. The aforesaid alloys were able to achieve 60% IACS conductivity within 48 hours (A2) and 39 hours (A5 – A7) of ageing after hot rolling, which amounts to a reduction in ageing duration by ~ 60% (in case of A2) and ~ 68% (in case of A5 – A7), as compared to conventional Al-0.25Zr (A1 alloy) which takes ~ 120

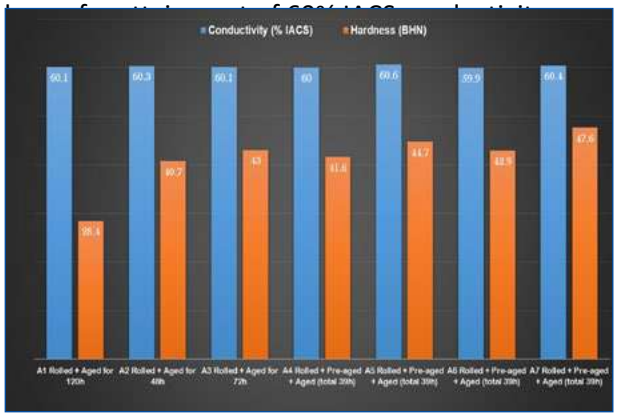


Figure 5: Comparison between conductivity and hardness of A1-A7 alloys after subjecting those to the optimized HR schedule and ageing conditions

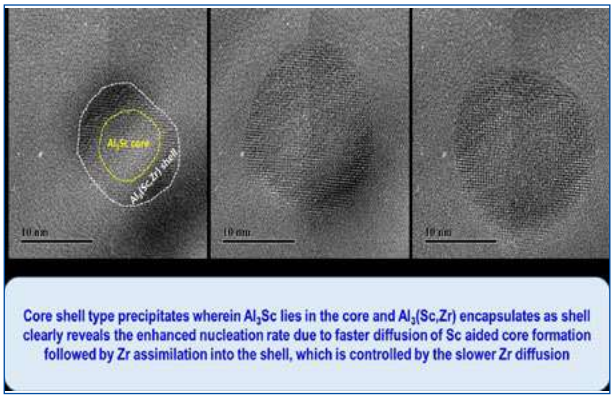


Figure 6: HRTEM and EFTEM of Al_3Zr precipitates in Al-0.25wt.% Zr-(0.1 – 0.25)wt.% Si alloy

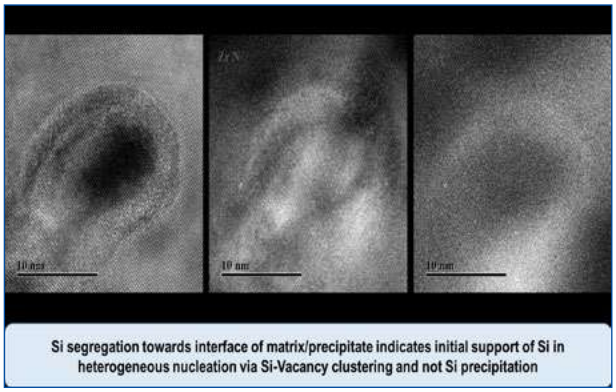


Figure 7: HR-TEM image of precipitate in a specimen of Al-0.25wt.% Zr-(0.025 – 0.01) Sc alloy aged at 400°C for 48 hours

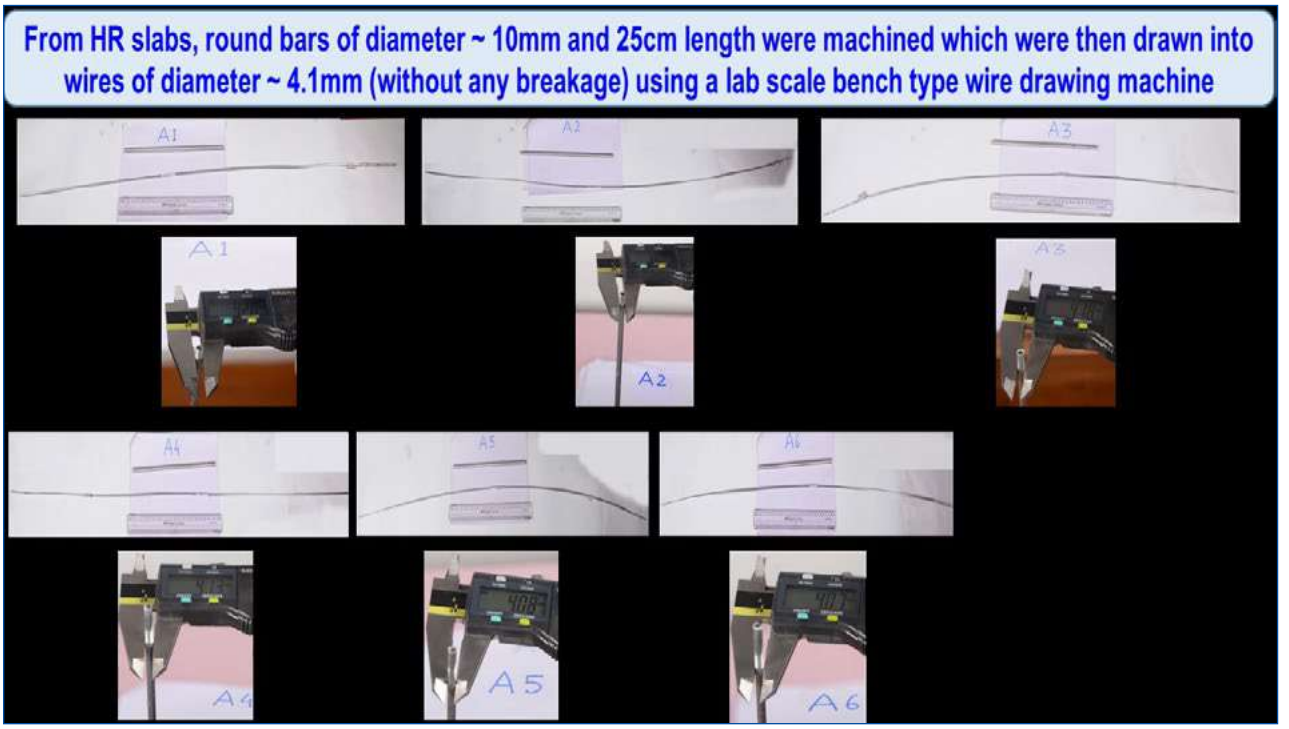


Figure 8: Pictures of round bars and drawn wires of A1 – A7 alloys

Development of wear-resistant steel for segment of coal sizer

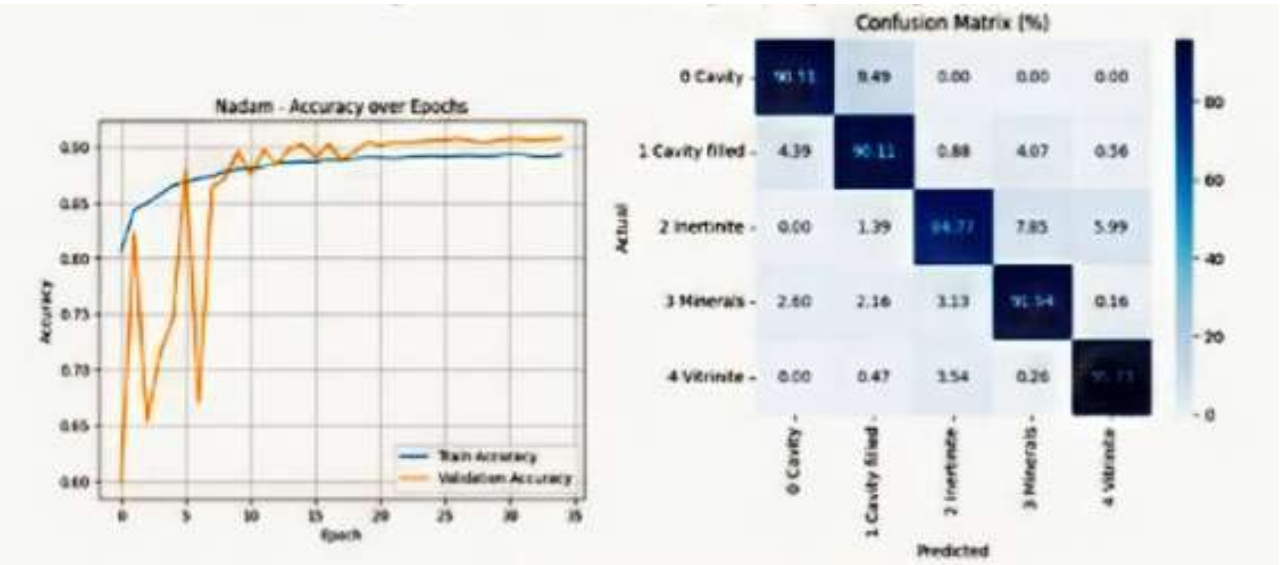
The objectives of the project are a**)** characterisation and evaluation of raw materials and existing segment material; b) establishment of a suitable lab-scale wear test method to simulate the industrial sizing and crushing operation; c) design and development of novel and economic alloy composition and its process technology; d) supervision of modified segment manufacturing, data analysis and suggestions on further areas of improvement. currently, lab-scale development has been completed for subsequent plant trials at sponsor. The project focused on addressing the issue of the higher wear rate of high-Mn Hadfield steel for a better life of a segment of the coal sizer. Under the project, laboratory scale-optimised alloy composition and energy-efficient process technology have been achieved. Problem-specific composition & process design was done based on an in-depth review of scientific literature, patents, and thermodynamic simulations. Identified novel steel composition and energy-efficient process technology to achieve up to 85% improvement in hardness and 36% reduction in material loss due to wear with comparable tensile strength and Charpy impact toughness. In future, the making of segments based on NML technology and its field trial will be done.

Process optimisation and predictive model development using AI for steels

The project aimed for a) AI-assisted characterization of raw material (iron ore and coal) using Infrared, multi-spectral and petrography imaging; b) design of high strength high toughness steel for wear resistance applications using a multi-objective AI model; and c) prediction of failure a priori of steel components used in power plants. Under the project, coal petrographic data collection and labelling have been completed for two coal batches. A 'Convolutional Neural Network (CNN)' model is developed to predict ash content from petrographic images of coal and is validated against ground truth. Two more batches of coal samples have been collected to generate petrographic data. Labelling of data for two more batches has been initiated. A strong correlation

between AI-based labelling and the experts' annotations is observed. The proposed AI model for raw material coal can be used in the industry for automated ash analysis. Further development of the database for iron ore images is in process. Further, the development of an AI-assisted automated composition analysis tool for raw materials of the steel industry, such as iron ore and coal is ongoing. Development of a prediction tool for High Strength High toughness steel for wear resistance applications, and failure prediction of steel components used in power plants will also be taken up.

Training with coal petrography image patches



Testing the CNN Model



Figure 9: Training and testing of the intelligent composition analyzer with pseudo-labelled output

Failure Analysis/Investigation and Structural Integrity Evaluation

Guided wave nonlinear ultrasonic and wave mixing techniques to assess fatigue damage in Al-Mg-Sc alloy.

The objectives of the project were**:** Fatigue damage evaluation of scandium added aluminium 5083 alloy using nonlinear guided wave ultrasonic technique in plate as well as rod/ cylindrical structures; Use of mixing of various ultrasonic guided wave modes to evaluate nonlinearity generated in aforesaid aluminium alloy during fatigue damage; and Comparison of ultrasonic nondestructive evaluation characteristics during damage assessment in Sc added Al 5083 alloy and Al 2024-T6 alloy. The activities involved : 1) Optimization of aging time and temperature for the developed alloy has been done; 2) Resonance frequency responses (under the conditions of longitudinal, shear, and surface waves propagations) have been evaluated. These evaluations are required to select the guided-wave propagation frequency and mixing frequencies for assessing damage in materials; 3) Cyclic damage to flat Al samples with loop analysis; 4) Simulation of wave propagation in nonlinear domain; 5) EBSD analysis of fatigued microstructures. The impact of this work on aerospace and automobile sectors is immense. Regular health monitoring is required for aircraft fuselage and wing structure made of aluminium alloy for the evaluation of integrity and remaining life. Till now, ultrasonic NDE is being used for detection and discontinuities/ anomalies/ defects on these types of structures. But no such assessment has been performed to evaluate these structures much before generation of cracks due to cyclic loading. Generally residual life assessment is being done based on fracture mechanics approach where evaluation has been carried out after assuming presence of defect of particular dimensions in the structures. But in this work, approach will be made to evaluate nonlinearities within the material that are generated during in-service much before macroscopic generation of defects. Based on that, remaining life of the components will be evaluated.

High temperature tensile and creep behaviour of TP347H and UNSS30432 stainless steel

The objective of this project is to evaluate the high-temperature tensile and creep behavior of TP347H and UNSS30432 stainless steel. The tensile properties of TP347H and UNSS30432 stainless steels will be characterized at room temperature, 705oC and 695oC. The creep behaviour of the stainless steels will be studied at 705oC (UNSS30432) and at 695oC (TP347H SS) for 1000h to 10000h, to evaluate long-term creep deformation in the materials. The project work is under progress: a) cutting of tube and bar, and fabrication of tensile and creep test specimens from TP347H and UNSS30432 stainless steel tube and bar; b) evaluation of tensile properties of TP347H and UNSS30432 stainless steel tube and bar, at room temperatures and high temperatures; c) creep testing of UNSS30432 and stainless steel at 705oC and 695oC, respectively, for 1000h; d) creep testing of UNSS30432 and stainless steel at 705oC and 695oC, respectively, for 10000h; e) tensile and creep data analysis; f) interim report preparation and submission.

Heat treatment of steel samples under varied furnace conditions

The project focuses on thermal processing of steel samples supplied by Tata Steel under controlled furnace conditions to establish suitable heat treatment parameters for industrial applications. The work involves heat treatment of approximately 175 steel samples using salt bath and conventional annealing furnaces available at CSIR–NML. Based on process requirements, intermediate hot forging, hot rolling, or cold rolling operations are carried out between heat treatment cycles to simulate practical processing conditions. All treatments are performed with precise control of temperature,

holding time, and process parameters to ensure consistency and repeatability. The project is centred on the execution of heat treatment and processing as per client requirements, and no characterisation activities are included within the project scope, with all evaluation to be carried out at the sponsor's end. During the reporting period, initial batches of samples have been successfully processed, and standardised furnace conditions have been established. The work is progressing as per schedule, and further efforts will focus on completion of the remaining sample processing and delivery of consolidated process data and reports for industrial application.



Figure 1: Treatment Facility

Remaining life assessment (RLA) study of gas turbine generator (GTG-1250-2E)

The objectives of the project were to a) assess the residual life of all the components that are replaced after 35,000 hours; b) residual life of the major components that are retained during the overhaul undertaken at 35,000 hours. This study was a continued effort by the Indian Navy to extend the life of critical components by remaining life assessment of their 'Gas Turbine GTG 1250-2E'. The laboratory has been entrusted with the remaining life assessment of their gas turbine generator after 35000 hours of service exploitation. The study integrated hardness profiling, microstructural evaluation, residual stress mapping, and precipitate coarsening behaviour across long-term service exposure, typically in the range of 30,000–35,000 operating hours. Overall, the assessments confirm that the studied components retained structural integrity and residual life margins under the observed service conditions for both compressor section and turbine blade section may be exploited for an additional 6000hrs. before revalidation. However, the flame tube showed significant degradation in properties compared to 30000 Hrs service. Figure-2 demonstrates that the rejuvenation treatment restored the flame tube microstructure close to its original condition, thereby recovering its mechanical properties. Therefore, it is recommended to rejuvenate the gas collector and flame tube components after 35000 hrs. service. The study enabled safe and reliable continued operation of critical components beyond their original design life while minimising the risk of sudden failure. It helps in informed decision-making for repair, rejuvenation, heat treatment, replacement, or life extension, thereby reducing unnecessary downtime and optimising maintenance costs. RLA becomes critical when geopolitical conditions restrict or deny the import of essential components, making life extension of existing equipment necessary to maintain operations. NDT evaluation of rejuvenated flame tube and gas collector by UT velocity measurements provides an opportunity to develop a customised UT velocity measurement tool for the qualification of rejuvenated components and further use it as a baseline value to monitor in-service degradation for remaining life assessment.

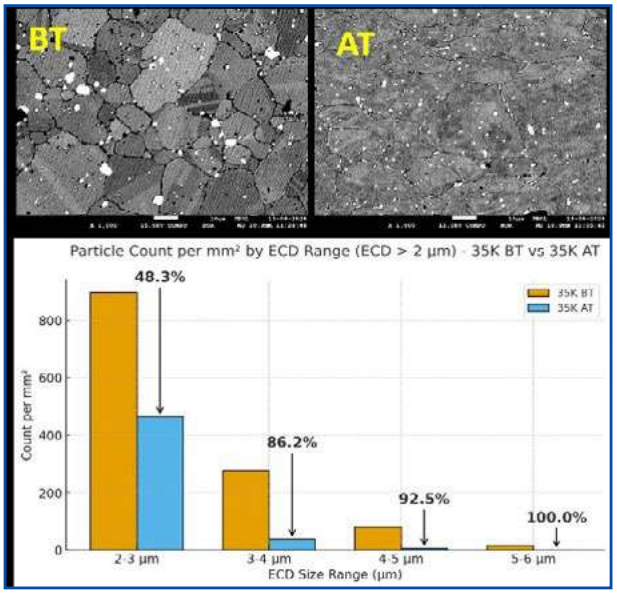


Figure 2: BT-before treatment and AT-after treatment

Integrity assessment of 'Konarka Iron Beams'.

The massive iron beams of Konarka have not been systematically studied yet, concerning their internal structure and integrity, although the broad method of manufacturing iron in ancient India has been established to be the bloomery process. In this method, 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 stress in service. The project essentially intends to undertake the following investigations: a) The exact method of manufacturing including the placement of internal plates, if any; b) Soundness of the interface between the plate and the subsequently poured bloom-matrix composition using ultrasonic non-destructive evaluation technique; c) Microstructural features in critical portions; d) 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 characterisation and corrosion analysis of iron beams of Konark, and to correlate the results with the microstructures to understand the technological acumen of our great ancestors. The project also aims to broadly review the technology available during that period, making beams, in-situ non-destructive characterisation of Konarka iron beams and validation with a few microstructural tests of selected samples and to characterise the nature of the corrosion occurring in iron beams at the Konarka using portable electrochemical corrosion testing equipment. The project team conducted a third visit to Sun Temple, Konark, recently, to carry out ultrasonic measurements on the Iron Beam to fully assess the internal structure. Ultrasonic data infer a composite structure with a number of lamellae within the beam. Assessment has also been done about the interface integrity between the matrix and lamellae. No such slag entrapments are found in 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.



Figure 3: Ultrasonic measurements on-site at 'Konark Sun Temple'

Material analysis and reclamation of flame tube for GTG-1250-2E

The aims and objectives of the proposed investigation are: a) Develop an in-depth understanding of the Flame tube material and use it to enhance its mechanical properties from its existing level; b) reversal of the degradation of the material due to service exploitation by appropriate annealing cycles; c) design a heating process and customised furnace for component-level annealing. This study presents a comprehensive investigation into the damage assessment and rejuvenation of long-term (30,000 hours) service-exposed gas turbine generator (GTG 1250 2E) flame tube component through detailed microstructural characterisation, mechanical property evaluation and rejuvenation

annealing trials. Initial analysis of a 30,000-hour service-exposed flame tube revealed severe degradation, including void formation, micro-cracking, precipitate-induced damage, and grain boundary decohesion. These microstructural deteriorations led to significant variability in tensile properties, notably reduced ductility and wide variation in yield and tensile strength. Based on these findings, an annealing treatment of 1050 °C for 4 hours was optimised at the laboratory scale, which demonstrated significant reversal of microstructural damage and restoration of mechanical properties. To enable full-scale rejuvenation, a specialised overhead flame tube annealing furnace was designed and developed by CSIR-NML. The furnace was installed and commissioned at INS Eksila, where component-level annealing trials were conducted on service-exposed flame tubes (30,000 hours and 35,000 hours). Post-trial, flame tube samples (service exposed for 30,000 and 35,000 hours) were subjected to microstructural and mechanical property evaluation. Post-annealing characterisation revealed significant improvements in mechanical performance. The total elongation increased from 28–30% to 36–37% in parent metal and from 12–17% to 23–24% in weld regions. Yield strength and ultimate tensile strength values also converged into narrow ranges, indicating microstructural homogenization and restored damage tolerance. The study demonstrates that controlled annealing can effectively recover the mechanical integrity of service-exposed components. Based on the improved mechanical response and structural uniformity, the rejuvenated flame tube components are recommended for life extension by an additional 7,000 hours, subject to routine inspection. The major achievement of the project is that the life of the service-exposed flame tube was extended by 7000 hours after rejuvenation annealing. Currently, all major milestones have been successfully achieved. As part of the feedback and follow-up activities, tensile testing and detailed characterisation of the flame tube component—whose service life has been extended by an additional 7000 hours—will be carried out after its actual service exposure.



Figure 4: Installation and commissioning of "Overhead Flame Tube Recalmation Furnace" at INS Eksila, Indian Navy.

Development of standard for procurement of center buffer coupler (CBC) for Indian Railways; evaluation and assessment of CBC manufactured by Indian vendors (Foundry) for supply to Indian Railway

Centre Buffer Couplers are used for joining freight cars of Indian Railways (Figure 5). 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. During 2010-11, RDSO approached CSIR-NML to have the root cause analysis of these CBC failures; suggest preventive measures and also help to develop a new standard for the supply of healthy CBC to Railways. RDSO in collaboration and consultation with CSIR-NML developed a standard WD-70-BD with the following objectives: (i) Indigenisation of Grade E castings used

for the manufacturing of Centre Buffer Couplers (CBC); (ii) Safety in rail transport; (iii) Revenue saving. The standard WD-70-BD envisage that the CBC manufactured by the foundry need to be evaluated at 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 in the developmental stage. The contribution mentioned above helped in Indigenous vendor development for Indian railways, saving in revenue losses resulting from parting of wagons, safety in rail transport, spin off projects led to ECF of about 800 Lakhs INR.



Figure 5: (a) Centre Buffer Coupler (CBC) joining two rolling stocks

Metallurgical investigation of fractured rails involved in derailment of Train No. 15904 Dn

The project aimed to discern the root cause of the fracture of rails, along with the evaluation of rails with respect to the IRST-12 standard and establish the fracture mechanism. In this work, metallurgical failure investigation of fractured rails, involved in derailment of Train No. 15904 Dn was carried out. It was reported by the competent authority 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, the entire surface showed a 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 (Figure 6 (a)). Albeit at some location, specifically close to neural axis in the web region, small fraction of grain boundary ferrite was observed (Figure 6 (b)). Presence of inclusion, primarily the MnS type stringers was also found close to neural axis in the web region (Figure 6(c)). However, the inclusion rating as per IS 4163 standards confirmed that the extent of inclusion was within the permissible limits defined in the IRS-T-12-2009 standard. SEM fractography investigation revealed a cleavage and quasi-cleavage nature at different regions of the fractured rail (Figure 7), which indicated brittle fracture of rails. There could be mainly two reasons for brittle failure of rails; one of them is high impact loading during service and the other is the presence of pre-existing crack within the rail which might had led to fast brittle fracture. Ultrasonic phased array inspection indicated the absence of any significant pre-existing defect/flaw within the investigated rail. Moreover, signatures of fatigue deformation such as striations/crack propagation steps/beach marks were also absent. Therefore, it was concluded that the rail was failed in a brittle manner due to overload during the service.



Figure 6: (a) Fully pearlitic microstructure in different regions of the investigated rail (b) presence of grain boundary ferrite in central region of web (c) presence of MnS stringers in central region of web.

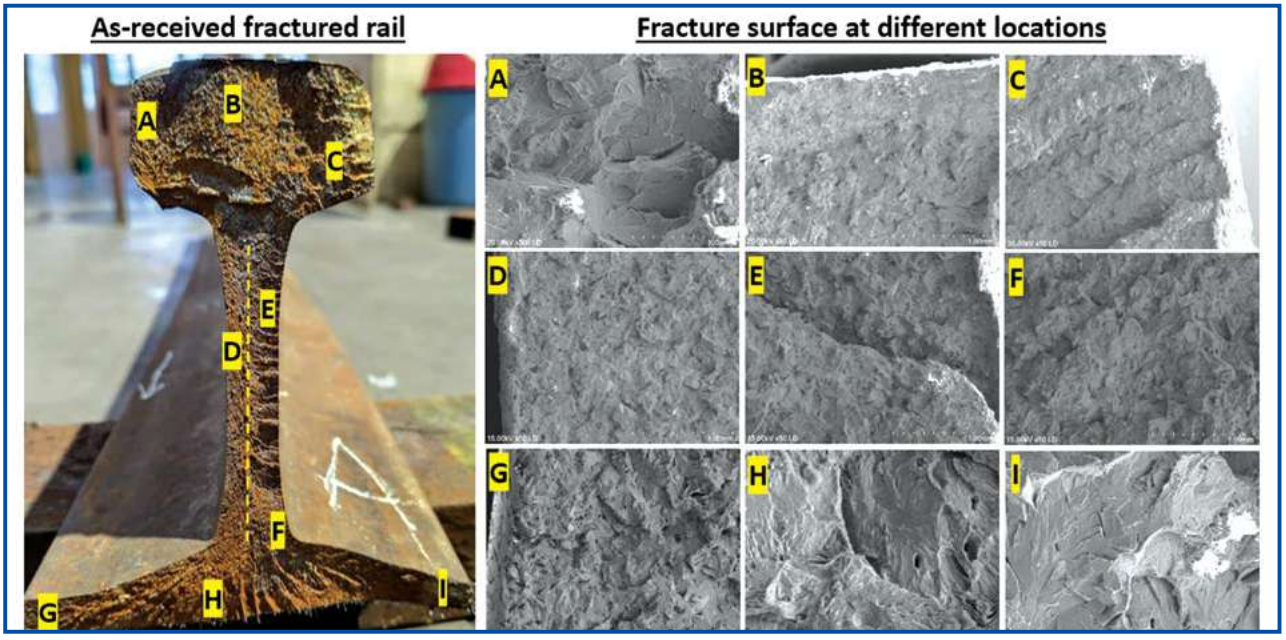


Figure 7: Fracture surface appearance in different regions of the investigated fractured rail.

Critical assessment of high-performance anti-corrosion coating for extreme environments

A comprehensive evaluation of high-performance anti-corrosion coating systems supplied by nine NTPC-approved vendors was carried out to assess their suitability for extreme service environments. The study focused on key performance parameters including adhesion strength, corrosion resistance, electrochemical behavior, drying characteristics, and chemical composition. Adhesion testing revealed notable variation in bonding strength across vendors, with values ranging from 1.85 MPa to 8.35 MPa. The adhesion performance (as shown in Table 1) followed a decreasing trend of Kirloskar > Synorganic > Grauer > Corkil > Berger > Asian > Agile > Oriental > Metachem. This indicates significant differences in coating-substrate interaction and mechanical stability among the systems. Corrosion resistance was evaluated through salt spray and cyclic salt spray exposure tests up to 2500 hours. All coatings successfully passed these tests, demonstrating robust resistance under aggressive saline environments. However, differences were observed in creepage values, with Berger coatings exhibiting the least creepage, followed by Grauer, Metachem, Corkil, Asian, Kirloskar, Oriental, Synorganic, and Agile. Cyclic salt spray results showed similar trends but with relatively higher creepage values, indicating increased severity under cyclic conditions. Electrochemical impedance spectroscopy (EIS) was conducted up to 2500 hours; however, no quantifiable impedance values were obtained, suggesting limitations in measurement sensitivity or coating characteristics under the test conditions. Drying time analysis showed considerable variation among vendors, impacting practical applicability. Agile coatings exhibited the fastest drying time (87 minutes), followed by Kirloskar (186 minutes), Corkil (244 minutes), Metachem (345 minutes), Berger (496 minutes), Grauer (564 minutes), Asian (863 minutes), and Oriental and Synorganic (1067 minutes each). Faster drying coatings may offer operational advantages in field applications. Fourier Transform Infrared (FTIR) spectroscopy confirmed the presence of key functional components such as micaceous iron oxide (MIO), zinc silicate, polyurethane, and epoxy in most coatings. Notably, Kirloskar and Metachem coatings lacked polyurethane, while Corkil and Metachem coatings were devoid of epoxy, which may influence their mechanical and barrier properties. Long-term durability assessments through humidity exposure (up to 25,000 hours) and cyclic aging tests (up to 1000 hours) indicated that all coatings performed satisfactorily, with no significant degradation observed. This demonstrates their reliability under prolonged environmental stress. Overall performance ranking, considering multiple parameters, indicated that Berger and Grauer coatings performed at the highest level, followed by Corkil, Kirloskar and Metachem, Asian, Oriental, and Synorganic and Agile. Despite variations in individual parameters, all nine vendor coatings demonstrated strong performance and successfully met the required criteria for high-performance anti-corrosion applications in extreme environments. In conclusion, the study highlights that while all evaluated coatings are suitable for NTPC applications, selection may be optimized based on specific operational requirements such as adhesion strength, drying time, and environmental exposure conditions.

Table 1: Adhesion strength (MPa) measured on the painted panels for nine different vendors

Sl. No.	Name of Paint Vendors	Average DFT (µm)	Average Adhesion Strength (Mpa)	Remarks
1.	M/S Agile Microsys Pvt. Ltd.	295	2.88	Whole Coat removed. Average readings of 2 samples.
2.	M/S Asian Paints (Anila Mayank Krishna Conchem Product, Pvt. Ltd.	256	3.46	4^{th} Coat removed partially Average readings of 3 samples
3.	M/S Bergers Paints India Ltd.	504	6.23	2nd & 3rd Coat removed Readings of 1 samples
4.	M/S Corrkil Solutions	160	6.25	2nd & 3rd Coat removed Average readings of 3 samples
5.	M/S Grauer and Weil India Ltd.	359	6.54	2^{nd}, 3^{rd} & 4^{th} Coat removed Average readings of 3 samples
6.	M/S Kirloskar Corrocoat Pvt. Ltd.	399	8.35	Only adhesive is removed Average readings of 2 samples
7.	M/S Magnum Associates and Engineers (Metachem represented)	102	1.83	4^{th} Coat removed Reading of 3 sample
8.	M/S Orential Enterprise (Partner with CSL Silicones)	350	2.10	2^{nd} Coat removed Average readings of 2 samples
9.	M/S Synorganic Paints Pvt. Ltd.	518	7.11	3^{rd} & 4^{th} Coat removed Average readings of 3 samples

Sensor & Devices

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

The objectives of this project are sensor array fabrication and instrumentation of mould and installation of instrumented mould and temperature-capturing. Under the project, twelve moulds have been instrumented with temperature sensors to measure surface-temperature variations during billet casting. Instrumented modules, along with the software, have been demonstrated for breakout prevention in the caster CC3. Peak temperature detection and time calculations have been completed for the PLC-based mechanism to avoid breakout. The temperature variations have been logged into the centralized data acquisition system for preventive actions. Software logic for the PLC-based breakout prevention mechanism is completed. The Real-time breakout prevention with a PLC-based mechanism will be operated by the industry partner. The technology implementation will have continuous operations, that will be handled by the industry partner.

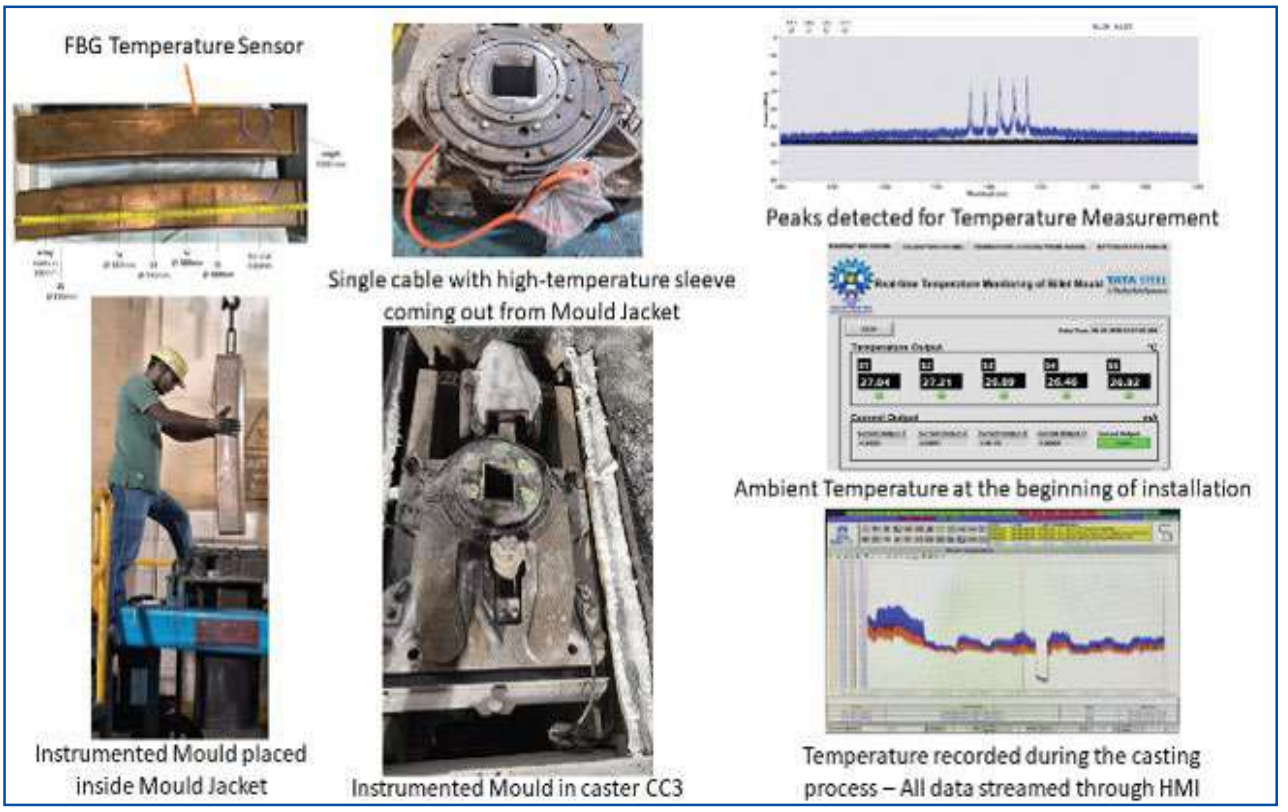


Figure 1: Installation and commissioning of FBG sensors on billet mould

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

The project aimed for the development of a) a snapshot dual-mode multi-wavelength interferometric method based on a polarization technique for high-speed and high-performance metrology; and b) phase unwrapping, stitching, and noise reduction using deep-learning image-processing algorithm. Design & optimization of the concave or convex rotationally symmetric or non-symmetric optical surface is completed. The engineering schematic drawing for the proposed configuration of the OMM interferometric system

during machining has been completed. A deep learning architecture has been trained to predict the surface profile from the input fringe images. The fringe images and corresponding surface map were used for training. The model showed good predictive performance for the surface profile from the input fringe image. The algorithm development for surface profile generation from input fringe images and correlation study on profilometer data has been completed. The future activities under the project include: a) Fabrication of ultra-precision machining to achieve desired accuracies in terms of form & finish; and b) Prediction of complex geometry surface profile from a deep learning model.

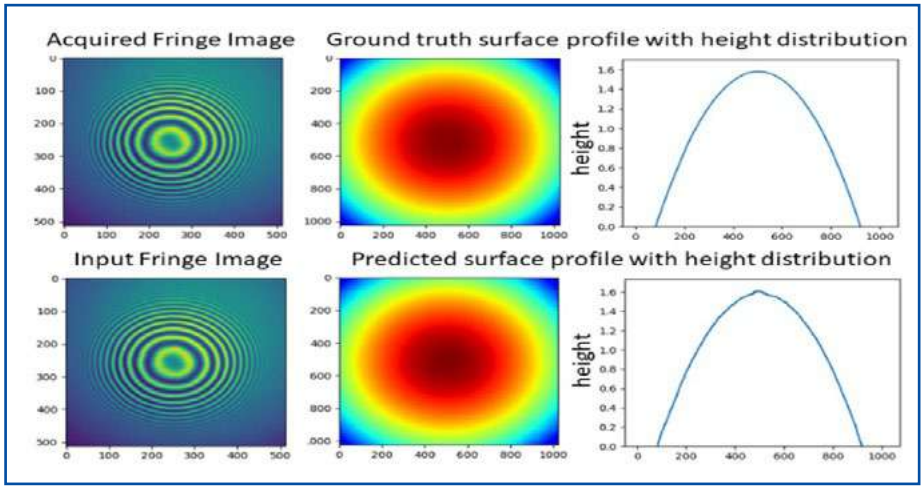


Figure 2: Proposed deep learning model-based prediction of surface profile from fringe input

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

The objectives of the project were a) to design and fabricate electronics packages for propellant gauging of spacecraft; b) to fabricate one number master calibrator for ground-based studies, calibration, optimisation 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.; c) to fabricate three electronics packages with space-qualified electronics components and to test them in the space environment at ISRO. The Master Calibrator System was successfully fabricated and delivered to LPSC. Trials using both continuous and pulsating flow modes have been completed successfully. The system was demonstrated to the Chairman of the Indian Space Research Organisation (ISRO), at the Liquid Propulsion Systems Centre (LPSC) premises. Based on the list of required components provided, an equivalent list of space-qualified components was prepared by LPSC. These components are currently available with LPSC. A meeting for circuit verification was conducted at the Vikram Sarabhai Space Centre (VSSC), Trivandrum, by a 19-member committee. The circuit design was approved with minor modifications. Under a new tender inquiry from LPSC, Bangalore for two additional Master Calibrator Systems, the technology licensee EECI, Mumbai, received the order. The systems have been dispatched following a successful pre-dispatch inspection by LPSC personnel. Till now, the successful trial of the Master calibrator system has helped to receive enquiries for two more systems by LPSC, ISRO. Both systems have been dispatched by the technology Licensee. Ground unit of Ultrasonic Flowmeter (UFM) along with a flight-worthy Carry case is shown in the picture below. Space qualified systems fabrication is in progress. Application of the ground unit in the launching station during the launching of spacecraft.



Figure 3: UFM-3GU portable Ground unit with flight-worthy Pelican carry case

Fabrication of two modified binder percentage detection devices.

Tungsten Carbide (TC) Rolls are manufactured through powder metallurgy route. In the powder metallurgy process, the mixture of two or more components are mixed with some binder material, then compacted in a die and finally sintered in a furnace. During sintering process, a metallurgical bond is formed between mixture of composite material along with the binder. For the TC rings, the tungsten carbide powder is mixed with some binder material such as cobalt or nickel, then compacted in a die and finally sintered in a furnace. The tungsten-carbide component thus manufactured have very high hardness and finds its applications especially in metal machining, metal forming tools, mining and cutting tips for saw blades etc. Also because of its good thermal conduction property, wear resistance and strength along with high hardness, makes this material an excellent choice for roll rings used in the production of wire rods, plain bars and deformed bars etc. at high rolling speeds. In such components, the percentage of binder contributes largely in controlling the mechanical properties of the components. Density, Young Modulus, Hardness, compressive strength decreases with increase in percentage of binder which ultimately affects the life span of the components. Generally, the components are supplied by manufacturers along with a datasheet and are inspected at the plant end only for checking physical dimensions and damages. These components are then sent for further operation before subjecting it to actual operation. Thus, in components where the binder percentage is more, it will cause reduction in pass life, variation in wear pattern which may lead to major concerns for the operators. There is no technique to verify the quality of supplied components on site, thus making it difficult to determine the said factors. Hence, the necessity arises to evaluate the quality of the supplied TC ring with respect to the binder percentage and homogeneity non-destructively before its application in the roll shop. The objective of this project was to fabricate 2 numbers of devices by developing a modified calibration module utilising the data collected by the industry partner using the device developed and supplied to them under the previous collaborative project. Under this project, two devices were fabricated to detect binder% and homogeneity of TC rings. Binder% and quality of TC rings in terms of homogeneity are displayed on the screen based on a minimum of 6 measurements on the TC rings using the supplied sensor. As per the deliverables of the project, two devices were handed over to the sponsor. A training and demonstration on the operation of the device were provided to the personnel of the sponsor



Figure 4 (a): Training to TATA Steel Personnel

Minerals Processing

Mineral Processing Division of CSIR-National Metallurgical Laboratory (NML) is dedicated to advancing the science and technology in the field of mineral beneficiation. As part of the Council of Scientific and Industrial Research (CSIR), this division plays a pivotal role in addressing the challenges for mineral resource utilization through innovative and sustainable techniques. Since its inception in 1950, the division has been actively engaged in developing beneficiation flow sheets, optimizing existing processes, and providing technical support for ore characterization, process mineralogy, and pilot-scale trials. It caters to a wide range of metallic and non-metallic ores, such as iron, manganese, chromite, limestone, dolomite, bauxite, graphite, lithium, and rare earth elements, among others.

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

As the quality of raw coking coal is deteriorating over years, it is essential to improve the quality of the feed raw coal prior to wet beneficiation. Accordingly, dry beneficiation of high ash, difficult-to-wash coking coal by dry de-shaling will improve the raw coal feed quality before subjecting to wet beneficiation. In the present work, a process flow sheet is developed, employing hybrid mode beneficiation of coking coal to reduce the ash level to14 -17% with maximum yield.

The two categories of samples (i) from M/s BCCL area and (ii) from West Bokaro area (industrial sponsor- M/s. Tata Steel), have been taken for the study. Firstly, dry deshaling was carried out for both samples in Air Fluidized Vibrating Deck Separator (FGX).

For the BCCL area sample, around 4-5% of ash reduction could be observed, whereas for the Tata Steel sample, about 4-4.5% ash reduction could be achieved. Pre-concentrate, generated after deshaling, has been subjected to wet processing by dense media cyclone and finer fractions, below 0.5 mm, by column flotation technique. With the application of a hybrid mode of beneficiation for the BCCL coking coal sample, the clean coal product generated with an ash content of ~15.6%, from the feed ash content of about 33.5%, with a maximum yield of about 52% could be achieved.

Similarly, for the West Bokaro sample, the total combined clean coal product, having an ash content of ~16.6% from a feed sample of ash content of about 37%, with a maximum yield of ~41.3% could be achieved.

Hybrid mode (dry and wet) processing of the high ash raw coal could be helpful in improving the feed quality and thereby, improving the plant productivity. The developed hybrid mode of beneficiation process may create a good impact and holds significant future prospects in the Indian coking coal washeries as well as steel-making industries.

Pilot-scale flotation of coal fines using a synthesised collector reagent

The synthesized collector (RDC) coal beneficiation process is a specialized chemical treatment technique used to enhance the efficiency of fine coal cleaning, particularly for low-rank or oxidized coal, through froth flotation. Performance of a synthesised collector (RDC) on the flotation of coal was evaluated. NALCO make collector, NALCO make frother and RDC make reagents were used during the experimental flotation trials. Collectors play a pivotal role in flotation, due to their ability to interact with the surface of particles, according to the nature of their hydrophobicity. A large number of surfactants, together with auxiliary additives, are used during flotation. Coal fines (−0.5 mm) samples having an ash content of ~28% were used for bench scale study, while ~29% ash content were used for pilot scale trials. Experimental trials were carried out with varied parameters like dosage of

collector, frother, feed flow rate and air flow rate, on the flotation of coal fines, at the pilot scale of 60-80 kg of dry solids per hour feed rate. Optimized results, during pilot scale flotation, were obtained with clean coal at 14.35 % ash content and a yield of 43.77%, for the seam no. 7 coal, at the following set of operating conditions: pulp density = 10%, NALCO frother dosage = 8 ml, NALCO collector dosage = 30 ml, RDC = 2.52 gm in 500 ml water, volumetric flow rate of 900 l/h and air flow rate of 15 lpm.

Beneficiation of coking coal by hybrid mode: dry and wet processing to reduce the ash forming impurities (Phase-1)

Indian coal's drift origin resulted in high ash content (35–45%) and intimate mineral-coal mixing, making it "difficult-to-wash". This causes significant issues for end-users. Also, as per the United Nations prediction of water scarcity in the next few years, suggesting for processing of ores/minerals by dry methods. The alternative route could be dry de-shaling to improve the quality of raw feed and to produce preconcentrate before subjecting to wet beneficiation, with advantages of no process water requirement, clean product with higher heat value, environment-friendly and cost-effective. Hybrid mode (dry and wet method) beneficiation of coking coal has been employed to achieve the present objective of ash level reduction with maximum yield. The feed sample for dry deshaling was prepared in the size range of 50 to 6 mm fractions with an ash content of about 38.46%. In this stage, the prime focus is to remove the high-density impurities as much as possible using the Air Fluidised Vibrating Deck Separator (AFVDS) to generate a preconcentrate for further processing in dense media cyclone and column flotation. A finer size mixture of ROM and pre-concentrate sample of size below 0.5 mm was prepared, and the ash content was found to be about 26.4% for processing using column flotation technique. From the dry deshaling study, around 4.5% ash reduction can be observed from the ROM sample having ash content of about 37%. Pre-concentrate generated through dry processing was further subjected to wet processing in dense media cyclone and flotation process. With the hybrid mode of processing, the total product having the ash content of ~16.6% with maximum yield of ~41.3% could be achieved. As water is becoming scarce in many regions of the country, the developed hybrid mode of beneficiation process may create significant prospects in the Indian coking coal washeries as well as steel-making industries to increase the plant productivity along with economics.

Development of a process for the synthesis of chromic oxide from the chromite beneficiation plant tailings

High and medium-grade chromite ore is processed and marketed directly. Low-grade ores are beneficiated to meet the quality demand of metallurgical industries (Cr_2O_3: 44-48 % and Cr/Fe-1.6:1 to 3:1, as per IS 10818-1984). Around 50-55% of chrome ore is discarded, as a tailing, during the beneficiation of low-grade chromite ore, containing 14-17% Cr_2O_3. This causes loss of chromite value, in addition to its adverse impact on the environment. The storage, handling, and processing of fine tailings, are also the major concerns of the operating process plants. The fine-grained tailing poses difficulty in processing by conventional physical separation methods, to produce a high-grade concentrate, with reasonable chromium recovery. In the present study, a process was developed for the synthesis of chromic oxide from the chromite beneficiation plant tailings, leading to its rational utilization. A comprehensive approach was adopted, with a combination of advanced gravity concentration and chemical purification, to produce the chromic oxide from the dumped tailings. Due to the fine nature of tailing, a conventional process is inefficient for the recovery of chromite mineral. An enhanced gravity technique was utilized to maximize the recovery of chromite mineral. Pre-concentrate, produced from physical separation, upgraded from 19.27% Cr_2O_3 to 28.74% Cr_2O_3. Around 90.6 % Cr_2O_3 was recovered in a single-stage operation of enhanced gravity

separation. Two different chemical purification schemes were developed; the first process comprises oxidative roasting, water leaching, and purification of the leach liquor to remove silica and alumina. The purified solution was crystallized to form potassium dichromate, which is reduced in the presence of coal to produce chromic oxide of purity 94.7%. In the second process, the leach liquor obtained after oxidative roasting and water leaching is purified, and the chromium is reduced through ethanol, followed by sodium hydroxide precipitation to form chromium hydroxide. The hydroxide was then roasted to produce chromic oxide of purity 99.57%. The developed product can be used for the Metallurgical and Pigment Industries.

Beneficiation of Limestone to Reduce Silica Content

Limestone's metallurgical significance is underpinned by its functions as a desulfurising agent, refractory protectors, and fluxes. Because of the increased need for high-purity flux materials, due to developments in steelmaking technology, there is significant industry interest for the beneficiation of these minerals. Limestone from **Nandini mines, Chhattisgarh**, was undertaken for beneficiation test-work. The as-received limestone sample assays 38.70% CaO, 9.05% MgO, 7.53% SiO_2, 1.92% Al_2O_3, 0.75% Fe(T), & 40.19% LOI. Mineralogical studies revealed that the limestone sample consists of calcite, as the dominant mineral, with a rhombohedral cleavage pattern, and quartz grains are also present. For the limestone sample, rougher flotation concentrate obtained using 2 kg/t of sodium silicate and 0.75 kg/t of sodium oleate emulsion, followed by one stage cleaning using 0.25 kg/t sodium oleate emulsion, was found to be effective in reducing the silica level of the concentrate to 2.92% with 43.29% CaO.

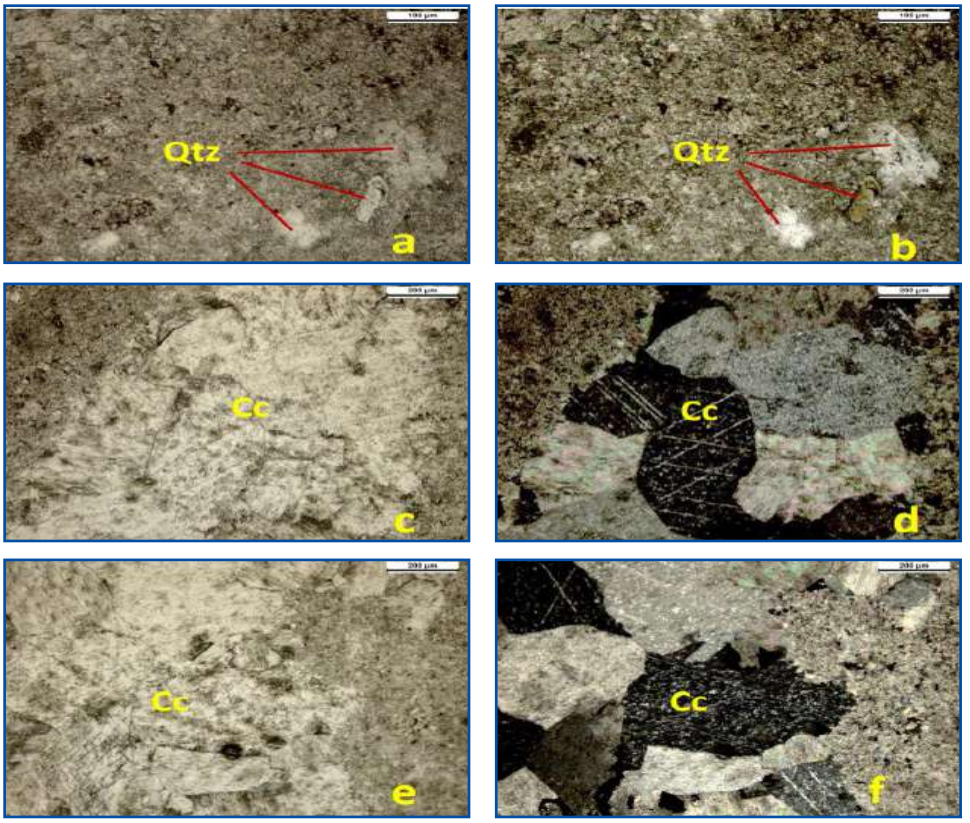


Figure 1.: Photomicrographs showing the presence and distribution of different rock-forming minerals in a limestone sample under both plane-polarised light (PPL), and crossed polars (XP). [a] & [b] quartz (Qtz) under PPL and XP; [c] & [e] typical calcite grains (Cc) under PPL; [d] & [f] calcite (Cc) grain showing polysynthetic twinning under XP

Beneficiation Studies of Dolomite to reduce silica content for its utilization in iron & steel making

Silica is the most detrimental impurity found in the metallurgical-grade dolomite. Beneficiation helps to remove siliceous and aluminous impurities, that dilute the CaO-MgO contribution. It provides sufficient MgO in the slag, which protects basic refractories, that prolongs furnace life. The improved quality results in better slag conditioning and reduced energy consumption. Dolomite samples from Hirri Mines, Chhattisgarh was considered for the study. The as-received dolomite sample assays 29.09% CaO, 19.73% MgO, 5.02% SiO2, 1.16% Al2O3, 0.44% Fe(T) & 43.97% LOI. Mineralogical studies of dolomite revealed that euhedral saddle shaped dolomite are present, along with quartz grains and opaque mineral i.e. magnetite, are also present. For dolomite, single stage cleaning of rougher concentrate yielded a product with silica content of 2.22% and 31.33% CaO. For dolomite, silica reduction was reduced to below 3% in all three schemes i.e. Direct flotation, desliming followed by flotation and reverse flotation, but optimal scheme was found to be direct flotation, considering the grade and yield of concentrate.

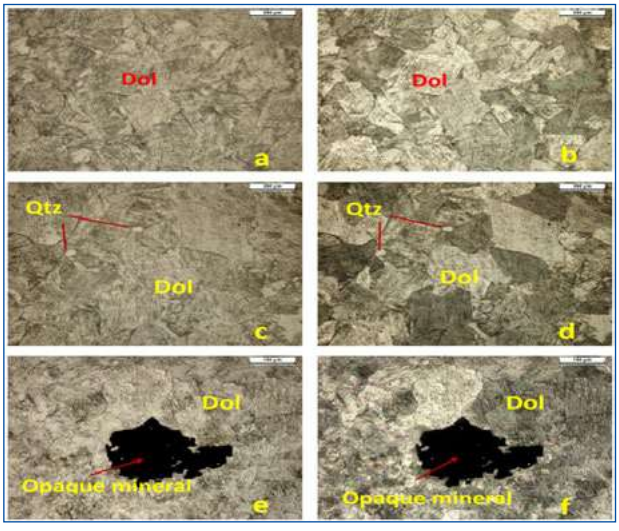


Figure 2: Photomicrographs showing the presence and distribution of different rock-forming minerals in a dolomite sample under both plane-polarised light (PPL), and crossed polars (XP). [a] & [b] euhedral dolomite grains (Dol) under PPL and XP; [c] & [d] typical dolomite(Dol), and quartz (Qtz) grains under PP and XP; [e] & [f] dolomite (Dol) grains, opaque mineral (may be magnetite?) under PPL and XP

Beneficiation of Lean grade Iron Ore having less than 45% Fe content

As the supply of high-grade iron ore reserves gradually depletes, beneficiation of lean-grade iron ores has become essential to capitalise on the iron values and, simultaneously, reduce the waste burden. A process scheme was developed for iron ore collected from a mine located at Sehore district of Madhya Pradesh, with the primary objective of developing an efficient process for the effective utilisation of lean-grade iron ores, containing less than 45% Fe content. A systematic beneficiation strategy involving scrubbing, hydrocyclone desliming, enhanced gravity separation, and wet high intensity magnetic separation (WHIMS) was developed and optimized, yielding a concentrate with ~61.9% Fe at 40.27% yield, from initial feed containing around 39% Fe.

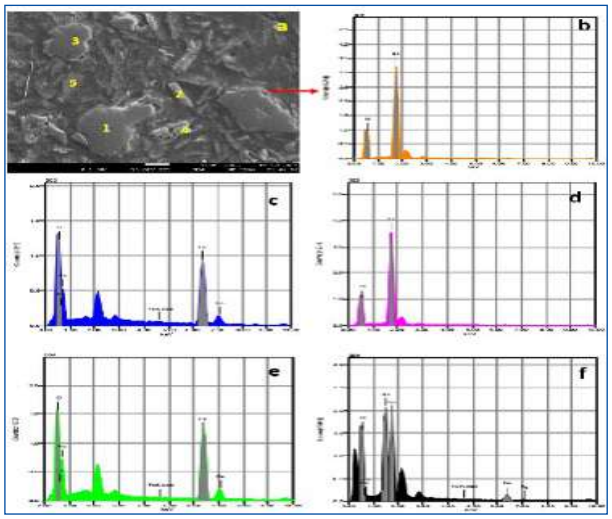


Figure 3: EPMA secondary electron image showing the presence of (a) quartz, microplaty hematite, and clay minerals; (b), (c), (d), (e) and (f) showing respective septra of point analysis.

Sustainable Technology for the production of high grade synthetic rutile (TiO2) form Odisha Ilmenite

Odisha holds significant beach placer deposits containing high-quality ilmenite, primarily, along the

Gopalpur coast and the Chhatrapur beach. These deposits feature 10-25% total heavy minerals, with ilmenite being a major component (30-40%), which is used extensively for titanium dioxide pigments. In continuation with the processing studies, carried out to enrich Odisha's ilmenite to synthetic rutile, studies were carried out, initially, by reducing the ilmenite ore to metallic iron, then subjecting the reduced ilmenite for magnetic separation. This reduced ilmenite was subjected for aeration leaching in an Ammonium chloride solution, along with few catalysts. Samples were withdrawn, on a hourly basis, and analysed for total iron and TiO2, respectively. The analysis showed that the TiO2 content was 85% and total iron at 13%, respectively.

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

Teri heavy mineral sand from Manavalakurichi, Tamil Nadu, is characterised by the presence of surface-bound clay coatings on heavy mineral grains, which are reported in slimes, during processing, thus, affecting the downstream separation processes, heavy minerals recovery, and plant productivity. To address this surface clay contamination in the Teri sand, the present work focuses on developing an eco-friendly surface-cleaning process. The study employs laboratory-scale (batch) attrition scrubbing assisted by natural, biodegradable, and environmental friendly scrubbing aids, to enhance the removal of adhering clay layers. Optimisation of key process parameters, for scrubbing and subsequent desliming, was systematically investigated to maximise slime removal, while minimising the heavy mineral loss. In addition, laboratory-scale ultrasonication tests were conducted, using a 500-watt sonication system, with 5-minute iterative cycles, which demonstrated effective disintegration and removal of slime coatings from the sand grain surfaces. Following surface cleaning, further studies were undertaken on desliming and clarification of the sedimented process water, to enable recycling. The work, also, includes the identification of suitable industrial applications for the generated slimes and the development of a process scheme for desliming and water clarification. This integrated approach reduces surface contamination on heavy minerals and improves slime management.

Process development for recovery of graphite from spent Li-ion battery black mass, using 75 mm dia laboratory scale flotation column

The study focuses on developing an efficient flotation-based process to recover graphite from spent lithium-ion battery (LIB) black mass. Since, graphite is a critical and valuable anode material, its selective recovery is essential for improving overall battery recycling efficiency. The study includes detailed characterisation and suitable pre-treatment of the black mass sample, to study its chemical composition and flotation response. Laboratory-scale batch flotation experiments will be carried out to determine process parameters such as pulp density, reagent dosages, and optimisation using a statistical design of experiments to achieve maximum graphite recovery and grade. Based on the optimised batch results, the black mass will be further processed in a 75 mm diameter laboratory flotation column to assess selectivity and separation efficiency for recovering graphite. Column operating parameters, including air flow velocity, feed flow rate, and froth depth, will be optimised. The overall objective is to develop an efficient flotation process for high-grade graphite recovery, while, also, enriching metal values in the non-float fraction, for further processing.

Feasibility Studies on Beneficiation of Quartz

Beneficiation studies were carried out on two quartzite samples, designated as Q1 and Q2, with the primary objective of improving their silica (SiO_2) content and minimising iron-bearing impurities, to improve the overall product quality. The

study involved a processing route, comprising of controlled crushing and grinding for size reduction, attrition scrubbing for surface cleaning and removal of adhering impurities, froth flotation for selective separation of iron minerals, and subsequent, acid leaching to further reduce residual iron content, to achieve high-purity silica concentrates. Quartzite sample Q1, initially assaying 93.9% SiO_2 and 2.27% Fe_2O_3, was effectively upgraded through attrition scrubbing, followed by flotation to 98% SiO_2 with Fe_2O_3 reduced to 0.26%, at 41.69% weight recovery. Acid leaching of the selected flotation concentrates, further, reduced Fe_2O_3, to as low as 0.09%. Quartzite sample Q2, containing 94.9% SiO_2 and 2.79% Fe_2O_3, showed similar beneficiation behaviour. Attrition scrubbing and flotation upgraded silica to 97.9% with Fe_2O_3 reduced to 0.25%, at 40.40% recovery. Subsequent, acid leaching enhanced the grades from 97.9% to 98.5% SiO_2, with 0.15% Fe_2O_3. The combined process, comprising attrition scrubbing, flotation, and selective leaching, helps to produce high-grade silica concentrates.

Feasibility studies on the beneficiation of secondary phosphate ore

The study focused on laboratory-scale feasibility investigations of the beneficiation of phosphate tailings from the existing industrial beneficiation plant, to enhance their P_2O_5 content and improve overall resource utilization. The chemical composition of the beneficiation plant tailings sample shows P_2O_5 content of 8.0–10.0% and SiO_2 of 4.0–5.0%. The major oxides present are CaO (32.0–36.0%) and MgO (14.0–16.0%), while Al_2O_3 (0.10–0.20%) and Fe_2O_3 (0.30–0.50%). Beneficiation studies involved grinding, followed by froth flotation (reverse), using different reagent systems. An optimized reagent regime, comprising sodium silicate, sodium oleate, and a silica collector, at a mild acidic pH, produced a high-grade phosphate concentrate with 69.9% recovery and 31.03% P_2O_5 grade, from the low-grade plant tailings feed assaying at 7.98% P_2O_5. The optimized conditions resulted in significant P_2O_5 upgradation, along with reduced MgO levels (~8%). Further, chemical leaching of flotation tailings, containing residual P_2O_5, yielded improved phosphate concentration, through selective dissolution of carbonate minerals. The integrated approach demonstrates the technical feasibility of recovering value from tailings, while supporting sustainable tailings management.

Laboratory-scale feasibility studies to beneficiate a secondary rock phosphate ore containing 10–14% R_2O_3 (Fe_2O_3 and Al_2O_3) with the objective of producing a concentrate containing less than 2% R_2O_3, while maximising the P_2O_5 recovery were carried out. A secondary rock phosphate ore sample was characterised, using mineralogical analysis, chemical analysis, and particle size distribution, to understand the liberation characteristics. The phosphate feed sample assayed at 14.95% P_2O_5, 4.67% Fe_2O_3, 1.91% Al_2O_3 (total R_2O_3: 6.58%), 48.73% SiO_2, 20.63% CaO, and 0.19% MgO, indicating significant siliceous and ferruginous gangue. Laboratory-scale beneficiation studies were primarily focused on froth flotation, to selectively reject R_2O_3 bearing gangue minerals and upgrade the phosphate values, using sodium oleate, as an effective collector for P_2O_5, supported by sodium silicate and causticized starch, as depressants, for gangue. An optimisation of reagent dosages and process parameters resulted in a final concentrate assaying 32.15% P_2O_5, 1.78% R_2O_3, and 8.12% SiO_2, at a weight recovery of 27.60%, using sodium oleate, sodium silicate, and causticized starch reagent system.

Metallurgical Failure Analysis of Roller Boss in a Cement Plant

Tamil Nadu-based industry approached CSIR-National Metallurgical Laboratory (NML), Madras Centre, for carrying out a comprehensive study on "Failure analysis of Roller Boss in a Cement Mill" at Puliyur. The main objective of the present investigation is to identify the root cause of failure of the roller boss in the cement mill. Based on the results obtained, the misalignment in the shaft, the severe wear on the shaft at both ends and the loss of design profile on the surface supported by the pits, wear tracks, and shiny patch surfaces on the seal rings indicate the possible load imbalance in the shaft.

Failure and microstructure characterisation of the cement mill roller shaft

A cement industry approached CSIR-National Metallurgical Laboratory, Madras Centre, for carrying out a comprehensive study on "Fracture and microstructural characterization of the cement mill roller shaft". The main objective of the present investigation is to identify the root cause of failure of the cement mill roller shaft. Based on the results obtained, the failure of the shaft is mainly due to rolling contact fatigue (RCF) between shaft and roller, originated by the generation of repeated/ cyclic contact stresses on the shaft surface.

Metallurgical failure analysis of combined emergency stop valve and control valve (ESVCV) of unit 1 of HP steam turbine

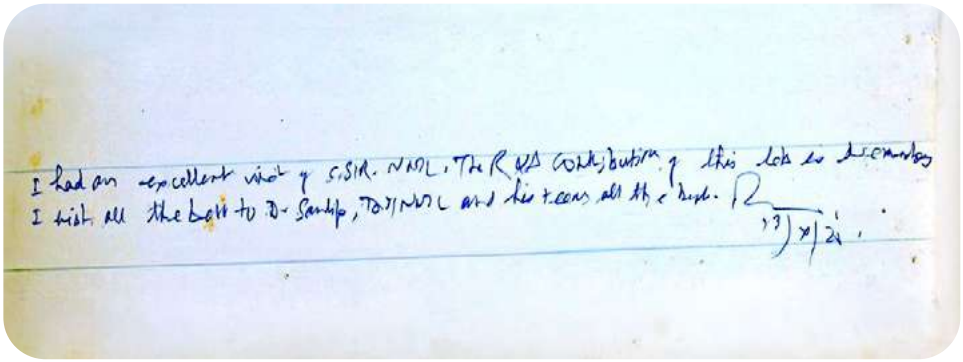
CSIR-National Metallurgical Laboratory, Madras Centre, undertaken a comprehensive study on "Failure Analysis of a combined emergency stop valve and control valve of Unit 1 HP steam turbine". The main objective of the present investigation is to identify the root cause of failure of the combined emergency stop valve and control valve of Unit 1 HP steam turbine. Based on the results obtained from various metallurgical characterization techniques, the failure of the valve is mainly due to high temperature surface oxidation induced fatigue, originated from the outside surface.

Metallurgical failure analysis of low pressure (LP) steam turbine blades

CSIR-National Metallurgical Laboratory, Madras Centre, undertaken a comprehensive study on "Metallurgical Failure Analysis of the LP turbine blade". The main objective of the present investigation is to identify the root cause of failure of the LP Turbine blade. Based on the results obtained, the failure of the blade is mainly due to misalignment between the blade and disk at the firtree region and consequent, erosion wear on the edge of the firtree slot profile of the blades led to the initiation crack and progressed by fatigue failure mechanism. The silica in the steam acted as a grinding media between the firtree location of blade and disk for formation of erosive surface on the edge of the firtree slot. The misalignment in the blade and disk at the firtree region can create passage sites for these corrosive elements to enter and through the gaps and further damaged the blade and disk by erosion wear and corrosion.

Metallurgical failure analysis of a windmill bearing

A Tamil Nadu based industry approached CSIR-National Metallurgical Laboratory, Madras Centre, for carrying out a comprehensive study on Failure Investigation of wind mill cylindrical roller bearings (CRB) and Taper Roller Bearings (TRB). The main objective of the present investigation is identification of the root cause of failure of the windmill failed CRB and TRB bearings. Based on the results obtained, the roller surfaces are suffered with a thin line like damage along the longitudinal direction on CRB roller surface and pitting damage on the TRB roller surface, respectively. Localised case pitting damage is observed in the circumferential direction of the outer raceway on both CRB and TRB bearing, is due to repeated metal hitting. CRB and TRB bearing inner raceway shows dark spots due metal rubbing, possibly, due to lack of lubrication. The presence of beach marks, striations, elliptical crack growth and pitting on the roller surface indicates the operation of rolling contact fatigue on failure of the both CRB & TRB roller bearings.



"I had an excellent visit of CSIR NML. The R&D constitutes of this lab is extraordinary. I wish all the best to Dr Sandip and his team all the best."

Mahendra Kumar Gupta
J.S / Admin , CSIR
Date: 13th October 2025

Advanced & Functional Materials

Hybrid Heusler-Glassy magnetic alloy composites for caloric and shape memory applications

The objective of the project is to develop magnetic composites comprising of Heusler and amorphous-nanostructured alloy systems for magnetocaloric and magnetic shape memory applications. Alloys of Ni55Mn22Ga22Al1 (at%), Fe80Si8B12 (at%) and Fe73.5Si13.5B15Cu1Nb3 were prepared by arc melting and then melt-spun into their respective ribbons. The magnetostrictions of single alloy ribbons were measured by the 2-Terminal capacitance technique. Using this 2-Terminal capacitance-based system, magnetostriction was measured for polymer-bonded ribbons of Heusler Ni55Mn22Ga22Al1 (at%) alloy with ribbons of either Fe80Si8B12 (at%) amorphous alloy or Fe73.5Si13.5B15Cu1Nb3 (at%) nanocrystalline alloy, wherein the alloys are symbolised as #NMG, #FSB and #FM, respectively. The #NMG, #FSB and #FM based ribbons were annealed at 800 °C for 48 hours, 300 °C for 15 minutes and 525 °C for 15 minutes respectively. The configuration of polymer-bonded #NMG with #FSB ribbons and their magnetostriction plots are shown in Figure 1 (T indicates ribbon thickness). Similar plots were also obtained for #NMG with #FM and shown in Figure 2. The polymer-bonded composite of # NMG-based ribbon displayed a magnetostriction of up to 460 ppm and 1070 ppm when stacked with either #FSB Figure 2, respectively. The ribbon composites showed much higher values as compared to 240 ppm, 40ppm, 12ppm for only #NMG, #FSB, #FM based ribbons respectively.

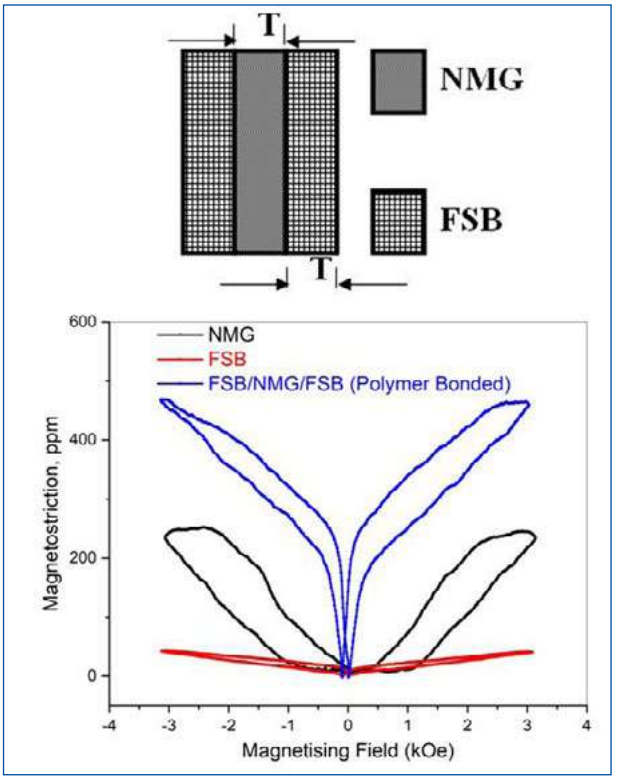


Figure 1: Magnetostriction Plot of #NMG and #FSB ribbons

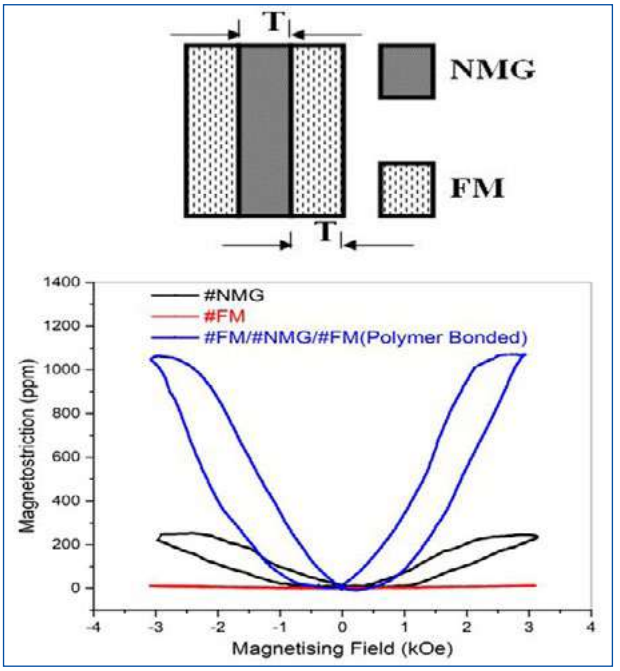


Figure 2: Magnetostriction Plot of #NMG and #FM ribbons

Thermal stability of nanocrystalline Cu-Nb binary alloy thin films: Phase separation, microstructure, residual stress and crystallographic texture

Cu and Nb are thermodynamically immiscible at equilibrium due to their positive enthalpy of mixing. The current project aims to develop the nanostructured Cu-Nb alloys and to understand the underlying alloying mechanism. To this end, $Cu_{100-x}Nb_x$ (2 at% ≤ x ≤ 25 at%) alloy thin films were deposited on SiO_2/Si(100) substrate using DC magnetron sputtering at room temperature. Only a very few literature exists on the miscibility of Cu-Nb within this Nb composition range. A systematic study examined how does the Nb content affect the phase formation, microstructure, residual stress, crystallographic texture, and the mechanical properties of the as-deposited Cu-Nb thin films. Remarkably, the nanocrystalline Cu_{100-x}-Nb_x thin films have been successfully synthesised at room temperature which is confirmed by XRD results despite the positive enthalpy of mixing between Cu and Nb. Characterisation by nanoindentation and high-temperature XRD revealed enhanced thermal stability and mechanical properties with increasing Nb content in the Cu-Nb alloy thin films. Ongoing research further investigates residual stress, texture, microstructure, thermal stability, and other properties of both as-deposited and annealed Cu-Nb films and the results will be published high rank international journals.

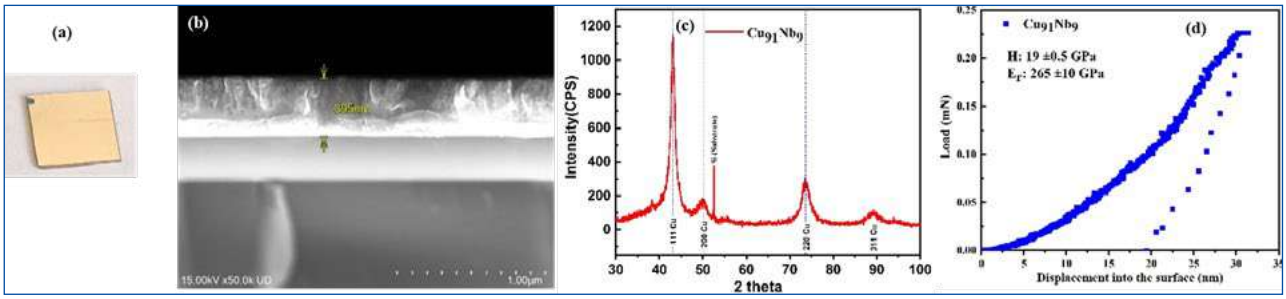


Figure 3: Nanocrystalline $Cu_{91}Nb_9$ thin film: (a) Photograph of the film surface showing its beautiful golden and shiny colour due to the solid solution of Cu-Nb (b) SEM cross-sectional image, (c) XRD pattern, and (d) Nano-indentation loading and unloading graph.

Development of novel microstructure and inhibitors to combat molten salt corrosion of thermal energy storage materials in concentrated solar power plants

The present study aims to design and develop microstructurally engineered, high corrosion-resistant thermal energy storage (TES) materials for concentrated solar power (CSP) systems by systematically optimizing processing parameters and identifying the optimal concentration of corrosion inhibitors, thereby minimizing molten chloride salt-induced corrosion and enhancing material durability under high-temperature operating conditions. To obtain different microstructural features (grain size, residual strain, grain boundary character distribution, and boundary connectivity) in commercial IN617 alloy, the as-received material was subjected to various cold working, heat treatment, and thermo-mechanical processing routes. The microstructural features of the processed materials were thoroughly analysed using electron microscopy techniques. To investigate the influence of microstructural features on molten salt corrosion behaviour, both isothermal and thermal cycling corrosion tests were conducted in molten nitrate and chloride salts using gravimetric (immersion) and electrochemical techniques. The tests were performed in nitrate salts (60 wt. % $NaNO_3$ + 40 wt. % KNO_3) for 720 hours and in chloride salts (18 wt. % KCl + 68 wt. % $MgCl_2$ + 14 wt. % NaCl) for 72 hours. Furthermore, to evaluate the role of an inhibitor on hot corrosion resistance, up to 2 wt. % Mg metal powder (as a corrosion inhibitor) was added to the

chloride salt mixture prior to testing. In the molten nitrate environment (associated with mass gain), all sample conditions, irrespective of grain size, residual strain, and grain boundary engineering (GBE), showed small positive mass changes. Static immersion corrosion tests consistently produced higher mass gain than thermal cyclic exposure. The highest corrosion rate (in terms of mass gain) under isothermal molten nitrate conditions was observed in the highly strained sample, followed closely by the solution-annealed and coarse-grained samples. Thermal cyclic testing in molten nitrate salts resulted in comparatively lower corrosion rates, with the highest value observed in the coarse-grained sample. Fine-grained and GBE samples exhibited the lowest corrosion rates in the isothermal molten nitrate salt environment. In the molten chloride environment (associated with mass loss), all values were negative, indicating consistent mass reduction. Isothermal molten chloride salt corrosion tests showed higher corrosion rates than thermal cyclic conditions across all samples. The most pronounced corrosion rate (in terms of mass loss) occurred in the GBE sample, followed by the solution-annealed and highly strained samples. Thermal cyclic exposure to molten chloride salts resulted in comparatively moderate corrosion rates, with the smallest mass losses observed in the samples containing the inhibitor. It has been demonstrated that the critical role of microstructural features in governing corrosion behaviour in both molten nitrate and molten chloride salts, enabling material design (based on microstructure optimization) and enhanced performance optimization for high temperatures application

Development of self-healing geopolymer composites

Self-healing materials are among the most sought-after due to the constant deterioration of structures and the difficulty of repairing them manually at regular intervals. The various approaches are (i) microcapsules containing mineral healing agents, (ii) bacterial healing, (iii) use of a shape memory polymer (SMP). However, most of the above efforts are trialled on conventional cementitious material and report some limitations. Self-healing of geopolymer composite by an intrinsic healing mechanism has not yet been attempted.

In the present work, hydrated lime is used as a self-healing agent in a metakaolin-based geopolymer where carbon fibre is used for reinforcement to develop the geopolymer composite. The amount of SHA and carbon fiber into geopolymer matrix is optimised considering the strength development, dimensional stability and healing ability of the composite samples. The chemically driven autogenous self-healing by formation of calcium carbonate for crack sealing/healing of the geopolymer composite is observed. The healed samples are evaluated by measuring regain of compressive strength, flexural strength, and change in water absorption value. Regain of mechanical properties is limited after healing. The developed geopolymer composite can heal microcracks of a width up to 250 mm within 1 month.

Rust converter ceramic primer and self-healing anticorrosion coating for corrosion protection of structural steel

Corrosion of mild steel structures is a major challenge faced in the industry, transport, and infrastructure sectors. There is an urgent need to develop anti-corrosion coatings suitable for direct application on rusted steel structures, eliminating the tedious, expensive and time-consuming surface preparation steps. This will facilitate the maintenance of existing corroded steel structures and enhance longevity. CSIR-National Metallurgical Laboratory, Jamshedpur, has formulated a rust converter ceramic primer suitable for direct application on rusted steel with minimal surface preparation. The active components of the ceramic primer react with rust and convert it to a ceramic coating. A self-healing anti-corrosion coating has also been developed, which self-heals autonomously in the presence of water to prevent the initiation of corrosion in the crack area. At CSIR-NML, the ceramic primer and

self-healing coating production process has been scaled up to 200 liters/batch scale. The technology has been transferred to M/s Asianol Biotech Pvt Ltd, Kolkata, for commercial production. CSIR-NML has achieved a breakthrough in rust converter and self-healing coating technologies by inventing a simple, scalable, and economical process. The rust converter ceramic primer formulation uses chemically bonded phosphate ceramic (CBPC) chemistry to create a ceramic coating on the rusted steel surface, eliminating the need for removal of rust (surface preparation) prior to paint application. The self-healing coating formulation involves blending of commercially available, low-cost, epoxy polymer resin, and inorganic powders. The developed coatings is suitable for application on metal surfaces using conventional paint application processes like brushing, rolling, or spraying, followed by curing in ambient conditions. Upon formation of a crack in the coating, water or moisture triggers autonomous self-healing of the crack/scratch. The developed coating passes 1000 hours of salt spray test (ASTM B 117) without the formation of red rust at the cut area. The performance of the coating has been evaluated both in laboratory conditions and in real-life environments. The ceramic primer and self-healing coating can be utilised for the maintenance-free corrosion protection of existing and new mild steel structures in infrastructure, transport and industry sectors. This will increase productivity, reduce accidents, and enhance the service life of steel structures.



Figure 4: Application of Ceramic Primer at Haldia Met Coke plant site, Haldia.



Figure 5: Signing of Technology transfer Agreement with M/s Asianol Biotech Pvt Ltd., Kolkata

Services to Defence Sectors

Hot corrosion behaviour of Ni-based and Co-based superalloys using thermogravimetric and electrochemical methods

The present study aims to examine the hot corrosion behaviour of Co-based (H-188) and its Ni-counterpart (H-230) with respect to concentration of Na_2SO_4, NaCl and $NaVO_3$ with emphasis on understanding the mechanisms of hot corrosion of the aforementioned alloy systems relevant to aero engine application. In order to examine the hot corrosion behaviour of Haynes 188 and Haynes 230, materials were exposed to different salt environments (i.e., bare, Na2SO4, Na_2SO_4 + NaCl, Na_2SO_4 + $NaVO_3$, and Na_2SO_4 + NaCl + $NaVO_3$) at 850 ^oC for 5 - 500 hrs.. Following exposure, mass loss data were compiled into thermogravimetric plots (i.e., mass change versus exposure time) to study corrosion kinetics. Elemental analysis of corrosion products/depositions was carried out employing various characterisation techniques such as EPMA-EDS/WDS, XRD. This present work clearly demonstrated that the hot corrosion behaviour of Haynes 188 and 230 at 850 ^oC is strongly influenced by the nature and composition of deposited salts. The base substrate showed minimal degradation under pure oxidation. However, the introduction of Na_2SO_4 substantially increased the corrosion rate due to acidic fluxing and sub-surface sulfidation. The addition of NaCl further intensified degradation through the formation of volatile metal chlorides, resulting in porous and loosely adherent oxide scales. Similarly, $NaVO_3$ contributed to accelerated oxide dissolution and vanadate formation, leading to internal damage and weight loss due to volatilisation. The most aggressive corrosion was observed with the combined presence of Na_2SO_4, NaCl, and $NaVO_3$, which caused synergistic damage through simultaneous fluxing and chloride volatilisation mechanisms. Future research will focus on systematically understanding the oxidation mechanisms and hot corrosion kinetics of Haynes-230 and Haynes-188 alloys at the molten salt-alloy interface. Electrochemical techniques will be employed to characterise interfacial reactions, quantify corrosion rates, and elucidate degradation pathways under high-temperature conditions.

High cycle fatigue characterization of compressor aerofoil material GTM-SU-718.

Gas turbine material SU-718 is a high-strength, corrosion-resistant nickel-based polycrystalline superalloy used for the manufacturing of the disks. This alloy has reasonably high cycle fatigue strength in the elastic regime. However, owing to its high fatigue strength, which is reduced mainly due to mean stress effects. Moreover, it has been reported that the largest single cause of component failures in modern military aircraft gas turbine engines is high-cycle fatigue, exceeding the number attributed to low-cycle fatigue, corrosion, applied stresses, manufacturing processes, and creep damage. The present investigation is to understand the effect of mean stress on high-cycle fatigue behaviour of alloy SU-718 at two different temperatures (300°C and 500°C) with varying stress ratios from 0.4, 0.6. Experimental data has reached the maximum number of cycles to failure at 10^7. The failure of the samples predominantly showed the brittle fracture as observed using SEM. Operating parameters were already selected based on the experience of the design engineer for safe operation of the gas turbine engine through field inspection and maintenance actions, and total economic loss during service to reduce component reliability.

Exploratory studies on creep crack growth rate behaviour of GTM Su 718

Creep crack growth data is an important part for the lifetime assessment of aircraft components operating at high temperature. Creep crack growth behaviour of hot-end engine alloys is required for accurate prediction of crack growth under creep conditions and high-temperature deformation. The accuracy of design and life prediction depends on the precision of the test data and the design

of experiments to generate those test data, simulating the actual engine conditions. Moreover, components with various levels of defects, such as segregation, precipitates, grain structure, etc., are classified as short or long cracks, which also play a vital role in the threshold stress intensity factor and crack propagation rate. It is also necessary to understand the crack closure methodology under operating conditions, so that the prediction will not be erroneous. All the above factors need to be addressed during material testing which are prerequisites for reliable design. It is also necessary to do exploratory tests to arrive at the crack growth behaviour under evaluation of load & time, simulating the operating load and temperature conditions. This project aims to generate the creep crack growth (CCG) data (da/dt Vs C*) of GTM Su 718 alloy at various temperatures as part of a round robin test exercise. GTM Su 718 is a candidate material for hot-end engine parts. Any pre-existing defect or incipient damage during service conditions can lead to crack extension due to the synergistic interaction of creep and fracture mechanisms. Evaluation of material behaviour for creep or fracture alone is inadequate to assess the material performance, since the contributions to life-limiting factors is due to more than one mechanism. This proposal thus aims to evaluate the creep crack growth (CCG) behaviour of the material at temperature regimes relevant to the component. The creep crack growth experiment is completed. This project has produced more precise information and data for the application of Su718 in critical applications.

Studies on the creep behaviour of the SS304L base and weld material

The proposed project aims at evaluating the creep stress rupture behaviour of SS304L base and weld material at high temperature and studying the effect of material discontinuity owing to weldments and geometric discontinuity such as notches. The creep stress rupture tests will be conducted in the temperature range of 550°C to 1100°C. The outcome of the study would be useful for improved assessment of the structural integrity of Calandria assembly in case of a severe core damage accident in Indian PHWRs. In addition to this, tensile, metallurgical investigation, such as micro-structural characterisation and fractographic examination (of tested specimens) will also be carried out. Austenitic stainless steels with their excellent corrosion resistance, good thermal conductivity and creep strength are extensively used in piping applications in process plants, superheaters in fossil-fired boilers of power plants and steam generators of nuclear reactors. For better utilisation of the alloy and to ensure safer structural integrity of the components made of these alloys, a better understanding of high-temperature strength behaviour, particularly under tensile and creep/stress rupture loading, is essential. Bhabha Atomic Research Centre (BARC, Mumbai), India, is engaged in research on nuclear reactor design and operation and maintenance aspects for the application of nuclear power needs of India. Stainless steels are widely used in nuclear installations, including pipes and pressure vessels. Accidental overtemperature and pressure excursions during service are possible, and even though design safety calculations consider such excursions and precautions are included, material behaviour under such accidental conditions is lacking. A better understanding of alloy behaviour at such beyond design extremes is needed for simulation studies, and the incorporation of such knowledge will strengthen the safety of nuclear power-generating structures. The project has generated information and data that would enable more accurate design calculations for the pressurized heavy water reactor (PHWR).

Creep and stress rupture behaviour of boiler tubes T11, T12 and T22 material

This project aims to study the creep and stress rupture behaviour of indigenously manufactured boiler tubes (T11, T12 and T22). A detailed study in the temperature range of 500°C-600 will be carried out. The results will ascertain the suitability of the tubes for application in thermal power plants, as

per the ASME-BPVC and BHEL's requirements. The reliable operation of thermal power plants depends critically on the high-temperature performance of boiler tubes, which are continuously exposed to severe stresses and elevated temperatures that can lead to creep deformation and eventual stress rupture. Materials such as T11, T12, and T22 ferritic steels are widely used for such applications due to their favourable balance of strength, thermal stability, and cost; however, their long-term performance must be thoroughly validated, especially when manufactured indigenously. With increasing emphasis on self-reliance and cost optimisation, it becomes essential to ensure that locally produced boiler tubes meet stringent design and safety standards under operating conditions typically ranging from 500°C to 600°C. Any failure in these components can result in unplanned outages, economic losses, and safety hazards. Therefore, a systematic study of creep and stress rupture behaviour is necessary to assess material durability, establish life prediction models, and confirm compliance with recognised codes such as the ASME Boiler and Pressure Vessel Code and BHEL specifications, thereby ensuring safe and efficient plant operation. The impact of this project lies in its potential to strengthen the reliability, safety, and economic efficiency of power plant operations by ensuring that indigenously manufactured boiler tubes meet stringent high-temperature requirements. It will also enable informed material selection and quality assurance practices aligned with standards such as the ASME Boiler and Pressure Vessel Code and Bharat Heavy Electricals Limited specifications. Furthermore, the findings will contribute to enhancing confidence in indigenous manufacturing capabilities.

Preliminary fatigue crack growth rate and fracture toughness testing at high temperatures

The aeroengine components must operate in hostile environments while meeting stringent design and performance requirements. Damage-tolerant (DT) approach for design of these components provides a method of monitoring crack growth and thereby avoid catastrophic failure of the operating components. For DT analysis, material evaluation for fracture toughness and crack growth parameters is essential. Therefore, this project aims to investigate elevated temperature fatigue crack growth rate (FCGR) and fracture toughness properties (K_{1C}/ J_{1C}) of forged aero-engine disc and casings of Ti-6Al-4V and Su718 alloys, and generate design data for DT analysis. The FCGR and fracture tests have been carried out at different high temperatures along different orientations in RIM and BORE locations of the forged disc and also on casing. Figure 26 shows the typical load-displacement behaviour (J-test) of Su 718. Based on the instability conditions exhibited by two different materials, single-point fracture toughness values have been evaluated as per the ASTM E1820. The orientation and temperature effect on FCGR and fracture toughness have been examined. The effect of stress ratios (R=0.1, 0.5 and 0.7) on FCGR was evaluated for both Su 718 and Ti-6Al-4V disc and casings. Figure 1 shows the high-temperature fatigue crack growth test system, which uses DCPD technique that has been established at CSIR-NML.

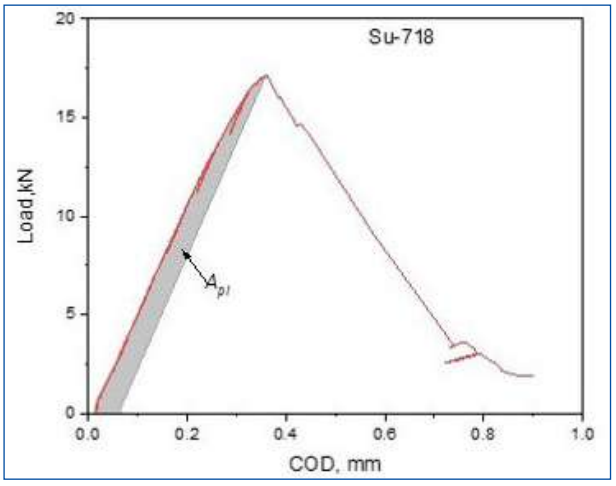
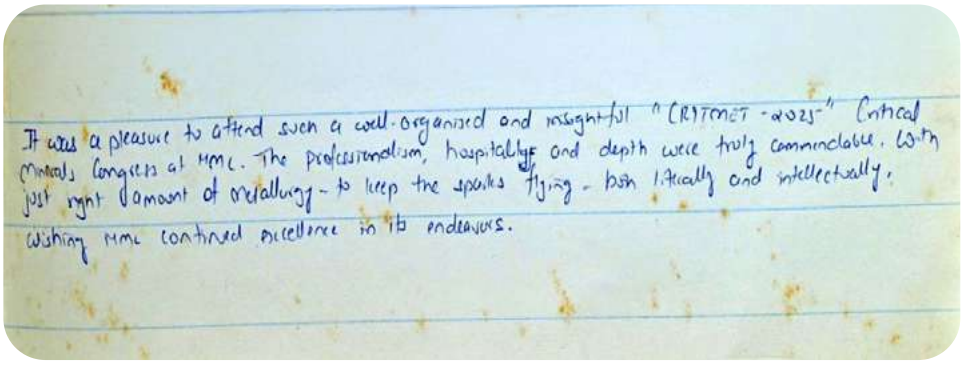


Figure 1: High-temperature fatigue crack growth test system


It was a pleasure to attend such a well-organised and insightful "CRITMET-2025" Critical Minerals Congress at NML. The professionalism, hospitality and depth were truly commendable. With just right amount of metallurgy - to keep the sparks flying - both literally and intellectually.
Wishing NML continued excellence in its endeavours.

"It was a pleasure to attend such a well organised, insightful CRITMET- 2025. Critical metal congress at NML. The professionalism, hospitality and depth were truly commendable. with just the right amount of metallurgy to keep the sparks. Wishing NML continued excellence in its endeavours."

Lekhan Thakkar
Joint Secretary,
National Security Council,
GOVT. of India.

Corrosion

The corrosion research activities at CSIR-NML include the development of advanced materials, techniques, and processes. It aims to improve material properties, enhance component performance, and reduce environmental degradation. Its work supports sectors such as energy, space, oil and gas, iron and steel, infrastructure, and the orthopedic sector. The division has two groups: *Functional Materials*, and *Corrosion and Coatings*. Research covers materials from nano to bulk scale. Key areas include graphene, metal chalcogenides, MXenes, and biowaste-derived composites for energy applications. The division also develops high-strength biodegradable magnesium alloys for implants. Key areas also include alloy design, rapid solidification, and metallic glasses for sensors and EMI shielding. Corrosion research focuses on aqueous, atmospheric, high-temperature, and molten salt environments. The team conducts failure analysis and corrosion audits. It develops sustainable coatings and surface engineering methods. The division has 20 scientists and 3 technical personnel delivering practical solutions. Key projects are outlined below:

Functional Materials

Development of Rare-Earth free Anisotropic α˝-$Fe_{16}N_2$ hard Magnetic Material

In the global search for rare-earth-free permanent magnets, several new magnetic phases with high magnetocrystalline anisotropy have been identified, including τ-MnAl, MnBi, Zr_2Co_{11}, tetragonal FeNi, nano-Co, Co_3C, Fe_3N, and α″-$Fe_{16}N_2$. Among these, the metastable tetragonal α″-$Fe_{16}N_2$ and α″-$(Fe,Co)_{16}N_2$ phases are particularly promising because they combine very high magnetic polarization (~2.1–2.3 T) with large magnetocrystalline anisotropy (K_u ~10^7 erg/cm³, ~1 MJ/m³), making them strong candidates for the development of bulk hard magnets with high (BH) max (Figure 3). From a sustainability perspective, their rare-earth-free composition and reliance on earth-abundant Fe and N make them especially attractive.

A comprehensive theoretical alloy design framework was developed to identify suitable alloying additions, based on the Lehrer diagram, austenite stabilization capability, nitrogen solubility enhancement, and weak nitride-forming tendency. Through iterative composition optimization from binary to quaternary alloy systems, two primary alloy families were identified: Fe–Mn–Co–Cu (FMCC) and Fe–Ni–Co–B–Cu (FNBCC). Melt-spun precursor ribbons from these systems exhibited fully single-phase BCC structures, validating the alloy design strategy. Following nitriding, quenching, and tempering, X-ray diffraction (XRD) confirmed α″-$Fe_{16}N_2$ as the dominant phase, accompanied by a fraction of untransformed γ-Fe(N) austenite. Preliminary transmission electron microscopy (TEM) revealed iron nitride nanoplatelets embedded within the austenite matrix, while selected area electron diffraction (SAED) showed characteristic streaking consistent with the rel-rod effect, supporting the presence of plate-like precipitates (Figure 4). Magnetic characterization demonstrated high saturation magnetization, coercivity below 100 Oe, and anisotropy fields of approximately 2000 Oe in tempered powders. This proof-of-concept study establishes a credible pathway toward the realization of scalable, rare-earth-free bulk permanent magnets based on α″-$Fe_{16}N_2$. An Indian patent with complete specifications has been filed. Future work will focus on increasing the α″-$Fe_{16}N_2$ phase fraction beyond 90%, enhancing magnetic anisotropy and coercivity, and optimizing the process route for industrial-scale production.

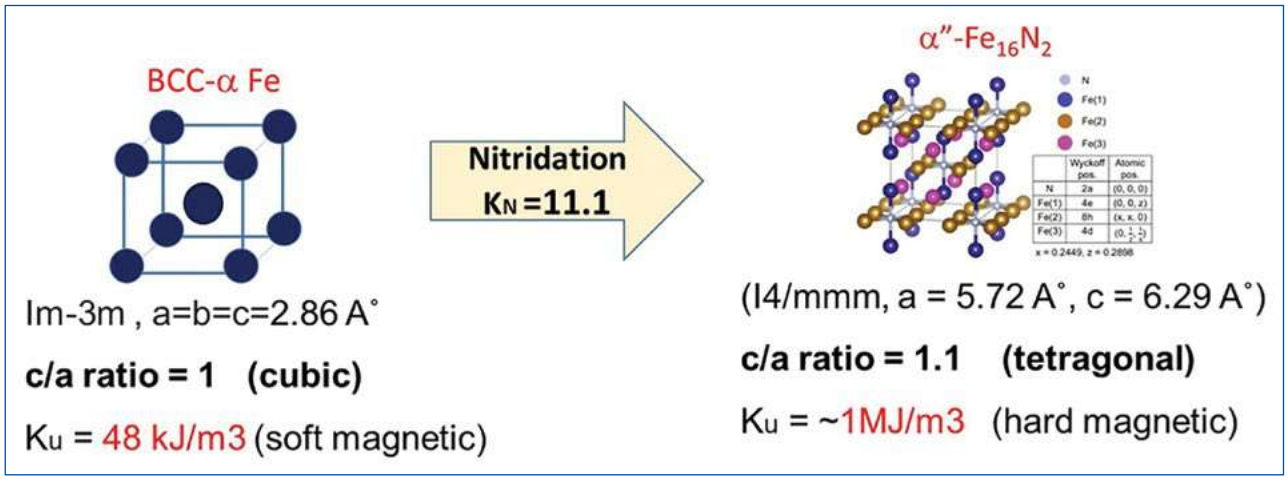


Figure 1: Schematic illustration of hard-magnetic Iron nitride phase formation under controlled nitriding treatment.

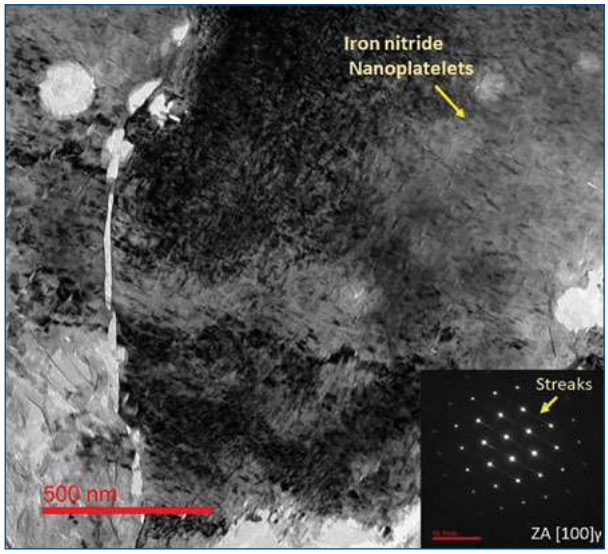


Figure 2: Bright field TEM image and corresponding SAED pattern depicting Iron nitride platelets dispersed in an austenitic matrix.

AC Magnetisation studies on cold-rolled non-oriented Silicon steels as per IS-649 (Phase I and II)

The sponsor Steel Plant (SAIL-RSP) produces lean-grade cold-rolled non-oriented (CRNO) electrical steel coils with a typical Si content below 2 wt.% for use in various commercial electromagnetic cores and yokes. The determination of AC magnetic properties, particularly magnetic induction (Bm) and core loss at 50–60 Hz, constitutes the final quality control criterion for qualification of these CRNO grades. In this context, SAIL-RSP will supply CRNO strip samples with varying physical dimensions, coating characteristics, and magnetic properties, and each batch will be evaluated for physical parameters, density, and AC magnetic performance to ensure conformity with IS 649 standards. The study will adopt the IEC 60404-4 standard for AC core-loss evaluation of electrical steel sheets using the Epstein frame method. The Epstein bridge to be used has a bridge size of 25 cm with a mean magnetic path length of 94 cm, 700 turns in both primary and secondary coils, and specimen dimensions of 30 mm width × 300–305 mm length × sheet thickness (~0.50 mm). Under this project, a total of 1,279 sets of coated CRNO strip samples containing approximately 1.5–1.7 wt.% Si will be investigated to evaluate their dynamic magnetization behavior and AC core-loss characteristics. The scope of work includes establishing a detailed experimental test matrix covering different magnetic induction (Bm) levels, the applicable AC frequency range, optimization of testing parameters, and systematic core-loss measurement. Based on the large experimental dataset generated, empirical correlations between steel grade, sheet thickness, and AC magnetic loss characteristics will be developed to enable qualitative grade identification and performance classification.

Large-scale production of M2AX (M=Ti/V, A=Al, & X=C) type MAX and corresponding MXenes-based electrodes for developing aqueous-based coin and cylindrical supercapacitors

The primary objective of the ongoing research in our lab is to develop scalable synthesis routes for high-purity MXenes and other 2D functional materials. Toward this objective, an indigenous pressureless sintering process has been developed for the synthesis of highly pure (≥97%) Ti_3AlC_2 MAX phase and Ti_3C_2 MXene, which has reached TRL-5 and was transferred to an MSME under project SSP-1399, marking an important step toward domestic production and commercialization of MXene materials. The ongoing work under SERB-funded project GAP-0319 (Title: Large-scale production of M_2AX (M = Ti/V, A = Al & X = C) type MAX and corresponding MXenes-based electrodes for developing an Aqueous Electrolyte-based Coin and cylindrical supercapacitor) focuses on the development of high-purity Ti- and V-based MAX phases and their corresponding MXenes through improved process engineering approaches. Preliminary success has already been achieved in synthesizing high-purity Ti_2AlC MAX phase, confirmed by XRD and SEM analyses (Figure 5), which will be followed by the development of the corresponding Ti_2C MXene as well as V_2AlC MAX and V_2C MXene. In alignment with the Waste-to-Wealth initiative, a biowaste-derived 2D graphitic carbon-supported Ni core–NiO shell heterostructure has been designed (Figure 6), demonstrating great potential in hydrogen production. Building on this sustainable approach, preliminary investigations have been initiated to derive high-purity (≥97%) Ti and V-based MAX and MXene materials from waste precursors, showing encouraging progress toward further reducing the cost of MXene production and improving market accessibility. Major research outputs of this study include a publication in *Discover Nano* (https://doi.org/10.1186/s11671-025-04396-3) reporting a Ti_3C_2 MXene–nickel cobalt sulphide composite for supercapacitor applications (capacitance of 1165 F g^{-1} at 1 A g^{-1}) and a forthcoming book chapter titled "MXene-based Functional 2D Nanostructures for Energy Application". Future work will focus on the development of various MXene-based composites, to employ in relevant applications.

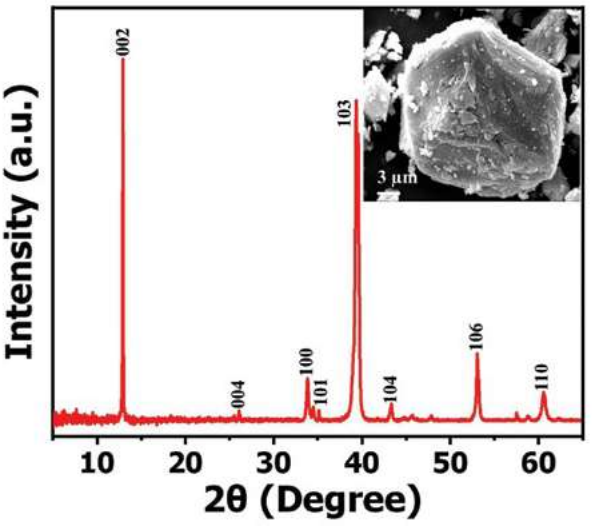


Figure 3: XRD pattern of Ti_2AlC MAX phase with corresponding SEM image shown in the inset (unpublished data).

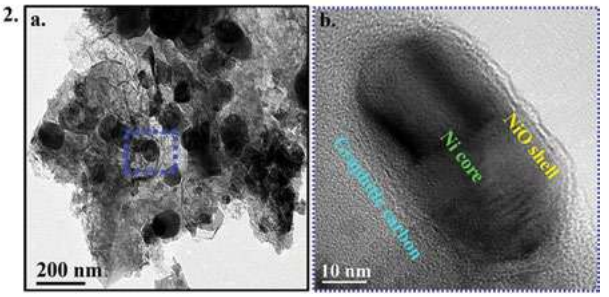


Figure 4: (a) TEM image of biowaste-derived graphitic carbon supported NiO shell@Ni core nanocomposite; (b) HR-TEM image showing the core–shell structure with graphitic carbon support (unpublished data).Bottom of Form

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)

Efficient and durable electrocatalytic water splitting activity of CeO2-NiMoO4@rGO porous hollow sphere nanocomposite at high current density.

Design and development of efficient low-cost transition metal-based electrocatalyst for green hydrogen production through water electrolysis is gaining more and more importance to address the tremendous environmental pollution from conventional energy sources. In this concern, we developed ceria (CeO_2) and reduced graphene oxide (rGO) incorporated porous hollow spheres of highly crystalline NiMoO4 (CeO_2-$NiMoO_4$@rGO) through a simple and scalable spray drying followed by calcination strategy. Synthesized CeO_2-$NiMoO_4$@rGO hollow spheres showed excellent OER activity having reasonably low overpotential of 230 mV at 10 $mAcm^{-2}$, a low Tafel slope of 38 mVdec-1 and stability for at least 100 hours. It also exhibited moderate HER activity. Constructed symmetric two-electrode electrolyser CeO_2-$NiMoO_4$@rGO || CeO_2-$NiMoO_4$@rGO required a potential of 1.56 V to attain a current density of 10 $mAcm^{-2}$, whereas asymmetric Pt/C|| CeO_2-$NiMoO_4$@rGO required lower potential, most probably due to the moderate HER activity of CeO_2-$NiMoO_4$@rGO. Most importantly, synthesized CeO_2-$NiMoO_4$@rGO showed excellent activity and stability in prototype AEM electrolyser. Respective electrolyser having 4 cmMEA Pt/C|| AEM ("Sustainion X37-50") || CeO_2-$NiMoO_4$@rGO achieved a current density of 211 mA cm^{-2} at an applied potential of 2 V and stable for 100 hours. The enhanced activity can be ascribed to the synergistic effect of porous hollow structure, incorporated CeO_2 and rGO. Thus, the developed catalyst can be used for industrial scale AEM electrolyser and the synthetic strategy can be used for synthesis of porous hollow spheres with variable compositions.

Development of Organic Polymeric Coatings for Heritage Conservation

The project on "Development of Organic Polymeric Coatings for Heritage Conservation" is currently in progress and has made significant advancement toward the development and evaluation of protective polymeric coatings suitable for the conservation of heritage metallic artifacts under Indian environmental conditions. In the initial phase of the study, Paraloid B-72-based polymeric coating formulations were prepared in different concentrations (1 wt%, 3 wt%, 5 wt%, and 10 wt%) using volatile organic solvents such as methyl ethyl ketone (MEK) to obtain homogeneous coating solutions. Brass substrates were selected as representative metallic heritage materials and were coated using a dip-coating technique, where key process parameters such as dipping time, withdrawal rate, and substrate surface roughness were systematically varied to achieve uniform and adherent coatings. The corrosion resistance of the coated specimens was investigated and compared with bare brass substrates using electrochemical corrosion characterization techniques, including open circuit potential (OCP), potentiodynamic polarization (PDP), and electrochemical impedance spectroscopy (EIS) in a 3.5 wt% NaCl solution to simulate aggressive chloride-containing environments often encountered in outdoor heritage structures. The electrochemical studies indicated a significant improvement in corrosion resistance for coated substrates compared to uncoated specimens. The corrosion rate was observed to decrease progressively with increasing polymer concentration, following the trend: Bare substrate > 1 wt% > 3 wt% > 5 wt% > 10 wt% Paraloid B-72 coating, demonstrating the effectiveness of thicker and more continuous polymeric films in providing barrier protection against corrosive environments. In addition to electrochemical analysis, real-time corrosion monitoring was performed through accelerated salt spray exposure tests as well as open-door atmospheric exposure studies to evaluate the durability and protective performance of the coatings under simulated environmental conditions. These studies provided valuable insights into the long-term protective behavior of the developed coatings. The surface wettability and hydrophobic characteristics of the coated substrates were also

investigated through contact angle measurements using the sessile drop method. The results revealed enhanced hydrophobicity with increasing coating concentration, indicating improved resistance to moisture ingress and environmental contaminants. Furthermore, the durability of the coatings under ultraviolet (UV) exposure conditions was examined through accelerated weathering experiments. Coated specimens were exposed to alternating UV irradiation and condensation cycles for a period of 10 consecutive days to simulate environmental aging effects. The coatings demonstrated good stability with minimal degradation, indicating their suitability for heritage applications exposed to sunlight and environmental moisture. Based on the encouraging results obtained so far, the project is progressing toward the development of standardized operating procedures (SOPs) for the practical application of these coatings in heritage conservation. The SOPs will provide detailed guidelines on surface preparation, coating formulation, application methodology, curing conditions, and performance evaluation, specifically tailored to the diverse climatic and environmental conditions prevalent in India. The ongoing work focuses on further optimization of coating formulations, long-term environmental exposure studies, and validation of the developed coatings for potential application in the conservation of heritage metallic artefacts and historical structures.

Corrosion and Coatings

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

In this investigation, a systematic study was performed to realize a suitable alloy composition and process route for obtaining a high-performance Al-Mg-Sc alloy for next-generation engineering applications that require high strength, durability, and energy efficiency. The alloy composition was judiciously selected utilizing the CALPHAD approach, considering the effect of magnesium (Mg), scandium (Sc), zirconium (Zr), copper (Cu), and Zinc (Zn). The alloys were prepared in a three (03) kg capacity furnace using a graphite crucible. After preparation of these alloys, the liquid metal was poured into a copper mold to achieve a high solidification rate and obtain a supersaturated matrix of the aluminium alloy. The thermo-mechanical processing of the as-cast alloy was performed using an optimized process schedule consisting of alloy homogenization, hot rolling, and ageing treatment. The optimized thermo-mechanically processed alloy enhances grain refinement, precipitation strengthening, as well as oxidation and corrosion resistance. The designed alloy demonstrates superior tensile strength exceeding 350 MPa while ensuring thermal stability at 200°C. A key advantage of this developed alloy is its superior weldability, making it ideal for structural applications. The preliminary fatigue data indicates 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 having ~126 mm diameter and ~320 mm length. The tensile properties of the hot-rolled aged specimen were better compared to the extruded rod, possibly due to better microstructure control through optimized thermo-mechanical process schedule. This could also be attributed to limitations in the processing schedule during the plant trial for the extrusion process. It is noted that large-scale melting in a plant with controlled casting parameters, an optimized thermo-mechanical process route, and tailored compositions can further enhance the alloy's properties by ensuring the required amount, morphology, type, size, and distribution of precipitates and intermetallics in the aluminium alloy matrix. Additionally, the alloy is cost-effective with optimized scandium content and is scalable using standard manufacturing techniques such as casting, extrusion, rolling, and forging.

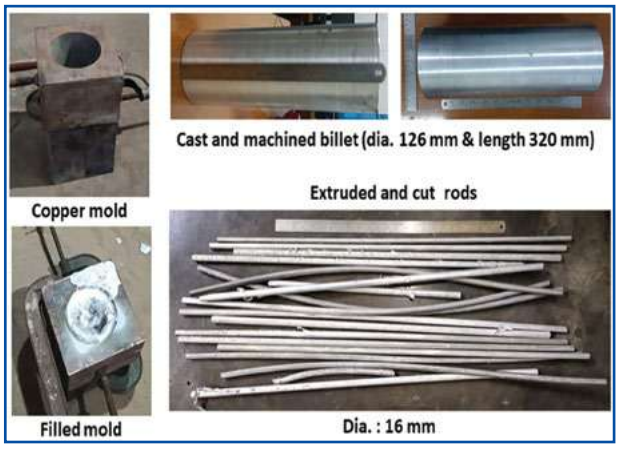


Figure 5: Large-scale melting of the alloy to obtain as-cast billet with ~140 mm diameter and 330 mm length. The final diameter of the extrusion rod was 16 mm

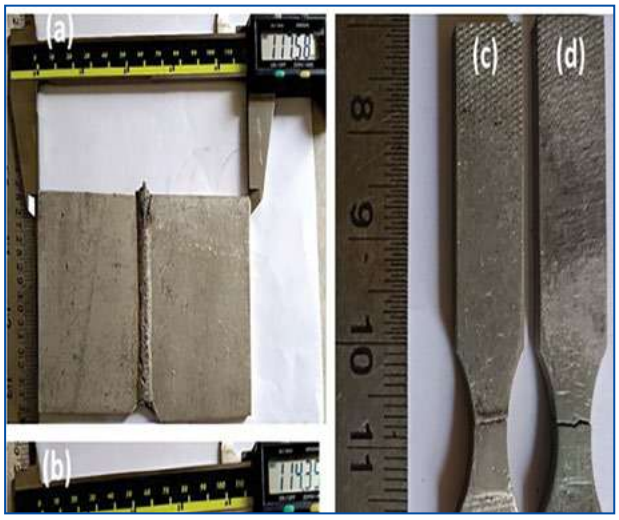


Figure 6: Welded specimens; (a) Specimen aged before welding, (b) Specimen aged after welding, (c) Tensile failure of specimen (a) & (d) Tensile failure of specimen (b)

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

The present study aims to investigate the effect of microstructural features on the corrosion behaviour of additively manufactured (SLM) 316L stainless steel in a simulated biological environment, with emphasis on understanding the microstructure-passive film-corrosion relationship relevant to biomedical implant applications. SLM-processed and conventionally manufactured 316L stainless steel samples were examined using optical microscopy, SEM, EBSD, TEM/STEM-EDS, and comprehensive electrochemical techniques, including potentiodynamic polarisation, potentiostatic tests, electrochemical impedance spectroscopy (EIS), and Mott-Schottky analysis in simulated body fluid at physiological temperature. The study has successfully demonstrated that despite pronounced microstructural anisotropy between BD and TD orientations, the electrochemical response remains largely comparable. However, both SLM orientations exhibit significantly improved corrosion resistance relative to conventional material. The enhanced performance is attributed to low porosity, cellular sub-grain structures, residual strain-assisted diffusion, and nanoscale enrichment of Cr-Mo-Mn at cell boundaries, which promote the formation of a thicker, more stable, and less defective passive film. This finding highlights the strong potential of additive manufacturing in developing reliable and long-lasting biomedical implants (Figure 9). Major outputs include demonstration of nearly doubled pitting potential in SLM samples, wider passive regions, higher polarization resistance, lower defect density in passive films, and improved resistance to localized corrosion with minimal anisotropic influence (Figure 9). The work provides new mechanistic insights into orientation-dependent corrosion behaviour, linking passive film semiconducting properties, defect chemistry, and microstructural evolution in additively manufactured stainless steel. Future research will focus on long-term immersion studies, surface modification strategies, fatigue-corrosion interactions, in vivo relevant environments, and optimization of SLM process parameters to further enhance durability and biocompatibility of AM-fabricated implants.

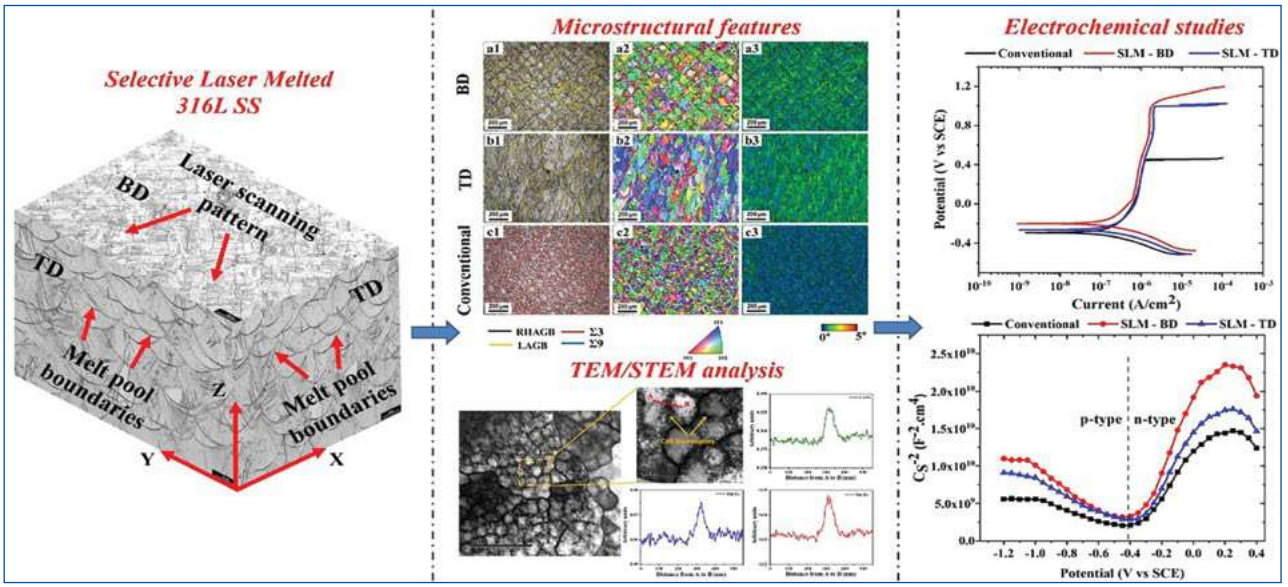


Figure 7: Microstructures (Optical, SEM, TEM/STEM) and electrochemical corrosion studies of conventional and SLM-processed 316L stainless steel samples

Development of novel microstructure and inhibitors to combat molten salt corrosion of thermal energy storage materials in concentrated solar power plants

The present study aims to design and develop microstructurally engineered, high corrosion-resistant thermal energy storage (TES) materials for concentrated solar power (CSP) systems by systematically optimizing processing parameters and identifying the optimal concentration of corrosion inhibitors, thereby minimizing molten chloride salt-induced corrosion and enhancing material durability under high-temperature operating conditions. To obtain different microstructural features (grain size, residual strain, grain boundary character distribution, and boundary connectivity) in commercial IN617 alloy, the as-received material was subjected to various cold working, heat treatment, and thermo-mechanical processing routes. The microstructural features of the processed materials were thoroughly analysed using electron microscopy techniques. To investigate the influence of microstructural features on molten salt corrosion behaviour, both isothermal and thermal cycling corrosion tests were conducted in molten nitrate and chloride salts using gravimetric (immersion) and electrochemical techniques. The tests were performed in nitrate salts (60 wt. % $NaNO_3$ + 40 wt. % KNO_3) for 720 hours and in chloride salts (18 wt. % KCl + 68 wt. % $MgCl_2$ + 14 wt. % NaCl) for 72 hours. Furthermore, to evaluate the role of an inhibitor on hot corrosion resistance, up to 2 wt. % Mg metal powder (as a corrosion inhibitor) was added to the chloride salt mixture prior to testing. In the molten nitrate environment (associated with mass gain), all sample conditions, irrespective of grain size, residual strain, and grain boundary engineering (GBE), showed small positive mass changes. Static immersion corrosion tests consistently produced higher mass gain than thermal cyclic exposure. The highest corrosion rate (in terms of mass gain) under isothermal molten nitrate conditions was observed in the highly strained sample, followed closely by the solution-annealed and coarse-grained samples. Thermal cyclic testing in molten nitrate salts resulted in comparatively lower corrosion rates, with the highest value observed in the coarse-grained sample. Fine-grained and GBE samples exhibited the lowest corrosion rates in the isothermal molten nitrate salt environment. In the molten chloride environment (associated with mass loss), all values were negative, indicating consistent mass reduction. Isothermal molten chloride salt corrosion tests showed higher corrosion rates than thermal cyclic conditions across all samples. The most pronounced corrosion rate (in terms of mass loss) occurred in the GBE sample, followed by the solution-annealed and highly strained samples. Thermal

cyclic exposure to molten chloride salts resulted in comparatively moderate corrosion rates, with the smallest mass losses observed in the samples containing the inhibitor. It has been demonstrated that the critical role of microstructural features in governing corrosion behaviour in both molten nitrate and molten chloride salts, enabling material design (based on microstructure optimization) and enhanced performance optimization for high-temperature applications.

Hot Corrosion behaviour of Ni-Base and Co-Base superalloys using thermos-gravimetric and electrochemical methods

The present study aims to examine the hot corrosion behavior of Co-based (H-188) and its Ni-counterpart (H-230) with respect to the concentration of Na_2SO_4, NaCl, and $NaVO_3$ with emphasis on understanding the mechanisms of hot corrosion of the aforementioned alloy systems relevant to aero engine application. In order to examine the hot corrosion behavior of Haynes 188 and Haynes 230, materials were exposed to different salt environments (i.e., Bare, Na_2SO_4, Na_2SO_4 + NaCl, Na_2SO_4 + $NaVO_3$, and Na_2SO_4 + NaCl + $NaVO_3$) at 850 ^oC for 5 - 500 hrs. Following exposure, mass loss data was compiled into thermos-gravimetric plots (i.e., mass change versus exposure time) to study corrosion kinetics. Elemental analysis of corrosion products/depositions was carried out employing various characterization techniques such as EPMA-EDS/WDS and XRD. Present work clearly demonstrated that the hot corrosion behavior of Haynes 188 and 230 at 850 ^oC is strongly influenced by the nature and composition of deposited salts. The base substrate showed minimal degradation under pure oxidation. However, the introduction of Na_2SO_4 substantially increased the corrosion rate due to acidic fluxing and sub-surface sulfidation. The addition of NaCl further intensified degradation through the formation of volatile metal chlorides, resulting in porous and loosely adherent oxide scales. Similarly, $NaVO_3$ contributed to accelerated oxide dissolution and vanadate formation, leading to internal damage and weight loss due to volatilization. The most aggressive corrosion was observed with the combined presence of Na_2SO_4, NaCl, and $NaVO_3$, which caused synergistic damage through simultaneous fluxing and chloride volatilization mechanisms. Future research will focus on systematically understanding the oxidation mechanisms and hot corrosion kinetics of Haynes-230 and Haynes-188 alloys at the molten salt-alloy interface. Electrochemical techniques will be employed to characterize interfacial reactions, quantify corrosion rates, and elucidate degradation pathways under high-temperature conditions.

Deposition and characterization of antimony chalcogenide-based light absorbers coatings for photovoltaic applications

Studies demonstrate that increasing the substrate temperature significantly improves crystallinity, morphology, and optoelectronic performance. Sb_2Se_3 films deposited at 300 °C show strong absorption in the 450-900 nm range with an optimal bandgap of ~1.08 eV, making them highly suitable for thin film photovoltaics (PVs). Furthermore, experimental findings are supported by DFT calculations, along with an investigation of other optoelectronic properties. This work offers new insights into the thermal evaporation process for Sb_2Se_3 thin film photo absorbers, advancing the ongoing development of next-generation chalcogenide-based PVs.

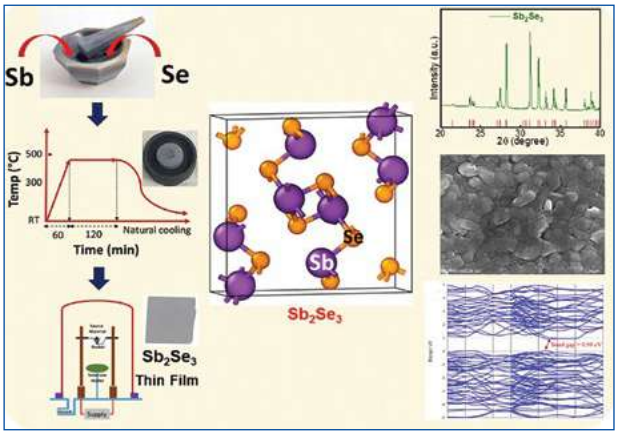


Figure 8: Temperature-dependent thin film growth and properties correlation of Sb_2Se_3 photoabsorber.

To explore Ferrochrome Slag as a Protective Coating Material to Prevent Corrosion of Caster Rolls

This study explores the potential of ferrochrome slag (FCS) as a protective coating for caster rolls'

steel. During the continuous casting process, these rolls operate at temperatures between 450 °C and 670 °C. Their surfaces are sprayed with cooling water, which can lead to oxidation, corrosion, and thermal cracking. Usually, the rolls are overlaid with martensitic stainless steel through a hard-facing process and are coated with WC-Cr-Oxide-based layers to prevent oxidation. However, these protective measures face challenges such as thermal cracking, limited toughness, and high costs. FCS, an industrial waste rich in oxides, offers a cost-effective alternative for coating caster roll surfaces in steel ingot production lines. In this study, FCS coatings containing 13% Cr2O3 and CaO were applied to EN-19 steel using the high-velocity oxy-fuel (HVOF) thermal spray technique. In Figure 10, AMC-X displays the structure, thickness, and elemental composition of the HVOF thermal-sprayed FCS coating. The XRD patterns of both the FCS powder and coating indicate that the dominant phase is the spinal phase of the Mg-Al-Cr-O4 compound.

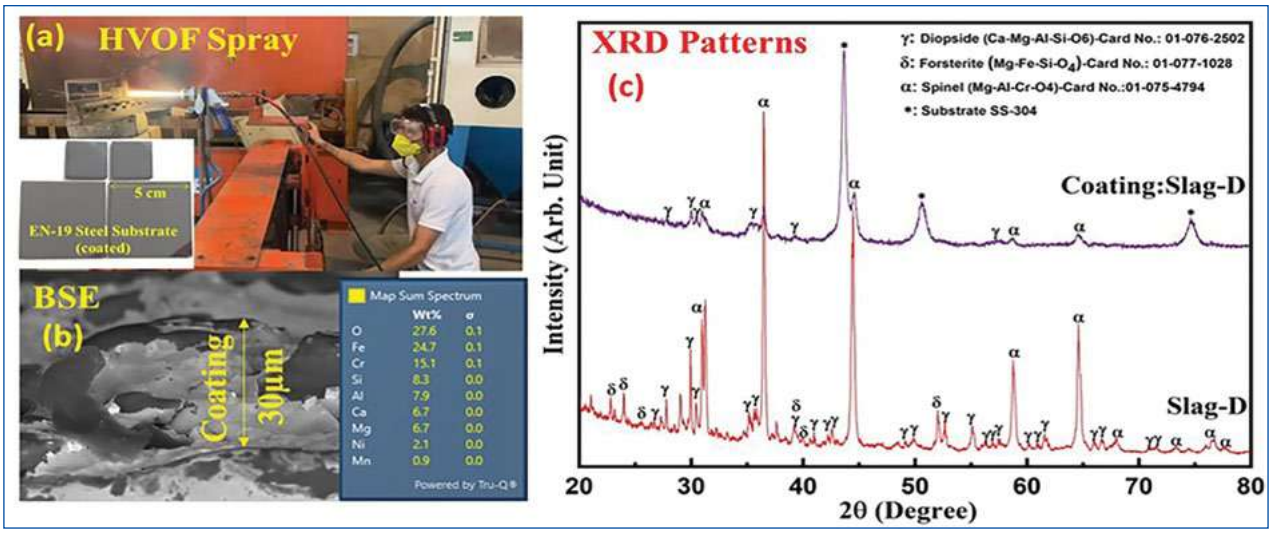


Figure 9: FCS coating: (a)-Thermal spray process, (b) Cross-sectional BSE image with inset of elemental composition
Figure 10: XRD patterns of the FCS powder and the FCS coating.

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 aluminium alloys known for their high fracture toughness; additionally, AA7085 exhibits low quench sensitivity. These alloys are also used in armour and ballistic applications because of their superior resistance to armour-piercing and ballistic impact. However, one of the major challenges associated with age-hardenable aluminium alloys in the 7xxx and 2xxx series is their susceptibility to environmentally assisted cracking under static and dynamic loading in chloride-containing and hydrogen-rich (humid air) environments. The combined effects of environment and cyclic loading significantly affect the structural integrity and service life of components made from these alloys. Notably, even these advanced aluminium alloys show greater susceptibility to hydrogen-assisted environmental cracking in humid air than earlier-generation alloys. The main objectives of the project are to develop modified retrogression and re-ageing (RRA) heat treatment routes for AA7085 (30 mm thickness) and AA2519 (20 mm thickness) alloys to enhance their environmental-assisted cracking resistance and strength in 3.5% NaCl and humid air/hydrogen environments. Aluminium alloy AA7085 (30 mm thick), received from DMRL, Hyderabad, was subjected to conventional RRA heat treatments consisting of solution treatment, pre-ageing, retrogression, and re-ageing (ST + PA + Retrogression + Re-ageing), with variations in treatment time and cooling rate after solution treatment at 495 °C. A modified RRA (MRRA) process was also developed by incorporating a cold-working step into the conventional RRA sequence. The MRRA routes consisted of (ST + cold rolling + retrogression + ageing) and (ST + cold rolling + ageing + retrogression

+ re-ageing). The strengths of conventionally and modified RRA-treated samples were found to be comparable, with hardness values in the range of 175–180 HV, similar to peak-aged conditions (Figure 11). The optimized heat-treated samples were evaluated for intergranular corrosion (IGC) susceptibility according to ASTM G110 by immersion in a NaCl + H_2O_2 solution. The IGC results (Figure 12) indicated that MRRA-treated samples exhibited significantly lower intergranular cracking and pitting compared to conventionally RRA-treated samples. These findings demonstrate that the modified process not only improves corrosion performance but also has the potential to reduce overall heat-treatment time, offering substantial cost benefits.

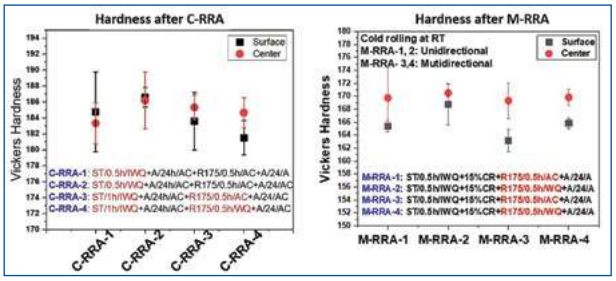


Figure 11: Hardness of AA 7085 alloy after conventional RRA and modified RRA

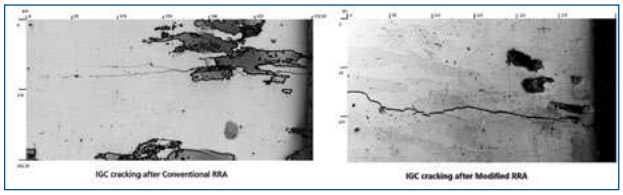


Figure 12: IGC susceptibility of AA7085 after C-RRA and M-RRA treatment

Investigation of Corrosion Behavior of CRS TMT Bars and Characterization of Mechanical Properties

A variety of standard and CRS (Corrosion-Resistant Steel) TMT rebars are manufactured by different industries and are widely available in the open market. However, there is considerable ambiguity regarding the selection and suitability of these rebars for different geographical conditions, particularly when comparing coastal and non-coastal regions. In this context, a comparative study was conducted to evaluate the corrosion performance of six commercially available standard and CRS TMT steel rebars produced by various Indian manufacturers. The corrosion behaviour of all TMT steels was assessed using multiple test methods, including: (a) immersion corrosion tests, (b) salt spray tests, (c) electrochemical corrosion test methods such as potentiodynamic polarization scans, and (d) electrochemical impedance spectroscopy (EIS).

The results from electrochemical and immersion corrosion tests in 3.5% NaCl solution, along with salt spray tests performed as per ASTM B117 in 5% NaCl solution (Figure 13), indicated that CRS-550D-M5 and CRS-550D-M6 steels exhibited superior corrosion resistance compared with the other CRS and standard rebars.

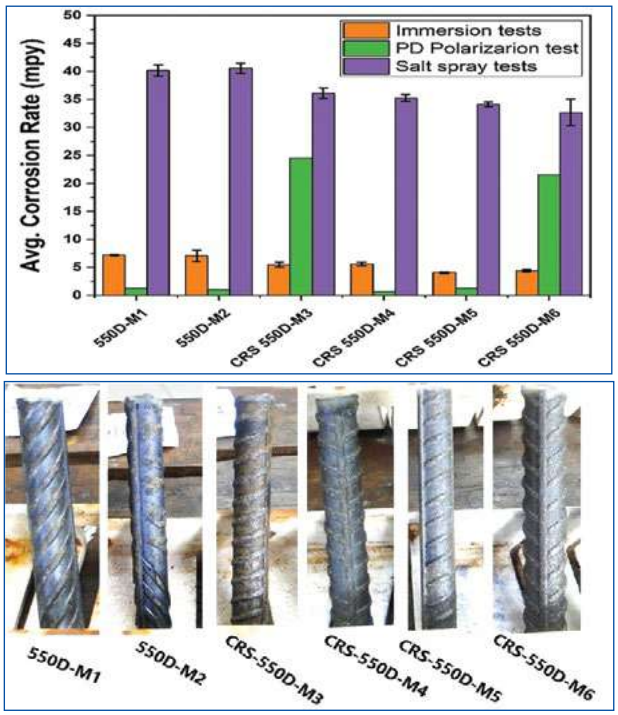


Figure 13: (a) Corrosion rates of various TMT rebars and (b) initial red spot appearance during salt spray test at after 20 minute of exposure.

CRS-550D-M3 and CRS-550D-M4 showed intermediate corrosion resistance. Whereas 550D-M1 and 550D-M2 showed poor corrosion resistance. Furthermore, the appearance of the initial red rust spot was recorded for all steels during the salt spray exposure tests. It was observed that steel grades 550D-M1, 550D-M2, and CRS-550D-M3 developed red rust within 20 minutes of exposure in the salt spray chamber, whereas the other steels required more than an hour for the initial rust spot to appear. Longest time was taken for red rust appearance in case of CRS-550M5 and CRS-550M6.

AI Mission

Intelligent Defect Identification and Classification Technique for Welded Assembly

Welded joints are critical components in many industrial structures, and their integrity directly affects safety and reliability. Failure of these joints arises from welding defects and structural irregularities that inevitably occur during welding. This study introduces a protocol for intelligent weld defect detection, utilising AI-assisted laser lock-in thermography to evaluate the quality of mild steel welded assemblies. This state-of-the-art approach integrates laser thermal excitation, infrared thermography, and advanced AI analysis to identify defects such as cracks, lack of fusion, porosity, and inclusions. Welded assemblies, both with and without defects, were fabricated at CSIR-NML using a robotic MIG welding facility. Initially, weld parameters were optimized to ensure the fabrication of defect-free joints, followed by the deliberate introduction of various defects by varying weld parameters and adding impurities during welding. Weld quality assessment was conducted using lock-in thermography, wherein a periodically modulated laser source in conjunction with an infrared camera was used to detect flaws in welded joints by analysing the propagation of thermal waves. Defects such as porosity, lack of fusion, lack of penetration, or cracks disturb the heat flow and reveal unique phase and amplitude variations in thermal images, differing from those of the surrounding sound material. An image-processing-based GUI was developed to analyse the thermal phase images for defect identification and their size estimation. Calibration curves were established to correlate phase shifts with defect depths, facilitating accurate defect depth estimation. Furthermore, an ANN model was developed to classify defects based on the thermal signatures and associated weld parameters, thereby streamlining the evaluation process and minimising the need for manual interpretation. Overall, the developed AI-assisted laser lock-in thermography is a modern approach to weld inspection, integrating advanced sensing technology with intelligent data analysis to achieve more accurate, faster, and more reliable defect detection in welded assemblies.

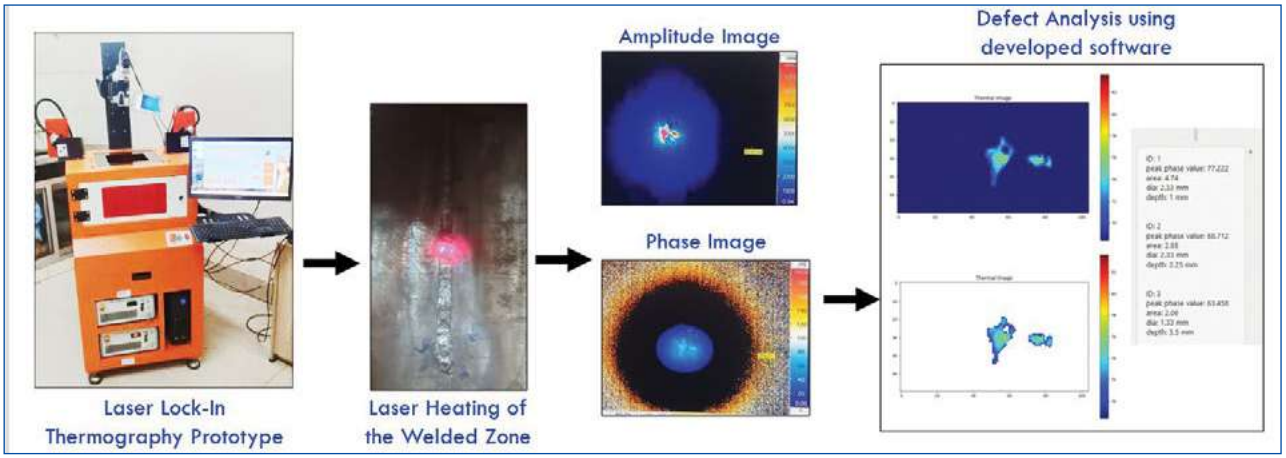


Figure 1: Laser Lock-in Thermography System for Subsurface Defect Detection in Welds

Process optimisation and predictive model development using AI for Steels

The project aims for development of an AI-assisted characterization of raw material (iron ore and coal) using Infrared, multi-spectral and petrography imaging; Design of High Strength High Toughness Steel for Wear Resistance Applications using a

multi-objective AI model; and Prediction of failure a-priori of steel components used in power plants. Currently the Coal petrography data collection and labeling have been completed for two batches of coal. A CNN model is developed for the prediction of ash content from petrography images of coal and validation with ground truth. Two more batches of coal samples have been collected for petrography data generation. Labelling of data for two more batches has been initiated. The proposed AI model for raw material coal can be used in the industry for automated ash analysis. The final deliverable of the project is an AI-assisted automated composition analysis tool for raw materials of the steel industry, such as iron ore and coal; AI-based prediction tool for High Strength High Toughness Steel for Wear Resistance Applications ; and An AI-based model for failure prediction of steel components used in power plants.

Establishment of a Centre of Innovation & a Manufacturing Eco-System for Sensors (CIMES) in Industrial IoT

The objective of the project is to explore commercialization of sensors 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 is being carried out with the support from West Bengal Electronics Industry Development Corporation Limited (WBEIDCL), a nodal agency of Department of Information Technology & Electronics, Government of West Bengal and other industry partners and stakeholders. The centre is being 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 vision of the proposed centre would be to

i. Enable a start-up and innovation ecosystem in the country as a solution provider in the sensor and instrumentation for industrial IOT,
ii. Create a knowledge and resource centre for Indian industries and
iii. Place India in the global market of sensors and instrumentation in the domain of geotechnical and structural health monitoring and industrial process control instrumentation.

CIMES is a consortium comprising five CSIR laboratories (CSIR-CGCRI, NML, SERC, CRRI, CIMFR), with CSIR-CGCRI serving as the nodal laboratory. The process for establishing the Centre is currently underway. Several technologies like *'Zincometer: A device for Coating Weight measurement in Galvanised wire lines', 'FOBOP technology for billet caster'* developed under the consortium have already been transferred to MSME companies for commercialization, reflecting the translational potential of the research and its relevance to industrial applications.



Technology transfer : ZincoMeter : A device for Coating Weight measurement in Galvanised wire lines.



Technology transfer : FOBOP technology for billet caster

Coal Characterization

The Coal Characterisation Laboratory at CSIR–National Metallurgical Laboratory (CSIR-NML) is a well-established facility dedicated to comprehensive chemical and thermal characterization of coal and coke, supporting both industrial requirements and strategic research initiatives. The laboratory plays a critical role in generating reliable, high-quality analytical data for coal quality assessment, beneficiation planning, grading, and efficient utilization of coal resources.

Through characterization techniques, which are fundamental processes for the energy sector, we provide the necessary scientific data to support mine planning, coal beneficiation, and the efficient utilization of coal resources.

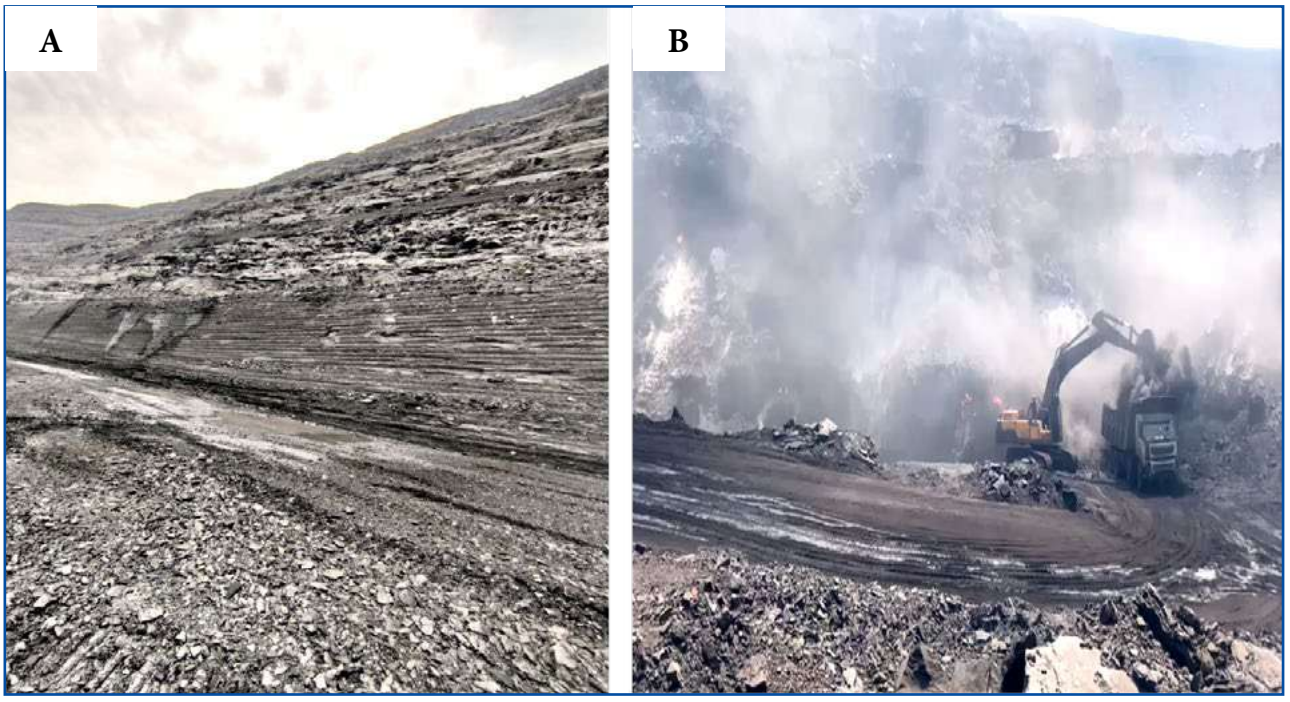


Figure 1. The photographs show (a) Dangerous extraction of coal amidst blazing fissures and toxic fumes. (b) Kharkharee Block, Jharia Coalfield, Dhanbad

Major Activities:-

The lab is equipped with advanced analytical instruments including Thermogravimetric Analyzer (TGA) for proximate analysis, Bomb Calorimeter for gross calorific value (GCV) determination, CHNS Analyzer for ultimate analysis, Ash Fusion Temperature (AFT) Analyzer for ash behavior studies, and state-of-the-art elemental analysis systems such as XRF, ICP-OES, and ICP-MS for detailed ash chemistry and trace element analysis. These capabilities enable both routine and advanced characterization, including band-by-band and seam-wise coal evaluation.

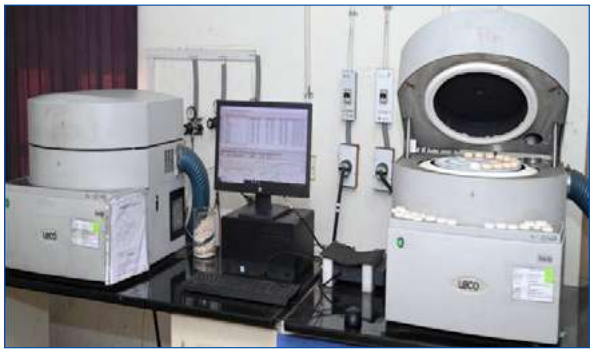
The laboratory operates in strict compliance with NABL accreditation requirements (ISO/IEC 17025), adhering to validated IS/ASTM standard methods, robust quality assurance protocols, and regular participation in proficiency testing and inter-laboratory comparisons. This ensures accuracy, traceability, and international acceptance of analytical results.



Bomb Calorimeter



Inductively Coupled Plasma Mass Spectrometer (ICP-MS)



Proximate Analyzer for Coal (TGA-701)



Swelling Index Apparatus



C H N Analyzer for Coal



Wavelength Dispersive X-ray Fluorescence Spectrometer (WD-XRF)

Figure 2. Some major analytical instruments in the Coal Characterization Laboratory

The objective is to establish comprehensive analytical databases that enable long-term resource management and evidence-based decision-making for mine operators and stakeholders.

- Collection of band-by-band & overall coal samples from Sarishatali Block, Raniganj Coal Field; Dholkata Garia Block, Birbhum Coalfield; Shunuri Block, Raniganj Coalfield; and Lalganj Block, Raniganj Coalfield mines.
- Preparation and homogenization of samples as per IS/ASTM standards.
- Laboratory analysis including:
- Compilation of a band-wise analytical database.
- Statistical evaluation and interpretation of quality variation across coal seams.

Table 1. Preliminary statistical analysis shows significant diversity in ash content and calorific value between coal bands, indicating the potential benefits of selective mining and beneficiation planning.

Parameter	Avg.Value (Sample Seams)	Range	Std. Dev.	Method
Moisture (%)	8.5	5-12	2.1	Oven drying @ 40°C
Ash (%)	32.4	25-40	4.3	Wet chemical/proximate
GCV (kcal/kg)	4200	3800-4800	250	Bomb calorimeter
Fixed Carbon (%)	45.2	40-50	3.2	ASTM standards
HGI	55	50-65	4.5	Grindability test

Significance and Key Achievements:

- Providing scientific data on quality fluctuations within coal seams is critical for optimizing coal beneficiation strategies, improving washability planning, and supporting mine-wise coal quality management.
- The research enhances blending efficiency and reduces quality-related losses during utilization, leading to improved industrial productivity and energy efficiency.
- A major achievement includes the development of empirical correlations to predict Gross Calorific Value (GCV) from ash and moisture levels, which is vital for power plant operations and coal marketing.
- The projects have established validated methods for trace element analysis (including arsenic, selenium, and mercury) using advanced instrumentation such as AAS, XRF, and INAA.
- By establishing standardized sampling and analytical protocols, the work provides a reliable database that supports economic evaluations and long-term resource management for stakeholders like CMPDI and the Indian coal sector.

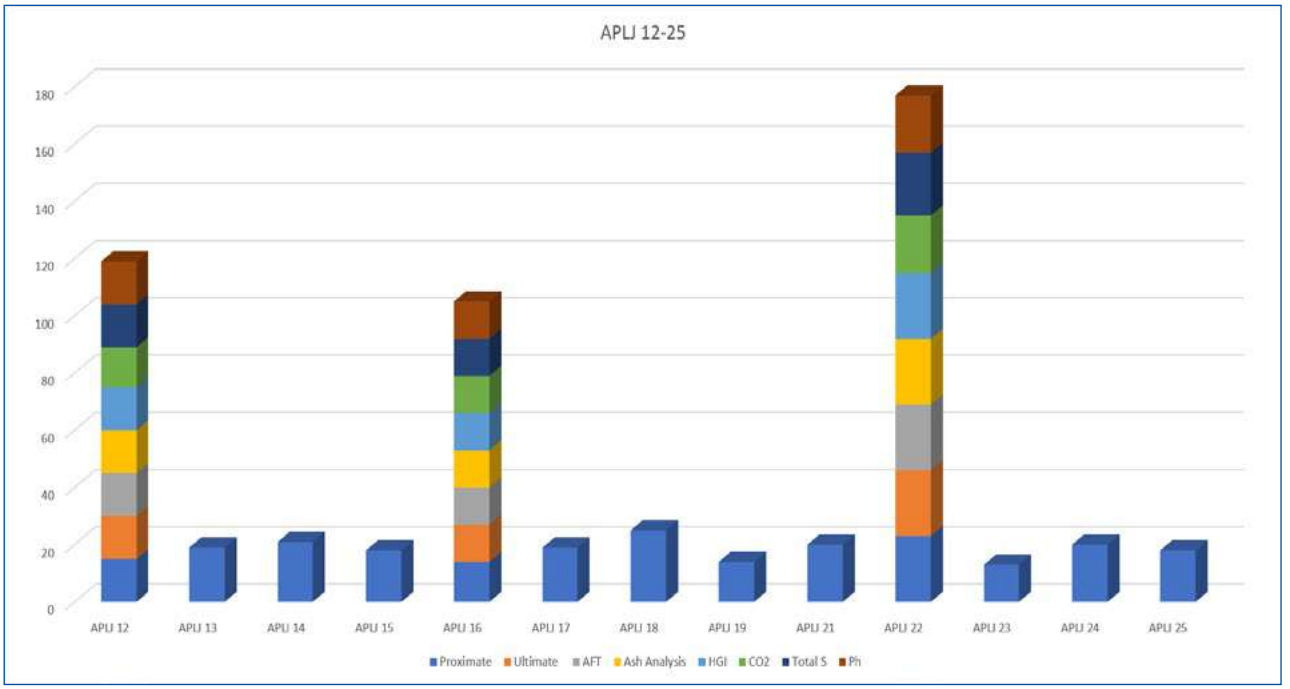


Figure 3: -The graph presents a comparative analysis of various parameters, including proximate, ultimate, AFT, ash analysis, HGI, CO_2, total sulphur, and pH across APLJ samples 12 to 25.

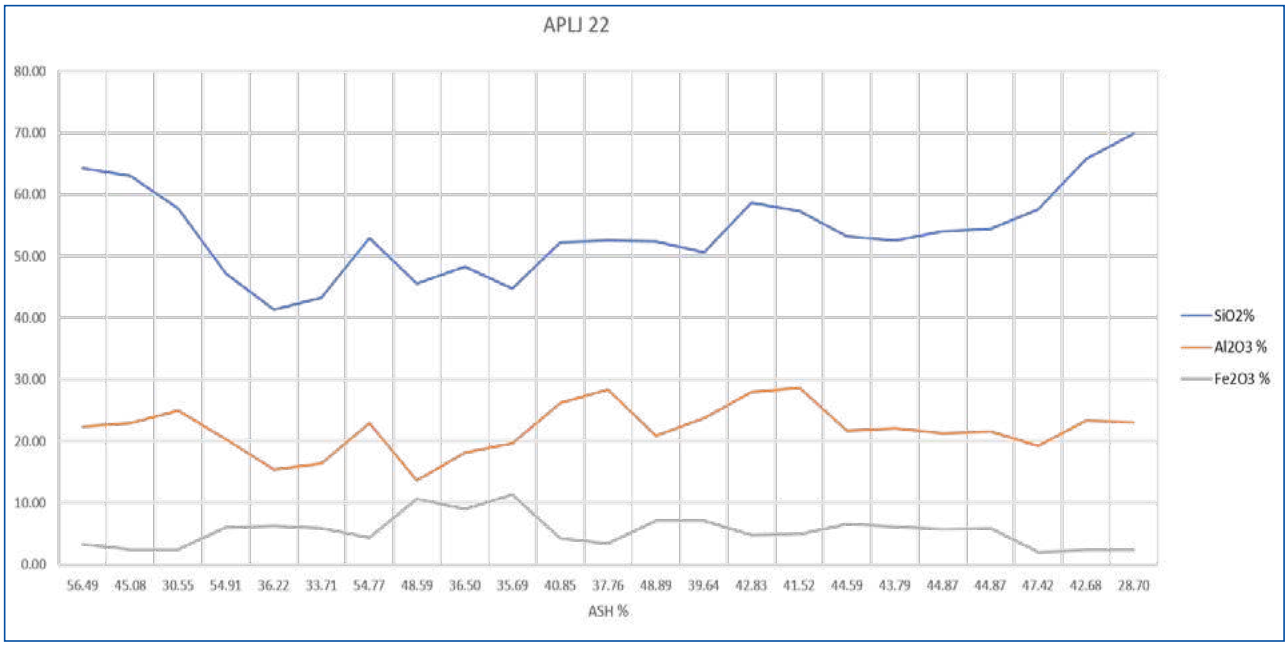


Figure 4:- Based on the chemical analysis of coal ash, the variation of major components—silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3)—is heavily influenced by the total ash yield and the geological origin of the coal.

Future Plans:

- Advanced statistical modelling of band-wise coal variability
- Development of predictive coal quality models
- Integration of data into mine planning and beneficiation frameworks
- Extension of band-by-band characterization to additional coalfields

Technical Services Rendered

Certified Reference Material (CRM) Services

CRM Unit, AAC Division, CSIR-NML is a pioneer in developing Certified Reference Material (CRM) . This Unit is established to develop, characterize, and supply high-quality reference materials for analytical quality assurance in industrial, environmental, and research laboratories. The unit's primary mandate is to ensure traceability, accuracy, and reliability of measurement results through the production of CRMs that are accredited with ISO 17034:2016and ISO/IEC 17025 standards.

To date, the unit is serving the nation with successfully produced 45nos of certified reference materials covering diverse matrices including metals and alloys, ores & minerals, Allied Material , Solid Fuels ,Gaseous in metals and Spectro Standard namely for Stainless Steel , Aluminum Alloy and Lead Alloy matrices. Each CRM is prepared under controlled conditions with strict adherence to homogeneity and stability protocols.

The produced CRMs serve critical roles in method validation, instrument calibration, proficiency testing, and internal quality control across sectors such as Industries, Analytical laboratory, Research Institution & Gov. laboratory like Custom & BIS in the field of Metal & Alloy, Mining, Coal and Environmental etc. By providing matrix-matched and element-specific CRMs, the unit supports laboratories in achieving accurate and internationally comparable analytical data.

CRM Preparation Year	Sl.No.	CRM No.	CRM Name	Date of Issue	Status
2025-2026	1	233.2A	H.C. Fe-MANGANESE (Powder form)	08.05.25	New
	2	215A	1 % CARBON STEEL(Turning Form)	08.05.25	New
	3	217A	0.4 % CARBON STEEL (Turning Form)	23.02.26	New
	4	153	COAL (Powder form)	21.03.25	New
	5	154	COAL (Powder form)	21.03.25	New
	6	155	COAL (Powder form)	21.03.25	New
	7	311	Aluminum Alloy (Disc Form)	26.11.25	New
	8	313	Antimonial Lead Alloy (Disc Form)	03.12.25	New
	9	312	Pure Lead Alloy (Disc Form)	27.02.26	New
	10	201.8	CAST IRON (Turning form)	09.07.25	Revalidated
	11	207.3	ALLOY CAST IRON (Turning form)	09.07.25	Revalidated
	12	241	BRASS 60:40 (Turning form)	09.07.25	Revalidated
	13	242	BRASS 70:30 (Turning form)	09.07.25	Revalidated
	14	251.1	6% Si-Al ALLOYS (Turning form)	15.07.25	Revalidated
	19	166.3A	MANGANESE ORE (Powder form)	03.11.25	Revalidated
	20	166.4A	MANGANESE ORE (Powder form)	03.11.25	Revalidated



Figure 1: New CRMs Developed

National Accreditation Board for Testing and Calibration Laboratories

NABL

CERTIFICATE OF ACCREDITATION

CRM UNIT, AAC DIVISION, CSIR-NATIONAL METALLURGICAL LABORATORY

has been assessed and accredited in accordance with the standard

ISO 17034: 2016

"General Requirements for the Competence of Reference Material Producers"

for its facilities at

POST OFFICE BURMAMINES, JAMSHEDPUR, EAST SINGHBUM, JHARKHAND, INDIA

in the field of

REFERENCE MATERIAL PRODUCER

Certificate Number: RC-1019

Issue Date: 13/01/2026 Valid Until: 12/01/2030

This certificate remains valid for the Scope of Accreditation as specified in the annexure subject to continued satisfactory compliance to the above standard & the relevant requirements of NABL.
(To see the scope of accreditation of this RM Producer, you may also visit NABL website www.nabl-india.org)

Name of Legal Identity: CSIR-NATIONAL METALLURGICAL LABORATORY

Signed for and on behalf of NABL

Anita Rani
Director

Dr. Ramanand N. Shukla
Chief Executive Officer

CSIR - NML Madras Centre

CSIR–National Metallurgical Laboratory Madras Centre, Chennai, has its roots in NML Foundry Station, which was established in 1965 at the Guindy Industrial Estate, Chennai (Figure 1). The idea of establishing foundry stations across the country was first proposed by Sir Jehangir Ghandy, then Chairman of the Executive Council of National Metallurgical Laboratory. The objective was to provide technical assistance and testing facilities to the foundry industry. Over the years, the station has extended its services in areas such as sand testing for foundries and chemical analysis of both ferrous and non-ferrous metals, etc.

Subsequently, the idea of establishing CSIR Madras Complex, in close proximity to several 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 the economy, and (ii) to promote interaction among scientists from different disciplines, thereby offering a unique opportunity for multidisciplinary research. The NML Foundry Station was relocated to the present campus of CSIR Madras Complex in 1973 and was subsequently renamed as the CSIR-NML Madras Centre. An ore dressing laboratory and a refractory unit were also included in the centre.

In the middle of 1980s, the centre shifted its focus towards ore dressing/mineral processing activities. Over the years, the centre has been instrumental in developing column flotation technology, which is one of the flagship technologies of CSIR-NML, in the field 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 have been designed, fabricated, and field tested at various private and public sector mineral processing plants located across the country. Column flotation technology has attained Technology Readiness Level (TRL-9), demonstrating its readiness for successful deployment at a commercial scale. The unique selling point (USP) of 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 (TMML), Bengaluru, and reagents manufacturer and supplier, M/s Sudarshan Chemical Industries Limited, Pune. The centre has received several prestigious recognitions, including the Altekar Award for the best technology transfer from CSIR–NML, the Technology Award for the most significant CSIR technology from CSIR, and the National Mineral Award from the Ministry of Mines, Government of India.

In 1998, the centre embarked on a major restructuring to meet the evolving demands of industry and stakeholders, and a new metallurgy section was established. A state-of-the-art metallurgy laboratory was set up, equipped with a range of sophisticated instruments, including optical microscopes, a micro-hardness tester, an image analyzer, a stereo microscope, and a range of metallographic sample preparation facilities. New facilities were also added to the chemical analysis laboratory.

With enhanced infrastructure and qualified manpower, the centre expanded its activities to include (i) failure analysis and classification of metallurgical components, and (ii) classification of import/export metallic consignments to meet the requirements of various government agencies, including Customs, the Directorate of Revenue Intelligence, and other statutory bodies of the Government of India. The metallurgical team has provided consultancy services to these agencies across the country, including the offices of the Commissioner of Customs in Chennai, Mumbai, Jaipur, Visakhapatnam, Tuticorin, and Cochin. These activities not only made the centre financially self-sustaining through significant external cash flow (ECF) but also earned widespread appreciation from the agencies for the timely, efficient, and transparent delivery of expert services. To date, the centre continues to play a leading role in column flotation technology and metallurgical failure analysis of industrial components, with several success stories being added each year.

In the previous financial year, the centre executed about nine industry-sponsored projects in the areas of (i) mineral processing and (ii) failure analysis & remaining life assessment of industrial components. It successfully delivered research outcomes to several prestigious organisations, including Rajasthan State Mines and Minerals Limited (RSMML), NLC India Limited, IREL (India) Limited, The Ramco Cements Limited, and RKM Powergen Private Limited. The centre also secured a project funded by the Ministry of Mines for the recovery of graphite from black mass. On 09.10.2025, the centre organized an "Industry Conclave 2025" on "Beneficiation & Extraction of Minerals and Metals - Bridging Research, Resources, and Industry for Sustainable Growth" to commemorate 75 years of CSIR-NML's legacy and leadership in fostering indigenous technologies for a Viksit Bharat. The event saw an active participation of nearly 100 delegates, from relevant & reputed organizations across India (Figures 2 & 3).

During 2025–2026, the centre's efforts, led to significant progress in the beneficiation of secondary phosphate ores and rock phosphate plant tailings through flotation-based process development. Laboratory-scale studies on secondary rock phosphate ore successfully reduced R_2O_3 (Fe_2O_3 and Al_2O_3) impurities to below 2% while substantially upgrading the P_2O_5 grade to around 32%. These results demonstrate the technical feasibility of producing a high-quality phosphate concentrate through optimized reagent schemes and process parameters. The developed flotation process thus enables the production of a marketable phosphate concentrate with improved quality and controlled impurity levels.

The centre also successfully demonstrated the technical feasibility of recovering valuable phosphate, from low-grade rock phosphate beneficiation plant tailings through an integrated laboratory-scale flotation study. Starting with tailings assaying approximately 8% P_2O_5, a significant upgrade to 31% P_2O_5 was achieved, with an overall concentrate recovery of 70% and minimal loss of phosphate values. In addition to phosphate enrichment, MgO levels were substantially reduced from approximately 16% to 8%, thereby improving concentrate quality and its suitability for utilization. This flotation-based process significantly enhances overall resource recovery, while providing a sustainable approach to reprocessing industrial tailings. It contributes to improved resource efficiency, reduced environmental impact, and effective tailings management.

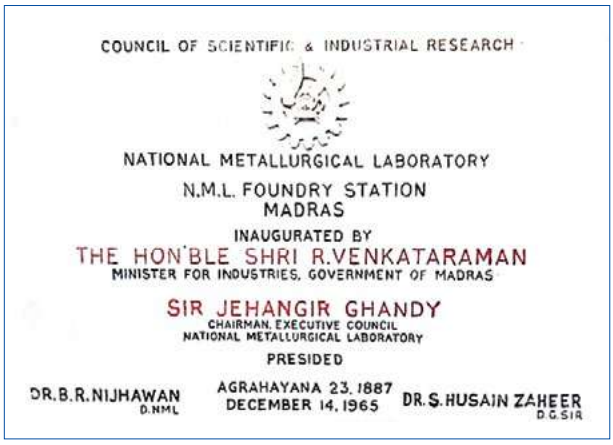


Figure 1: CSIR-NML Foundry Station (Est. 1965)



Figure 2: Industry Conclave at CSIR-NML Chennai Center held on 09.10.25



Figure 3: Address of Mr. Pradip Kumar, MD, M/s Kerala Mines and Minerals Limited, Kerala during Industry Conclave on 09.10.25

In-house Project Support Group (i-PSG)

In-house Project Support Group (i-PSG) at CSIR-National Metallurgical Laboratory strives to promote excellence in in-house research goals and their achievement by enabling the researchers and supporting their aspirations. The group supports research in pre-identified thematic areas, on technology development initiatives, research of scholastic nature leading to master's / 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 of new research in minerals, metals and materials at CSIR-NML. A total of twenty-eight i-PSG-supported projects were in progress during the year 2025-26. Some of the significant outcomes/achievements of these projects are as follows:

- Antimony selenide (Sb_2Se_3)-based photoabsorbers have been synthesized using the solid-state reaction followed by thermal evaporation on glass substrate at different substrate temperatures. The deposited Sb_2Se_3 thin films were systematically investigated and the films deposited at 300 ◦C showed superior properties with an optical bandgap of 1.081 eV. The deposition process and suitability for large-scale production make these Sb_2Se_3 thin film photoabsorbers highly appealing for next-generation photovoltaic technologies aimed at a sustainable future.

- Computational techniques of DFT and RMD were efficiently employed to design and develop corrosion inhibitor for mild steel surfaces. A number of corrosion inhibitors such as anthracene, anthrone, xanthene, xanthone and xanthione were tested for their inhibition efficiency. The combined simulation and experimental results showed xanthione to have the best performance by strongly adsorbing on the iron surface forming stable protective layer and significantly reduces

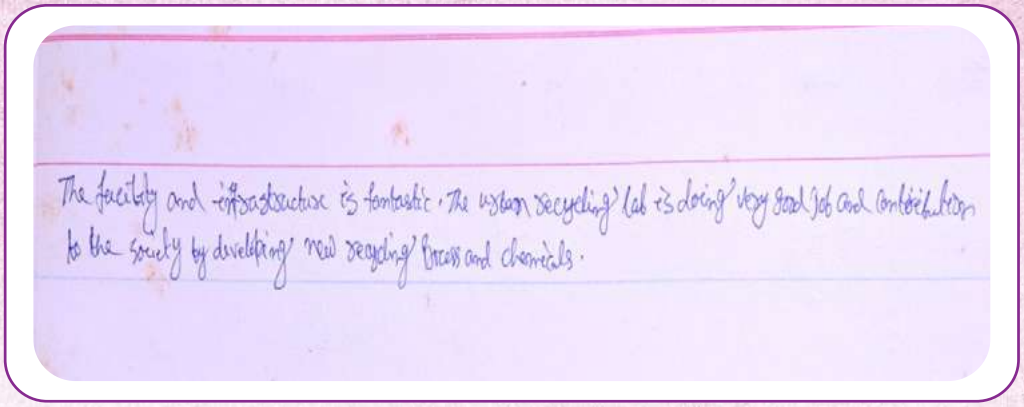
- A process for organic polymeric coating for heritage metallic artifact conservation has been developed. This dip coating process for brass artifacts is efficacious in providing long-term barrier to corrosive environment. A high stability, with minimal degradation, under UV irradiation and condensation cycles indicated its suitability for heritage conservation applications exposed to sunlight and environmental moisture. The development of standardized operating procedures (SOPs) for the onsite practical application is in progress.

- Design, fabrication and installation of an innovative reactor for the effective reduction of iron oxide fines to magnetite powder using H2 / Syn gas (10 kg scale). The improved reactor design with better blending mechanism will help in processing low purity iron oxide fines also.

- "Temperature-dependent thin film growth and properties correlation of antimony selenide photoabsorber for solar cells, Inorganic Chemistry Communications, 186(2), 2026, 116300.

-"An overview on emerging green organic corrosion inhibitors: sustainable solution for oil and gas industrial applications", RSC Advances, 16, 2026,3909-3948.





"The facility and infrastructure are fantastic. The urban recycling labs doing very good job and contribution to the society by developing new recycling process and chemicals."

Seekumar Mishra
Director, IIT(ISM) Dhanbad.
Date:21st May 2025

Impressions

Academy of Scientific & Industrial Research (AcSIR) - NML Activities

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 a PhD. AcSIR is ranked 13th by "Scimago Institutions Rankings", 10th by "Nature Index" and 9th by "NIRF" in the Research Category, among the academic institutions in India.

As one of the academic research centres among 78 affiliated institutes of AcSIR, NML offers Integrated Dual Degree (M.Tech + Ph.D.) Program as well as Ph.D. in Engineering Sciences, Chemical Sciences and Physical Sciences discipline. A total of 19 students have been admitted in the year 2025-26.

In the year 2025-26, the following students of AcSIR-NML were awarded their PhD degree:

Scholar Name	Supervisor/(s)	Thesis Title
Nemai Chandra Gorain	Dr. B. Ravikumar & Dr. A. N. Bhagat	Processing and properties of high martensite volume fraction steels for automotive applications
Santosh Kumar	Dr. K. Mukherjee	Stretch flangeability assessment of hot-rolled low carbon microalloyed steel
P S Manoranjan Jena	Dr. J. K. Sahu	Development of a forgeable nickel-based superalloys for aero engine disk application
Shubhada Kar	Dr. G. K. Mandal & Dr. V. C. Srivastava	An insight into the development of precipitation-hardened Ni- based medium entropy alloys

AcSIR-NML Science Club Events

AcSIR-NML has a Science Club which organises events throughout the year to encourage students to meet and share ideas about science. The following events were organised during the financial year 2025-26.

AcSIR 13th Foundation Day: AcSIR Foundation Day was celebrated on 3rd April, 2025. Guest of Honour, Prof. P.P. Chattopadhyay, Director, NIAMT Hatia Ranchi, honoured the occasion. AcSIR students participated in Oral and Poster Presentation thereafter.



The Orientation Day: The Orientation Day for the new Ph.D. Batch of January 2026 of AcSIR–NML was successfully conducted on 28th January, 2026, at the Committee Room of CSIR-NML organized by AcSIR Science Club. The Programme aimed to welcome the new batch of scholars and familiarise them with the institute, its research vision, academic structure, facilities, and opportunities available during their Ph.D. journey.



National Metallurgist Day 2026: The AcSIR-NML Science Club commemorated National Metallurgist Day 2025 at CSIR- National Metallurgical Laboratory on 18th –19th November 2025. The event commenced with a Quiz Competition on November 18, centred on the theme "Materials Around Us". The highlight of the celebration was an expert technical talk held on November 19, delivered by Dr. Monojit Dutta from Tata Steel on "Addressing the Future Development of Automotive Steels."



National Startup Day: The AcSIR-NML Science Club celebrated National Startup Day at CSIR-National Metallurgical Laboratory by organizing an engaging online quiz competition focused on startup ecosystems and entrepreneurship. The initiative was part of the broader celebration marking 10 years of Startup India.



National Science Day 2026: The AcSIR-NML Science Club celebrated National Science Day 2026 at CSIR-NML on March 6, 2026. The highlight of the programme was an expert talk delivered by Dr. Abhishek Kumar Thakur from Tata Steel on the topic "Material Design and Process Optimization using AI/ML." The session witnessed active participation from students, researchers, and faculty members



International Women's Day 2026: The AcSIR-NML Science Club observed International Women's Day jointly with CSIR-NML with an awareness-oriented session focusing on workplace ethics and safety.

As part of the celebration, a talk was delivered by Mrs. Mamta Singh, High Court of Jharkhand, Ranchi & Advocate, Civil Court, Jamshedpur, on the POSH Act, highlighting the importance of creating a safe, inclusive, and respectful work environment. The session emphasised key provisions of the Act, mechanisms for redressal, and the collective responsibility of individuals and institutions in preventing workplace harassment



R&D
Facilitation/Support

Paris 2024 Olympic Games

France created medal designs in history by incorporating fragments of the Eiffel Tower into the medals. For the bronze medals, leftover materials from the French Mint (Monnaie de Paris) were repurposed.



https://www.seagames2025.org

https://www.olympics.com

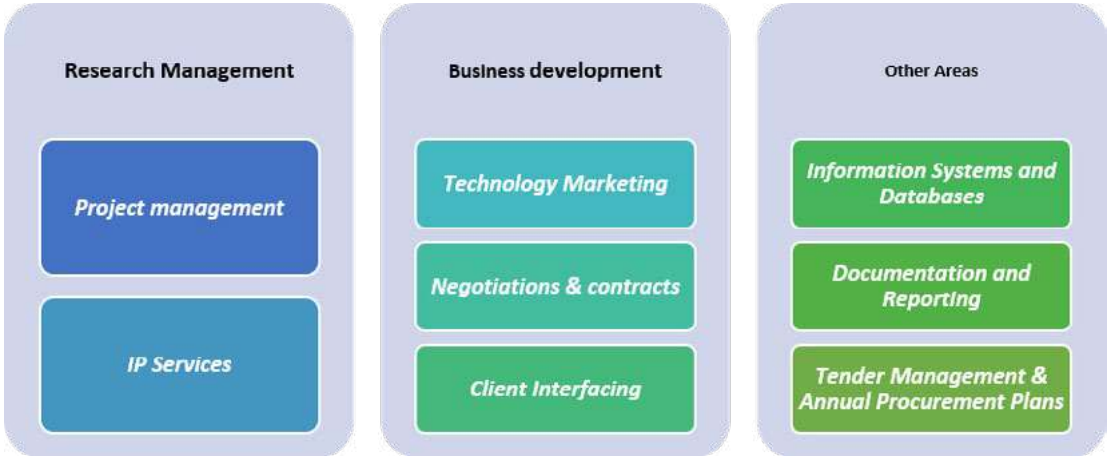
"Overall, it was a very positive experience. We appreciate NML's technology and look forward to more such developments in the future."; "Overall, it was a very positive experience. We appreciate NML's technology and look forward to more such developments in the future."

(SSP 1399)
Mr. Jinesh Shailesh Shah,
M/S. Global Nanotech, Mumbai
Date:10-03-2026

Impressions

Research Planning & Business Development (RPBD)

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*.



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 2025-26, 108 new projects were initiated in varying fields of Minerals, Materials, and Metals. 996 Nos. of Tax Invoices were sent to various customers, and Corresponding E-Invoices were created in the GST Portal by the division. The division also facilitated 164 numbers of Proforma Invoices for the advance payments.

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 2025-26, six patent applications, one copyright and one industrial design are processed for filing.

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 56 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; Vedanta Pvt. Ltd.-Odisha, Sarthi Aerospace & Defence Pvt. Ltd.-Haryana, Eyantram Waste Management Pvt. Ltd.-Andhra Pradesh, IISC-Bengaluru, CSIRO-Australia, Tata Steel Ltd.-Jamshedpur, CIMFR-Dhanbad, Hindustan Zinc Limited-Udaipur, TCS-Mumbai,

Ordanance Factory-Ambajhar, UNDP-New Delhi, NIT-Raipur, and NALCO-Bhuwaneshwar are a few to name. Multiple drafts are in the pipeline, which will be executed in the next fiscal. RPBD facilitated collaboration with a foreign institution named CSIRO, Australia.

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 a good number out of those.

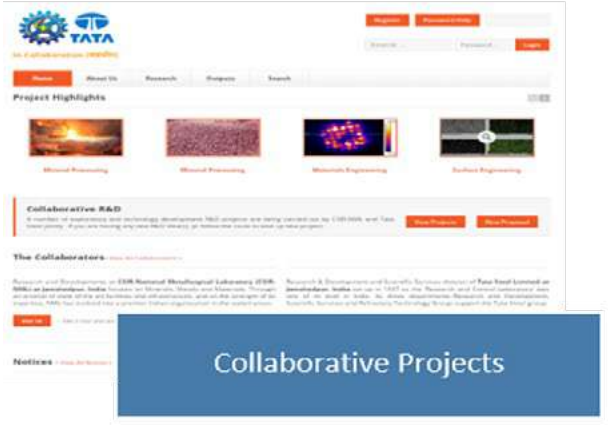
The division also ensures that customer feedbacks are sought to understand the impact of the CSIR-NML technologies and services, which further allows us to fine-tune them.

Information Systems & Databases

The division has developed several in-house web-based information systems and databases for the 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 systems also act as the decision support systems for the management. RPBD is involved in the preparation of reports for various government bodies; these systems assist in the timely submission of various data. Some of the significant documents are the Key Performance Indicator (KPI) Document, the PMO Portal Data, the Research Utilisation 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.









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.



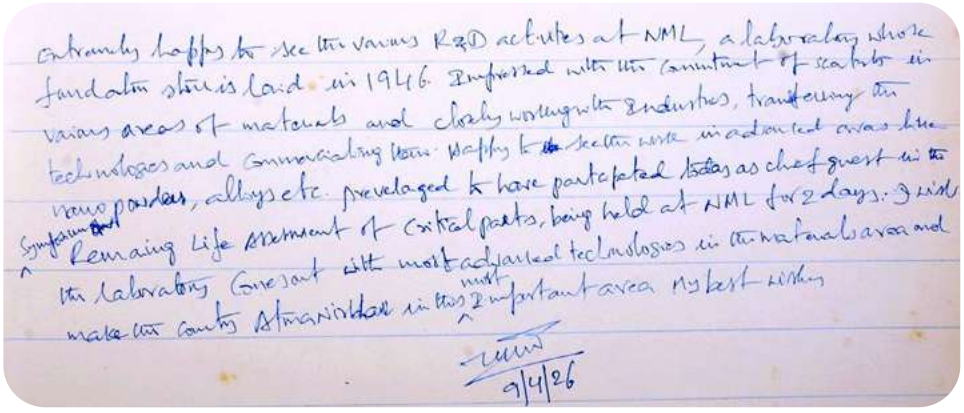
Documentation and Reporting

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 100 customers were provided testing services. The division also coordinates the summer/winter student trainings. In the last fiscal, 106 students pursuing undergraduate and post-graduate courses like B. Tech and M. Tech. from 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.

Impressions


Entirely happy to see the various R&D activities at NML, a laboratory whose foundation stone is laid in 1946. Impressed with the commitment of scientists in various areas of materials and closely working with industries, transferring the technologies and commercialising them. Happy to see the work in adjacent areas like nano powders, alloys etc. prevelaged to have participated as chief guest in the Symposium on Remaining Life Assessment of Critical parts, being held at NML for 2 days. I wish the laboratory Conversant with most advanced technologies in the materials area and make the country Atmanirbhar in this most important area My best wishes
9/4/26

"Entirely happy to see the various R&D activities at NML, a laboratory whose foundation stone is laid in 1946. Impressed with the commitment of scientists in various areas of materials and closely working with industries, transferring the technologies and commercialising them. Happy to see the work in adjacent areas like nano powder, alloys etc. Privileged to have participated as the chief guest in the symposium on Remaining Life Assessment of Critical Metals, being held at NML for 2 days. I wish the laboratory to be conversant with the most advanced technologies in the materials area and make the country Atmanirbhar in this most important area. My best wishes."

Dr. G. Sateesh Reddy,
National Security Advisor Board, Mumbai
Former Chairman, DRDO.
Date:09-04-2026

Information Management & Dissemination Centre (IMDC)

The Information Management and Dissemination Centre (IMDC) at CSIR–National Metallurgical Laboratory plays a crucial role in the collection, organization, preservation, and dissemination of scientific information and knowledge resources. The centre serves as an important support unit for research, academic activities, and outreach programs of the laboratory. Apart from its information management role, IMDC also contributes to various outreach and training programs such as Jigyasa Program and Skill Development initiatives, which help in spreading scientific knowledge and developing technical skills among students and trainees.

CSIR–Jigyasa 2.0 Program

The Council of Scientific and Industrial Research (CSIR) launched the CSIR–Jigyasa 2.0 Program: Virtual Lab Integration to inspire school students to learn science in an easy, joyful, and engaging way. Under this initiative, CSIR-NML promotes scientist–teacher–student interaction and develops innovative educational resources through Virtual Laboratory (VL) platforms using digital technologies, focusing on materials, minerals, and metals. The program targets students of Classes VIII–XII, especially from government-funded rural schools. During FY 2025–2026, CSIR-NML connected 26 schools around Jamshedpur and organized multiple outreach programs. Activities conducted under Jigyasa include:

- 17 'One-day NML visit' programs involving 1497 students and 76 teachers
- 'One Day as a Scientist' programs for 451 students and 12 teachers
- 5 'Popular Lecture Series' attended by 524 students and 21 teachers
- 1 'Anveshana' Phase-II programs for 59 students and 8 teachers
- 2 programs under the India International Science Festival (IISF) 2025 involving 90 students and 4 teachers
- 1 special visit program on Janjatiya Gaurav Varsh 2025 benefiting 272 students and 14 teachers.

CSIR-NML also developed three "Do-It-Yourself (DIY)" science kits:

- Frequency Modulation Receiver
- Temperature Measurement with Bar Graph
- Electromagnetic Field Detector

CSIR–Integrated Skill Initiative Phase-III

Under CSIR–Integrated Skill Initiative Phase-III, CSIR laboratories conduct skill development and training program across various sectors aligned with Skill India objectives.

The program aims to develop a skilled workforce at multiple levels, providing training opportunities to school dropouts, farmers, ITI diploma holders, graduates, postgraduates, B.Tech and M.Tech students, as well as industry professionals, with emphasis on upskilling and reskilling.

During FY 2025–2026, CSIR–NML conducted 11 training programs, benefiting 239 participants.

CSIR-NML also organized Societal Training Programs (STP) for college students and community members, which included hands-on training on:

- Water splitting for green hydrogen generation
- Assistant Manual Metal Arc Welding / Shielded Metal Arc Welding
- Ultrasonic and electromagnetic Non-Destructive Test techniques

In addition, exposure visits to research facilities were organized for undergraduate and postgraduate students to provide practical insights into scientific research and laboratory infrastructure.

CSIR-NML is also working towards aligning its training programs with the guidelines of the National Skill Development Corporation (NSDC) to ensure standardized and industry-relevant skill development.



Impressions

Impressions

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

(SSP 1362)
SooraJ. S, Researcher,
R&D TATA STEEL
Date: 06-03-2025

Information Communications & Technology Unit (ICTU)

During 2025–2026, the ICT Unit (ICTU) continued to strengthen its role as the digital backbone of CSIR-NML, providing secure, resilient, and future-ready IT infrastructure that is essential for research excellence, operational efficiency, and institutional transparency.

- Ensured high-speed, secure network connectivity across all campuses through proactive monitoring, preventive maintenance, and rapid fault resolution, supporting uninterrupted data transfer, manuscript exchange, and global collaboration.
- Maintained servers, storage systems, and computational resources to ensure high availability, optimized performance, and secure handling of critical research and administrative data.
- Executed structured maintenance of lab-wide IT assets, successfully resolving over 900 service requests/jobs initiated by system users, minimizing downtime, and maximizing IT resource utilization.
- Planning, estimation, and installation of IT facilities in renovated areas, ensuring immediate operational readiness for research and administrative functions.
- Development and maintenance of in-house web applications to streamline workflows, improve data accuracy, and accelerate decision-making processes across the institute.
- Provided IT support for HR activities, including interviews, assessments, Departmental Promotion Committees (DPCs), and attendance management via Turnstile and Aadhaar Enabled Biometric Attendance System (AEBAS), ensuring transparent and compliant processes.
- Enabled high-quality video conferencing for multi-location project reviews, national and international collaborations, and virtual team meetings, establishing it as a central pillar of institutional research and administration.
- Supported seminars, workshops, and conferences while managing Large Format Display (LFD) content to disseminate achievements, announcements, and event information in real time, enhancing internal communication and institutional visibility.
- Maintained CCTV surveillance, identity verification, and access control systems to strengthen campus security and protect institutional assets.
- Ensured uninterrupted telephone and teleconferencing services across five campuses in Jamshedpur, supporting reliable internal and inter-campus communication.
- ICTU executed the roles of Central Public Information Officer (CPIO) and Link Officer–CPIO, efficiently processing RTI applications, coordinating with divisions to verify information, maintaining proper records, and assisting appellate authorities, thereby reinforcing transparency, accountability, and statutory compliance.

ICTU remains an enabler of CSIR-NML's R&D ecosystem through IT support & services, providing robust infrastructure, rapid service resolution, digital governance, and global collaboration support to ensure uninterrupted operations, secure data management, and enhanced institutional efficiency, driving scientific excellence and digital transformation.

Activities planned for 2026-2027 :

Access & upgrade network and server systems as per requirement to provide more secure and uninterrupted connectivity and to support growing computational and research needs.

- Procurement & Continuation of lab-wide IT asset maintenance, anticipating an increased number of service requests from users due to expanding IT usage, while strengthening preventive maintenance and response efficiency to ensure smooth operations.
- Expand IT facilities in renovated spaces to ensure operational readiness and support advanced research and administrative requirements.
- Develop and enhance in-house applications to improve digital governance, workflow automation, and data management.
- Access & optimise central video conferencing facilities as per requirement to support larger hybrid meetings, project reviews, and international collaborations, ensuring seamless virtual engagement.
- Streamline LFD content management for the timely dissemination of institutional achievements, announcements, and event information, enhancing visibility and communication.
- Technical support to the security department to strengthen security and surveillance systems to enhance campus safety, access control, and protection of institutional assets as per.
- Upgrade telecommunication services to ensure reliable telephone and inter-campus communication across all campuses.
- Introduce employee cyber awareness programs to promote safe digital practices and strengthen the information security culture across the organisation.
- Continue to execute roles of Central Public Information Officer (CPIO) and Link Officer–CPIO.
- Provide employee ID card printing services based on verified data by the Administration.
- Manage biometric attendance services, including employee fingerprint registration and ongoing technical support.

Engineering

The Engineering Division caters to and coordinates the engineering needs, both R&D and infrastructural, of the laboratory, Large Scale Testing Facilities & Residential Complexes. Most of the needs are non-repetitive in nature, though some are of a routine type. The division has two groups called Works Services and Maintenance (WSM) group and Project Planning and Engineering (PPE) Group. WSM groups 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.

Maintenance and upkeep of equipment:

The division has limited manpower but is actively involved in the in-house maintenance to support the high-value equipment 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 development training activities in the areas 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-

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.

Works Services and Maintenance Group:

This group has diverse responsibilities 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, refrigeration & air conditioning, lifts, water supply etc. The work accomplished by the group can be categorized into 3 major categories, namely new infrastructure, renovation jobs and routine maintenance jobs.

The CSIR NML Housing Complex, Agrico is a well-maintained scientific residential complex located at Agrico, Jamshedpur, known for its green environment and clean ambience. The twelve-storied MS-II Building has undergone special repairs, including strengthening of beams and balconies, followed by premium acrylic external painting. The completed work is shown in Figures 1(a) & (b).



Figure 1 (a) & (b): Special repair of the twelve-storied MS-II Building under construction & after finishing in CSIR-NML housing complex, Agrico

The new Type-IV Building has been maintained through periodic maintenance and external repair works. The related photographs are provided in



Figure 2(a) & (b): Periodic maintenance of the new Type-IV Building under construction & after finishing in CSIR-NML housing complex, Agrico

Special construction works have been executed including the construction of a new bituminous road, establishment of a new security-cum-surveillance room, upkeep of pathways, beautification works, and special repairs and renovation of the Scientists Apartments and the Executive Centre. The photographs of these works are shown in Figures 3(a) & (b).



Figure 3(a) & (b): Bituminous road under construction in CSIR-NML housing complex, Agrico



Figure 3(c)& (d): New security cum surveillance room under construction in CSIR-NML housing complex, Agrico



Figure 3(f) & (g): Establishment of pathways and kerb stones in CSIR-NML housing complex, Agrico

In addition, a new Entrance gate of the complex has been constructed with an architectural design, enhancing the safety and aesthetic appearance of the campus. The photographs are shown in Figures 4(a) & (b).



Figure 4(a) & (b): Construction of new modified gate under construction & after finishing in CSIR-NML housing complex, Agrico

The Functionaries

NHAI Reused 63 Million Tonnes of Waste for Roads

In FY 2023-24, National Highway Authority of India utilized over 631 lakh metric tonnes of recycled and reused materials, including fly ash, plastic waste, steels slag, silica fume, geo composite, geo synthetic, recycle asphalt pavement, rubberised bitumen, recycled glass aggregate, bio-cement, and bio-bitumen, in National Highway construction



https://nhai.gov.in

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

(SSP 1376)
Sahil Aggarwal,
Advanced Metals Inc., Rajasthan
Date: 203-01-2025

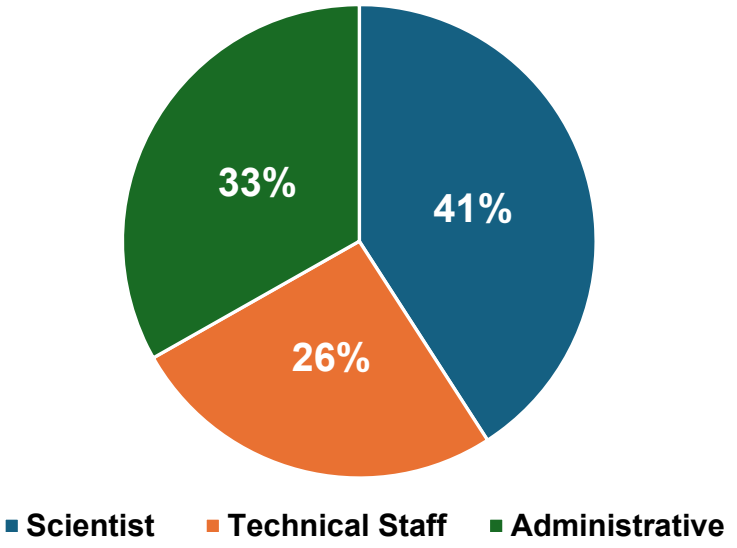
Impressions

Human Resource

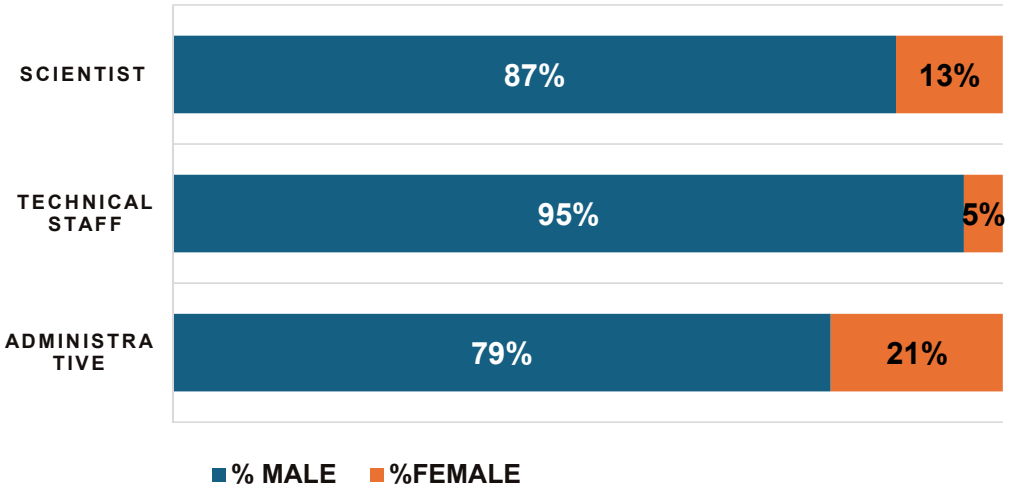
GENDER WISE PERCENTAGE DISTRIBUTION OF STAFF



DISTRIBUTION OF STAFF

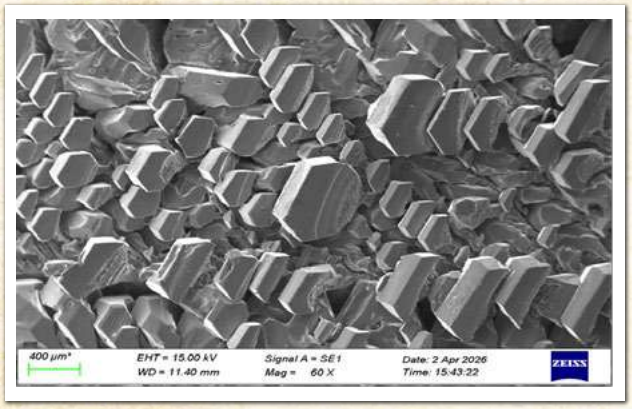


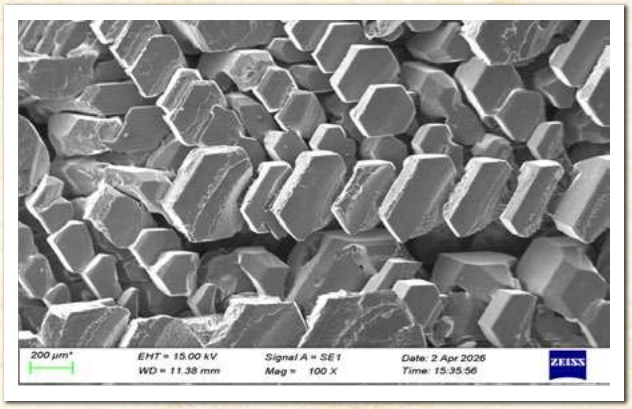
CADRE-WISE GENDER DISTRIBUTION OF STAFF

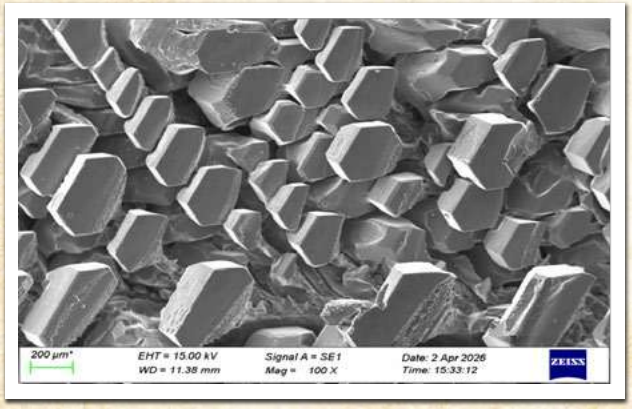


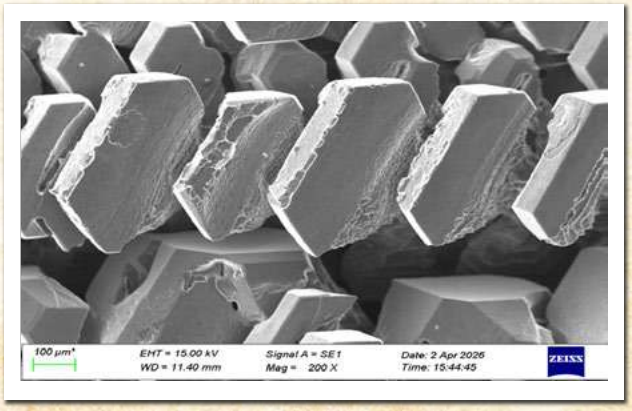
Magnesium Dendrites













Staff News

Superannuation

We wish them a healthy and prosperous life ahead



Shri S. Paswan
Bearer
30th April 2025



Shri T K Minz
Senior Technician(2)
30th April 2025



Dr. Sanjay Prasad
Principal Scientist
30th June 2025



Mrs. J. lakshmi
Multi Tasking Staff
31st August 2025



Mrs. Madhabi Jagdala
Multi Tasking Staff
30th September 2025



Dr. K.L. Sahoo
Chief Scientist
31st October 2025



Shri B.K. Routray
Lab Assistant
31st November 2025



Md. Nayamuddin Ansari
Assistant Section Officer (G)
31st December 2025



Dr. Purushottam Kumar
Senior Hindi Officer (SG)
31st December 2025



Dr. A K Pramanick
Senior Principal Scientist
31st December 2026



Dr.(Mrs.) Sanchita Chaktavarty
Chief Scientist
31th January 2026



Mrs. Rajkumari Devi
MTS
31st March 2026



Smt. Devendra Kaur
MTS
31st March 2026

Staff Transferred from CSIR-NML

We wish a great career ahead!!



Mr. Ravi Ranjan Kumar
Senior Secretariat Assistant (G)
CSIR-NEIST, Jorhat
26th December 2025



Ms. Sheela Kumari
Senior Secretariat Assistant (S&P)
CSIR-CIMFR, Dhanbad
26th December 2025



Mr. Rajeev Ranjan
Senior Secretariat Assistant (G)
CSIR-CSIO, Chandigarh
29th December 2025



Mr. Dhananjay Chaudhary
Senior Secretariat Assistant (G)
CSIR-HQR., New Delhi
29th December 2025



Mr. Piyush Ranjan
Senior Secretariat Assistant (S&P)
CSIR-NPL, New Delhi
29th December 2025



Mr. Sitaram Murmu
Senior Secretariat Assistant (S&P)
CSIR-HQR., New Delhi
29th December 2025

Staff Transferred to CSIR-NML

Newly Joined Staff: Welcome to the CSIR - NML family



Shri. Raju Kumar
Section Officer (G)
15th April 2025



Ms. Jyoti
Section Officer (F&A)
21st April 2025



Shri. Raj Malhotra
Section Officer (S&P)
09th May 2025



Shri. Sulekh
Assistant Section Officer (G)
01st April 2025



Shri. Santosh Kumar Modi
Security Officer
21th April 2025



Shri. Manoranjan Kr Sinha
Junior Secretariat Assistant
25th July 2025



Shri. Gopal Samajpati
Junior Secretariat Assistant
28th July 2025



Shri. Nadim Parvez
Junior Secretariat Assistant
28th July 2025



Shri. Soumen Nayek
Junior Secretariat Assistant
28th July 2025



Ms. Neeraj
Junior Secretariat Assistant
28th July 2025



Shri. Rahul Kispotta
Junior Secretariat Assistant
28th July 2025



Shri. Sachin Kr Meena
Junior Secretariat Assistant
28th July 2025



Shri. Akash Pandey
Junior Secretariat Assistant
29th July 2025



Shri. R Chattopadhyay
Junior Secretariat Assistant
31st July 2025



Ms. Kajal Kumari
Junior Secretariat Assistant
01st September 2025



Shri. Bhaskar Deo
Junior Secretariat Assistant
08th September 2025



Shri. Himanshu Kumar
Junior Secretariat Assistant
15th September 2025



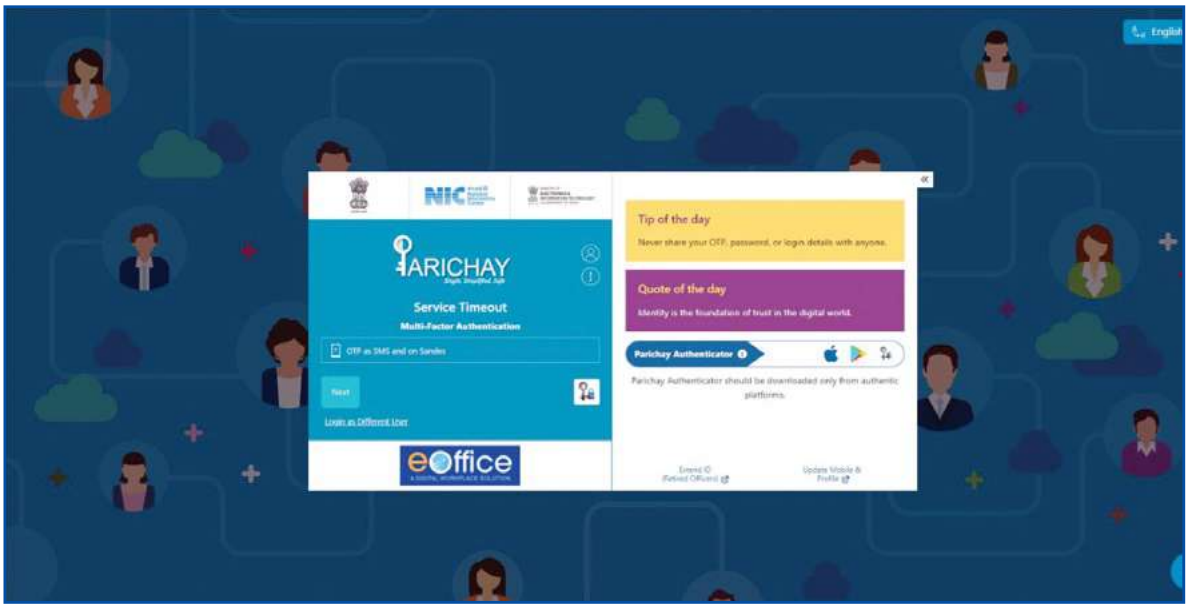
Ms. Nidhi Kumari Keshri
Junior Secretariat Assistant
03th October 2025

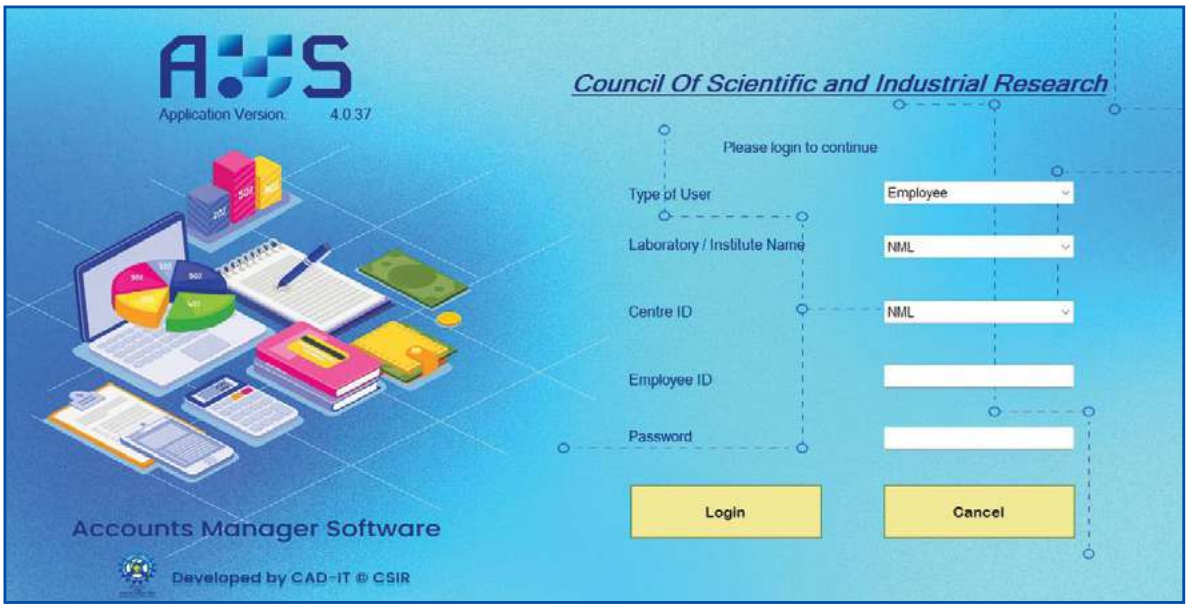
Administration

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.


NIC
PARICHAY
Service Timeout
Multi-Factor Authentication
Next
Login as Different User
eOffice
Tip of the day
Never share your OTP, password, or login details with anyone.
Quote of the day
Identity is the foundation of trust in the digital world.
Parichay Authenticator
Parichay Authenticator should be downloaded only from authentic platforms.


Application Version 4.0.37
Accounts Manager Software
Developed by CAD-IT @ CSIR
Council Of Scientific and Industrial Research
Please login to continue
Type of User
Employee
Laboratory / Institute Name
NML
Centre ID
NML
Employee ID
Password
Login
Cancel

Stores & Purchase

Stores and Purchase Division is a core administrative Division responsible for the end-to-end management of Institute's material resources. The Stores & Purchase at CSIR-NML endeavours to make the materials management process efficient, transparent, time-bound, and user-friendly to its stakeholders and facilitate meeting the vision of CSIR-NML for the development of various technologies and increasing its application. The Division is guided by the mission: Ease of Doing Procurement for Ease of Doing Science. It typically functions through two distinct but closely integrated sections: the Purchase Section and the Stores Section. The Purchase Section focuses on the strategic and transactional acquisition of goods and services. Its primary goal is to obtain the right quality and quantity of materials at the best price and time. The Stores Section acts as the custodian of all materials once they are delivered to the organisation.

Common Functions:

- Identifying and verifying requirements from various internal divisions.
- Researching potential vendors, issuing Requests for Quotation and negotiating prices and contract terms.
- Creating and issuing Purchase Orders and tracking deliveries to ensure they arrive on schedule.
- Adhering to government norms, procurement policies and legal regulations to ensure transparency and efficiency.
- Receiving incoming goods, verifying them against purchase orders, and inspecting for damage or quality issues.
- Systematically storing materials, maintaining accurate digital or physical records and ensuring stock levels do not fall below minimum requirements.
- Distributing supplies to the right departments based on authorised requisitions.
- Overseeing the disposal of obsolete, unserviceable, or scrap items through periodic physical verification and write-off processes.

Target Achieved during financial year 2025-26:

- Successfully handled utilisation of total procurement budget as per the annual procurement plan, which includes major equipment, vehicles and furniture.
- Entered into various contracts for the maintenance of sophisticated equipment.
- Carried out 100% physical verification of assets
- Conducted disposal of obsolete/ unserviceable stores/ scraps with Book Value worth Rs 9.20 Cr. appx., earning a total revenue of Rs. 55.00 Lac
- Prepared Standard Operating Procedures for various processes, developed various formats and defined a timeline for various activities in S&P division to meet our objectives.



SUSTAINABLE HOUSING PROJECTS IN INDIA – THE CANAAN (HOUSE), KERALA, INDIA

Material – Bamboo, Mud, Bricks, Tiles (90% recycled waste)Year – 2019 The world-fame 2-stroyed house used recycled material like bricks, beer bottles, salvaged doors, windows, and tiles from the previous building demolished. This eco-friendly house was constructed in a period of 4 months with only minimal site coverage and no damage to existing vegetation.







https://www.re-thinkingthefuture.com/

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 2025-26

1. Utilized Budget Grant allocated by CSIR- Rs. 8359.154 lakhs + Rs. 7100.728 lakhs (pension)
2. Utilization from Laboratory Reserve-Rs. 590.40 lakh
3. Generation of interest by investment of surplus funds- Rs. 872.991 lakhs
4. Generation of Lab Reserve - Rs. 2290.350 lakhs.
5. Bank reconciliation of the Cash Book completed up to 31st March, 2026.
6. GPF Account as on 31-03-2026 has been reconciled, finalized and closed.
7. During the year new cases of 10 pension and 2 family pension have been completed with issuing of PPO and pension papers on time.
8. CSIR-NML finance successfully switched over to PFMS system for payments out of Govt. grant, where payments are directly made to vendors by RBI under Single Treasury Account system.
9. Several CAG Audit para have been settled.
10. One Section Officer & Junior Secratariat Assistants Four JSAs have joined the F&A Deptt.
11. Provisioning of QR Code for online money receipt in the NML official Account.


Public Financial
Management System
$
34%
12%

Hindi Cell

Implementation of Official Language

CSIR-National Metallurgical Laboratory has an active and well-structured programme for the effective implementation of the Official Language, Rajbhasha Hindi. In addition to carrying out routine official work in Hindi and undertaking translation of technical and administrative documents, the Laboratory proactively organized a series of activities throughout the year. These included publications, training programmes, workshops, lectures, annual competitions, and divisional inspections aimed at strengthening the use of Hindi in scientific and administrative functions.

Publications in Hindi

The Annual Report, CSIR-NML Newsletter, and various brochures were published bilingually (Hindi and English) and circulated to CSIR laboratories and units, as well as to various organizations of the Government of India. Press releases highlighting significant achievements were issued in Hindi and published in leading daily newspapers to promote wider outreach in the official language.

Promotional Activities for Hindi Implementation

- Five divisional inspections were conducted by the Hindi Officer to assess the status of Hindi implementation and to identify areas for further improvement in official work.
- Hindi workshops were organized in the Laboratory for employees across all divisions with the objective of strengthening proficiency in Official Language implementation, including Hindi noting and drafting, preparation of quarterly progress reports, and effective use of Unicode for official correspondence.
- An Incentive Scheme for Working in Hindi was implemented to encourage employees to use Hindi in official correspondence and documentation. Under this scheme, nineteen employees were awarded for their commendable contribution.

Hindi Workshops

Four Table Workshops were organized in different sections of the Laboratory. The key objectives were:

- Addressing issues related to preparation of the Quarterly Hindi Progress Report
- Training in Hindi noting and drafting
- Imparting practical training in Unicode-based Hindi typing

These workshops significantly enhanced the functional proficiency of employees in official Hindi usage.

Hindi Competitions

Hindi Competitions were organized from 1st to 8th September, 2025, for employees of CSIR-NML. The competitions included:

- Discussions on the implementation of Hindi
- Self-composed poetry recitation
- Singing and other literary activities

The programme witnessed enthusiastic and wide participation from employees across divisions.

Activities of TOLIC, Jamshedpur

Town Official Language Implementation Committee (TOLIC), Jamshedpur functions with its Secretariat at CSIR-NML. The Committee comprises 68 member offices from various Central Government establishments located in and around Jamshedpur. The Director, CSIR-NML, serves as the Chairman of the Committee.

Under the aegis of TOLIC, Jamshedpur, a Literary and Cultural Programme was organized on 22nd December, 2025 at CSIR-NML. The event was attended by more than 150 officers from different Central Government offices.

Key highlights of the programme included:

- Prize Distribution Ceremony for winners of various Hindi competitions



Town Official Language Committee (TOLIC) Meeting (23rd April 2025)

Social Responsibilities

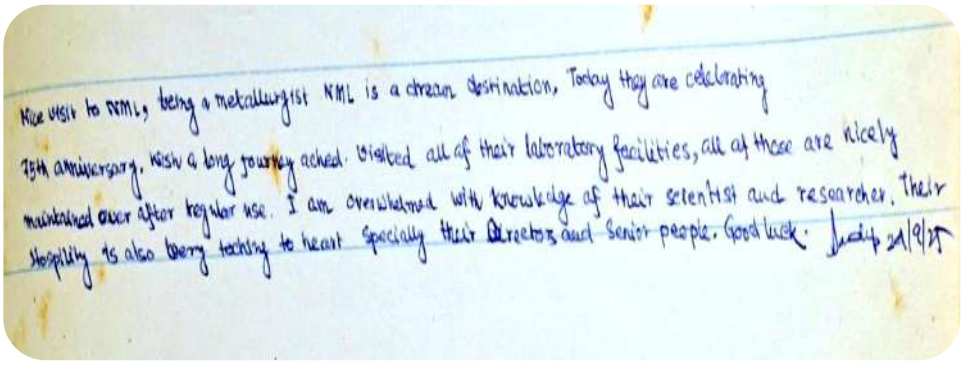
Giving metals A Second Life

Major consumer electronic company uses more than 30% of recycled materials including several metals in their products





Source: https://www.apple.com


Nice visit to NML, being a metallurgist NML is a dream destination, Today they are celebrating 75th anniversary. Wish a long journey ahead. Visited all of their laboratory facilities, all of these are nicely maintained even after regular use. I am overwhelmed with knowledge of their scientist and researcher. Their hospitality is also very touching to heart specially their Director and Senior people. Good luck. 24/9/25

"Nice visit to NML, being a metallurgist, NML is a dream destination, today they are celebrating 75th anniversary. Wish a long journey ahead. Visited all of their laboratory facilities, all of which are nicely maintained even after regular use. I am overwhelmed with the knowledge of their scientist and researchers. Their hospitality is also very touching to the heart, especially their director and senior people. Good luck."

Sandip Kumar Kar
Ispat Bhawan, RDCIS , SAIL.
Date: 24th September 2025

Contributions to Society

Technological Intervention in The Dokra Handicrafts for Increased Productivity, Aesthetic and Quality

Dhokra (or Dokra) art is the oldest known art form in India and is considered to be India's cultural heritage. The name "Dhokra" comes from the Dhokra Damar tribes, the traditional metalworkers of West Bengal, Odisha, Jharkhand and Chhattisgarh. Dhokra artefacts are made using a unique and labour-intensive lost wax process of metal casting technique capable of producing unique and beautiful designs for fine art. These artisans use a traditional home-based brass melting furnace, which is uneconomical, unhealthy and polluting. The CSIR-NML proposes to customise an energy-efficient brass melting furnace for increased productivity, along with reduced product cost. It has initiated anti-tarnishing lacquer development to prevent tarnishing and to educate artisans for modern surface finishing with non-hazardous and economical technologies. The CSIR-NML team has installed and demonstrated 250 kg energy-efficient brass melting furnace at Ramakrishna Mission Ashram, Murshidabad in February 2026. The team has also successfully demonstrated *Ashtadhatu* melting and casting in the developed furnace at Ramakrishna Mission Ashram, Murshidabad. The team has filed one design patent in October 2025 and plans to file two more by May 2026. In the next phase, the team is also scheduling to install a 20-50 kg energy-efficient brass melting furnace at Devrai Art Village, Panchgani, Maharashtra.





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

The Project commenced on the 3rd of July 2023, which is an extension of the awareness programs carried out by MeitY. The major aim of the project is to enable the informal sector to obtain adequate training and state-of-the-art recycling technologies and thereby formalise. Under this initiative, the informal sector carrying out e-waste recycling activities will be upgraded to a formal entity with adequate capacity building and handholding with PCB recycling as well as plastics processing technology indigenously developed by CSIR-NML, C-MET and CIPET-LARPM to enhance the recovery of resources from e-waste, which will help in promoting resource efficiency and circular economy. Subsequently, the formalised clusters will be facilitated with the MSME cluster formation scheme (CFC) to create infrastructure under the State Government and MSE-CDP program of MSME.

The major objectives of the project are mentioned below:

- Creation of 50 master trainers for handling 15000 informal operators engaged in the area of e-waste, identification of the value chain, and to convert them to micro entrepreneurs.
- Dissemination of technology for recycling PCBs & recycling of e-waste, plastics through setting up of recycling common facility in the form of clusters of micro-entrepreneurs in different states of the country.
- Creation of content (manuals) in various scripts, PowerPoint presentations and video recordings and shall be translated to different Indian languages.

Figure 1: Facilities for E-waste Recycling at CSIR-NML

The scrap or e-waste recycling sector has noteworthy potential to contribute to the country's economy and create employment. E-waste recycling will generate a new market for precious, non-ferrous, and recovery of rare earth metals by gaining high revenue due to lower process cost, gain of high-value recycled metals/ materials and techno-economic benefits. In India, CSIR-NML, Jamshedpur is pioneer for the development of various recycling technologies. For the last 20 years, CSIR-NML has been working on the development of a process to recycle various e-wastes to recover valuable metals and materials. The developed processes are fully indigenous, economically feasible, less energy intensive and have received high value of metal and materials. In order to carry out scale-up and pilot scale trials, a centre dedicated for the development of feasible technologies to recover non-ferrous, precious and rare earth metals from secondary resources has been established. The transfer of technologies is a contribution towards the "Swachhata Abhiyan" and "Atmanirbhar Bharat" initiative taken by the Government of India.



CSIR Jigyasa 2.0

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 FY25-26, CSIR-NML organised various programs for the students and teachers and connected 26 schools located around Jamshedpur. Under the Jigyasa program, we have conducted 17 nos. of one day CSIR-NML visits for 1497 students and 76 teachers. We have also conducted one day as a scientist program at NML for 451 students and 12 teachers, 5 nos. of Popular lecture series for 524 students and 21 teachers, 1 nos. of ANVESHANA Phase-II program for 59 students and 8 teachers, 2 no. of IISF' 2025 (I-II) program for 90 students and 4 teachers, 1 no. of visit program for the Occasion of Janjatiya Gourav Varsh 2025 for 272 students and 14 teachers. CSIR-NML has also developed 3 nos. of "DO IT YOURSELF (DIY)" kit, like, Frequency Modulation receiver, Temperature Measurement with bar graph, Electromagnetic field detector. Apart from this, CSIR-NML has developed 1 nos. of virtual content covering videos; the topics covered x-ray diffraction etc. Through this Jigyasa activity, CSIR-NML has impacted 2893 students, out of which 50.24% are girl students. These programs help bridge the gap between textbook learning and practical application by exposing students to hands-on experiments, societal issues such as environmental sustainability, and technology-based problem-solving. Participation in rural and aspirational communities often builds confidence and communication skills, motivating students to pursue further studies in science and technology. Additionally, different outreach activities can increase awareness of social challenges and inspire civic engagement, especially among students from underrepresented or rural communities. Through Jigyasa activities, CSIR reaches young aspirants from an inclusive society by providing a platform to showcase their innovative talent, thereby widening its visibility. Overall, such programs contribute to a stronger scientific temperament and a more informed, empowered youth population for Viksit Bharat.

Skill Development Program

The "CSIR-Integrated Skill Initiative Phase-III" programme was started by the Council of Scientific and Industrial Research (CSIR), in partnership with the Indian government and in support of the "Skill India" mission. Every CSIR laboratory has implemented a variety of skill training initiatives across multiple areas, all falling within the purview of skill India. 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, postgraduates, B. Tech, M. Tech and everyone in between. It also covers the upskilling and reskilling of the 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, ultrasonic and electromagnetic, metal arc welding, and green hydrogen, waste utilization, advanced material, additive manufacturing, analytical chemistry and soft skills development. In FY 25-26, we have conducted a total no. of 11 training program for 239 participants. CSIR-NML has conducted Societal Training programs (STP) for college students and others. The societal training includes Hands-on experiments on water splitting for green hydrogen generation, Assistant Manual Metal Arc Welding Shielded Metal Arc Welding, Lemon grass cultivation and oil extraction, mushroom cultivation, ultrasonic, and Electro-Magnetic. CSIR NML has also organised an Exposure to the research facility for graduate and undergraduate students. CSIR-NML is also focusing on the orientation of the training as per NSDC guidelines.

Jungle Trail Park, Noida-A Waste-to-wonder initiative

It aims to promote sustainability, public art, and environmental education by repurposing scrap metal into lifelike animal sculptures. Materials: Uses 500 tones of iron scrap—fuel tanks, gears, chains, nuts, bolts.









https://jungletrailnoida.com/

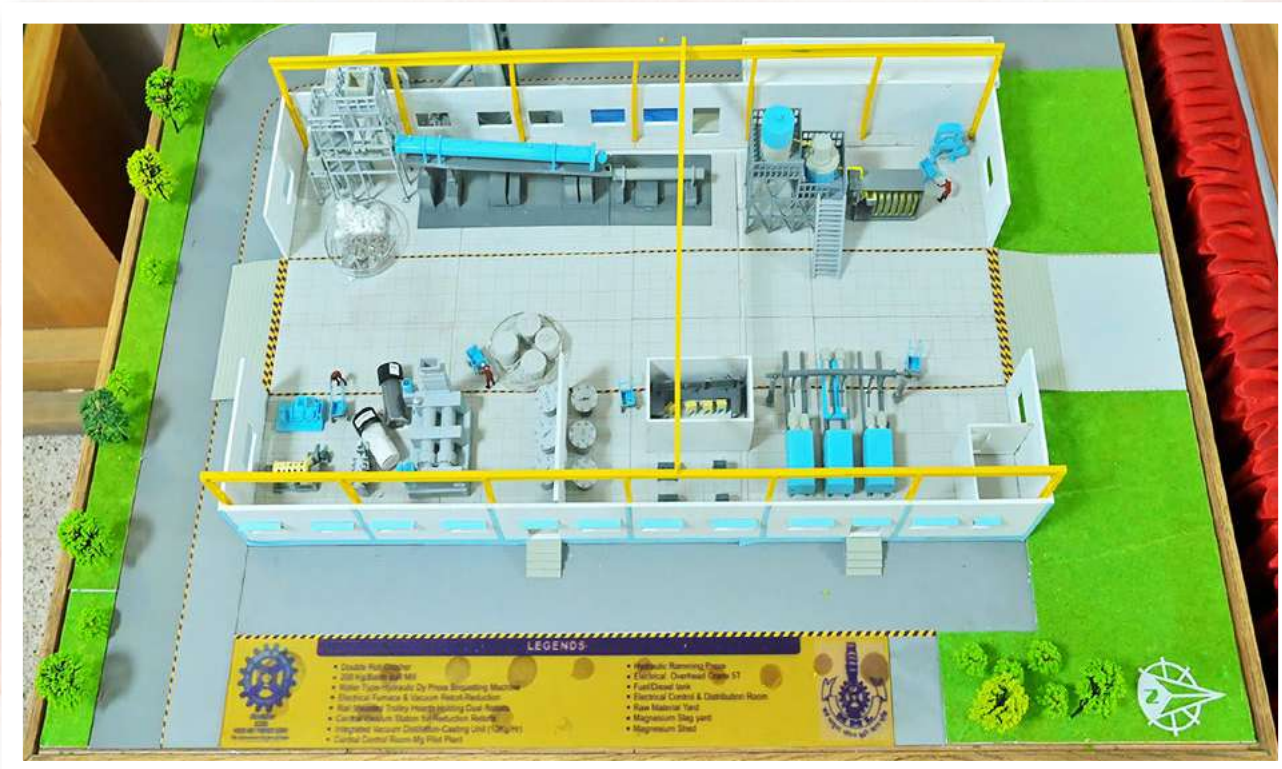
CSIR - NML in News



Model of Urban Ore Recycling Centre



Model of Magnesium Pilot Plant



The Clientele

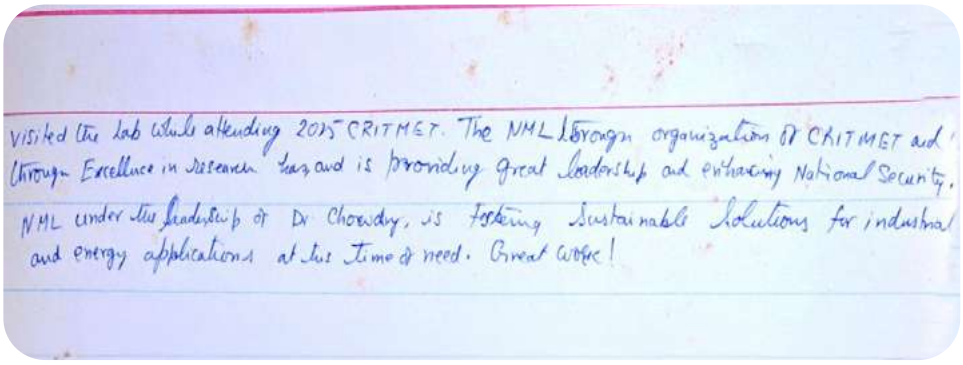
Greener EVs

Growing market for Electric Vehicles means growing demand for rare earth elements.

Several major EV manufacturers are tapping on a hidden resource: 100% recycling of Li-ion Batteries and transforming EVs from Green to Greener option



https://www.tesla.com/support/sustainability-recycling


Visited the lab while attending 2025 CRITMET. The NML Lthrough organization of CRITMET and through Excellence in research has and is providing great leadership and enhancing National Security. NML under the leadership of Dr Chowdry, is fostering Sustainable Solutions for industrial and energy applications at this time of need. Great work!

"Visited the lab while attending 2025 CRITMET . The NML organization through excellence in research, has and is providing great leadership and enhancing national security. NML, under the leadership of Dr. Chowdhary is fast-tracking sustainable solutions for industrial and energy applications at this time of need. Great work!"

Sarma V Pisupati
Prof., Dept. of Energy & Mineral Energy
Director, Centre for Critical Minerals, Penn State University PA USA
Date: 07th November 2025

Our Clientele















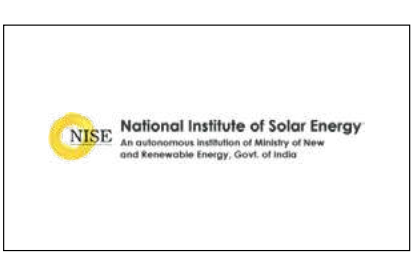

























INDIA
CREATING WEALTH
FOR WELLBEING


Maheshwari


WELSPUN CORP
PIPES AND PLATES


Alleima


Bharat Heavy Electricals Limited


बीसीसीएल
BCCL
भारत कोकिंग कोल लिमिटेड
Bharat Coking Coal Limited


Research Designs & Standards Organisation
Manaknagar Lucknow - 226011


SARTHI
Aerospace and Defence


TerraNova
Eco Management Pvt Ltd.


खान मंत्रालय
MINISTRY OF
MINES
सत्यमेव जयते


THE RAMCO CEMENTS LIMITED
RAMCO


एनटीपीसी
NTPC
50
OF POWERING GROWTH


TATA STEEL
#WeAlsoMakeTomorrow


TUBACEX
INDIA
TUBACEX
GROUP


सत्यमेव जयते
DRDO


GTRE - DRDO


JSW


Cummins

MoUs / Agreements Signed

Collaborative agreement signed with:

- CSIR-CIMFR Dhanbad, and Tata Steel, Jamshedpur

Umbrella/General agreements signed with:

- Bhuwaneshwar Bhushilp Mines and Minerals Pvt. Ltd., Maharashtra
- CSIR-CIMFR Dhanbad Tata Steel
- Electrotherm India Ltd., Ahemdabad
- Gati Shakti University, Research Designs and Standards Organisation (RDSO), Lucknow
- Hindustan Zinc Ltd., Udaipur
- IISC Bengaluru, Foundation for Science Innovation and Development (Formerly SID)
- Inspectorate Griffith India Pvt.Ltd,(Kolkata)
- Jharkhand State Faculty Development Academy (JSFDA), Ranchi
- Mineral Exploration Corporation Ltd., Maharashtra
- National Aluminium Company, Bhubaneshwar
- National Industrial Corridor Development Corporation Ltd., New Delhi
- National Institute of Technology, Raipur
- Quality Council of India, New Delhi
- Rubamin, Gujarat
- Sampark Solutions, Jharkhand
- Siddharth Geo Consultancy, Raipur
- Simon India Ltd., Haryana
- Tata Steel Ltd.
- Tata Consultancy Services, Mumbai
- The Energy Resources Institute, New Delhi
- Indian Rare Earths Ltd., Odisha
- Know-How Transfer agreements signed with:
- EnviroServe Technologies, New Delhi
- Renocell Recycling (P) Ltd,Kolkata
- Sarthi Aerospace & Defence Pvt. Ltd., Haryana
- Tata Steel Ltd, CSIR-CGCRI and Ajanta Refosteel, Jamshedpur
- TerraNova Eco Management Pvt Ltd., Bengaluru

Non-Disclosure agreement signed with:

- Electronic Industries Association of India (ELCINA), New Delhi
- Frametrics Consulting Private Ltd. (Meity), New Delhi
- Impact Rays, Hyderabad
- Renocell Recyling Private Ltd., Kolkata
- Mineral Exploration and Consultancy Ltd., Nagpur.
- Maheshwari Mining Pvt. Ltd., Kolkata
- Ordanance Factory, Ambajhar
- Raj Metal Industries, Kolkata
- Rekart Innovations Pvt. Ltd., New Delhi
- Rubamin, Gujarat
- Simon India Ltd. New Delhi
- Superform Chemistries Ltd.
- TD Connex, Tamil Nadu
- United Nations Development Program, New Delhi
- Unicel Greens Pvt. Ltd. Gurugram

Secrecy agreement signed with:

- EnviroServe Technologies, New Delhi
- Renocell Recycling (P)Ltd,Kolkata
- Sarthi Aerospace & Defence Pvt. Ltd., Haryana
- TerraNova Eco Management Pvt Ltd., Bengaluru

Sponsored agreements signed with:

- Central Mine Planning & Design Institute Ltd., Ranchi
- Tata Steel Ltd., Jamshedpur
- Vedanta Pvt. Ltd., Odisha















Glimpses of MOU/Agrements Signing Ceremonies

Events & Visitors

Sustainable Construction materials made from recycled materials

Recycling waste into modern buildings or turning trash into sturdy homes and offices. Instead of using brand-new steel and cement, building with scrap metal, old plastic, and debris from demolished buildings. This approach creates affordable housing while protecting the environment. Common Recycled Materials Used in India are:



Fly Ash Bricks: Made from coal-fired power plant waste, requiring less energy to produce than traditional clay bricks.



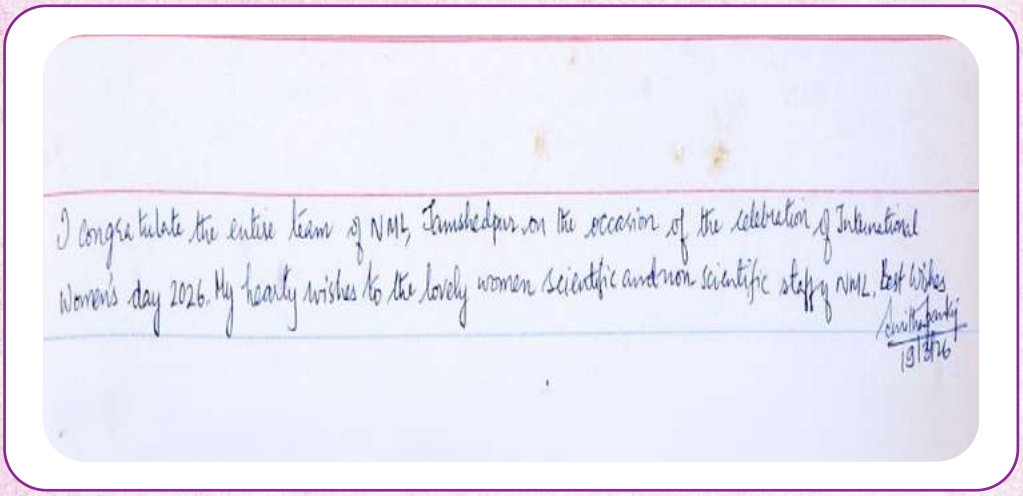
Recycled Aggregates: Crushed concrete from demolished buildings used to pour new structural foundations.



Recycled Plastics: 100% plastic waste is converted into durable, eco-panels for interior cladding and retail fixtures.

https://www.minusdegre.com/
https://wowmaterials.in/recycled-building-materials-in-india




I congratulate the entire team of NML, Jamshedpur on the occasion of the celebration of International Women's day 2026. My hearty wishes to the lovely women scientific and non scientific staffs of NML. Best Wishes
Smitha Pankaj
19/3/26

"I congratulate the entire team of NML, Jamshedpur, on the occasion of the celebration of International Women's Day 2026. My hearty wishes to the lovely women, scientific and non-scientific staff of NML. Best Wishes."

Smitha Pankaj IFS
Regional Chief Conservator of Forests,
Singhbhum, Jharkhand
Date:19th March 2026

Special Days & Events

Conferences /Workshops/Seminars Organised:

Industry Conclave on "Indigenization of Materials (IndiMat): Challenges and Opportunities in the Strategic Sector" (29th April 2025)

As part of its Platinum Jubilee celebrations, CSIR-National Metallurgical Laboratory (CSIR-NML), Jamshedpur, organized one-day Industry Conclave on "Indigenization of Materials (IndiMat): Challenges and Opportunities in the Strategic Sector". Under a single umbrella, the event offered a platform bringing together eminent stakeholders from the Indian Navy, Indian Air Force, ISRO, DRDO, HAL, Mahindra Defence, L&T Precision, Skyroot Aerospace, Vedanta, Ordnance Factories, and other strategic manufacturing sectors. Their participation created a vibrant multidisciplinary stage, where real-world challenges met with innovative R&D perspectives and possibilities.





Students' Seminar "Behind the Teacher's Desk " -BTTD 2025 (25th -27th June 2025)

The Indian Institute of Metals (IIM) Jamshedpur Chapter, in collaboration with the National Institute of Technology (NIT) Jamshedpur, CSIR-National Metallurgical Laboratory (CSIR-NML), and Tata Steel Ltd., jointly organised the 14th edition of the nationally acclaimed student seminar Behind The Teacher's Desk (BTTD-2025). BTTD is a students' seminar on Metallurgical and Materials Engineering that has been held annually since 2011. The event has been attracting more than 200 students from across the country. Dr. Vilas Thathavadkar, Senior VP, Hindalco Industries, Prof. S B Singh, HoD, MME, IIT-KGP, Dr. Monojit Dutta , Chief Researcher, TATA Steel Ltd. anad Ms. Deeba Ahmed, Chief HRBP Corporate Functions, Tata Steel were the keynote speakers for the event. Over the course of the seminar, around 150 student participants from 34 premier institutions—including IITs, NITs, CSIR labs, and leading universities presented 78 technical papers across 15 parallel sessions under eight thematic areas. The program also featured interactive quizzes, expert talks, and industrial visits.





National Conference on Emerging Trends in Mineral Beneficiation Technologies-EMBT-2025 (23rd -25th July 2025)

CSIR-NML organised a National Conference, titled "Emerging Trends in Mineral Beneficiation Technologies (EMBT-2025) with Theme: Sustainable Utilization of Natural Resources". Over 175 delegates participated in EMBT-2025 from 25 different organisations across India. Distinguished speakers from Industry and Academia presented 4 Plenary lectures and 9 keynote lectures. Several themes, such as Advanced Beneficiation Techniques, Processing of Critical & Strategic Minerals, Application of AI/ML, in Mineral Processing, Dry Beneficiation, Process Mineralogy, Agglomeration & Sustainable utilisation of tailings & waste were part of this conference. There were 65 technical presentations covering three days running in two parallel sessions, and there were committed sessions for sponsors and poster presentations for students too.



Critical Metal Congress -CRITMET 2025 (06th -08th November, 2025)

The three-day Critical Metals Congress (CRITMET) 2025 was organised. The first of its kind event on Critical Metals, the event emphasised the crucial role of Critical Metals. CRITMET 2025 saw a participation of over 275 participants. The event brought the best in the field on a single platform to deliberate technical, policy and supply chain issues in the field. The event also included an exhibition of the latest technologies in Critical Minerals by industries and research organisations, and a poster session displaying the latest research in Critical Minerals.







Workshop cum Training Program "Corrosion and Wear Resistant Coating Technology" (25th November 2025)

CSIR–National Metallurgical Laboratory (CSIR-NML), Jamshedpur, organized a Workshop-cum-Training Program for Micro, Small and Medium Enterprises (MSMEs) and Allied Industries on "Corrosion and Wear Resistant Coating Technology". The program was conducted under the activities of the Centre of Excellence on Wear and Corrosion Resistant Coating Technology, established at CSIR-NML with support from the Department of Science and Technology – Advanced Manufacturing Technologies (DST–AMT), India. The workshop received an enthusiastic response, with over 35 participants from MSMEs and major industrial organizations across the region. Core Scientific Topics covered included Fundamentals of corrosion mechanisms and electrochemical behaviour, Surface engineering principles and microstructural design and Coating techniques.





Corporate Training on the Analysis of Raw Materials and Metallurgical by-products of the Steel Industry (ARMBIS-2025) (15th -19th December 2025)





International Conference on Next Generation Galvanized and Color Coated Steels (08th -09th January 2026)

The International Conference on "Next Generation Galvanized and Colour Coated Steels (GalvaNext-2026)", organized by IIM Jamshedpur Chapter in association with TATA Steel and CSIR-

NML, Jmahedpur was a significant event for the steel and coatings community. With participation from over 300 delegates and speakers representing more than 70 organisations, the conference brought together industry leaders, academicians, researchers, policymakers, and technology providers from India and across the globe. Organized with the vision of fostering innovation, sustainability, and industry–academia collaboration, GalvaNext-2026 provided a platform to deliberate on emerging technologies, advanced galvanizing and colour-coating processes, corrosion protection, digitalisation, green technologies, and future-ready steel products.

Best Welder Competition (11th to 12th September 2025)

A Branch Level Best Welder Competition was Jointy organized by Indian Institute of Welding, Jamshedpur Branch and CSIR-NML Jamshedpur





Observance of Occasions of National Relevance :

13th AcSIR Foundation Day Celebration (3rd April 2025)

The 13th AcSIR Foundation Day was celebrated by The Science Club of the AcSIR-NML . Prof. P. P. Chattopadhyay, Director, NIAMT graced the occasion as the chief guest.





Janjatiya Gaurav Varsh Celebration(16th April 2025)

To commemorate the 150th birth anniversary of Dharati Aba Bhagwan Birsa Munda (26th November,2024) and the celebration initiated under “Janjatiya Gaurav Varsha” by Hon’ble Prime Minister, CSIR-NML organised the programs for about 300 tribal students from various schools across East and West Singhbhum on 16th April 2025. Shri. Ramdas Soren, Hon’ble Minister of School Education and Literacy, Government of

Jharkhand, graced the occasion as the chief guest in the program and Dr. Naresh Chandra Murmu, Director CSIR-CMERI, joined as the guest of Honour. Dr. Murmu also delivered a lecture on the topic " "Exploring Science & Technology Careers in India". On 18th November 2025, Prof. Sanjeev Kumar Biruly delivered a lecture "Vikashit Bharat from Lenses of Constitution: Individuals' Role & Fundamental Duties of Citizens To the Nation".







Swachhta Pakhwada- 2025 (5th-15th MAY2025)

As a Part of the Swachchatha Pakhwada 2025, several events were organised . The cleaning of the premises of the laboratory as well as the residential colonies was undertaken. CSIR-NML also took the initiative for a cleaning drive at the TATANAGAR railway station and for planting trees. Various Competitions for employees, including Essay Competition, Extempore Competition, and Quiz Competition, were held as part of the event. In order to create awareness among the youngsters, a sit and draw competition for the wards of employees was also organised. The celebrations concluded with the Closing ceremony held and Shri Ananya Mittal, Deputy Commissioner, East Singhbhum, graced the occasion as the chief guest.











National Technology Day (21st May 2025)

The occasion was celebrated at CSIR-NML with several activities. Several Technology Partners, Licensees and customers participated in the event and shared their experiences during the main function. The event was celebrated as the part of Platinum Jubilee celebrations of the laboratory. Prof. Sukumar Mishra, Director, IIT-ISM Dhanabd and Shri Anand Dayal, Managing Director, MSME Technology Centre graced the function as the chief guest and the guest of honour respectively. The technology day lecture was delivered by the chief guest. An exhibition "TechExpo" was also organized as the part of the celebration to showcase the technologies and facilities of the laboratory. The Platinum Jubilee Annual Report of CSIR-NML 2024-25 was also released by the dignitaries. The new look of the CSIR-NML website was also inauguratred by the dignitaries. Two agreements were also signed on the occasion with industries. The licensees, technology partners and industries who participated in the program included Mr. Aseem Trivedi, Founder & CEO, M/s Novasensa Pvt. Ltd., New Delhi ; Mr. Bishnu Lohiya from Eyantram Waste Management Pvt. Ltd., Bengaluru ; Mr. Sahil Dhanuka, CEO, Refosteel Instruments, Jamshedpur ; Sri. Rahul Singh from Exigo Recycling, Mr. Munish sudan, Head of IP and Innovation from Tata Steel; Mr. Avinash Chowdhary from Omkar Global Hitech Pvt. Ltd., Ranchi and other invitees from industries from the country. The function concluded with the National Anthem.









11th International Day of Yoga (21st June 2025)

CSIR-NML organised yoga sessions on the occasion of International Day of Yoga-2025 on the theme "Yoga for One Earth, One Health," with the gracious involvement of instructors from the Art of Living, Jamshedpur Chapter. This initiative aimed to promote the physical, mental and environmental benefits of yoga in the community. Stress Management & Yoga Workshop and Yoga Sessions were organised for employees and family members, respectively.

Independence Day 2025

Independence Day was celebrated with immense patriotic fervour with programs including flag hoisting in the institute as well as the residential campuses, parade by the Secuity staff of CSIR-NML followed by the cultural programs by wards of employees. Several competitions were also organised on the occasion for the employees and wards, such as Drawing competition, Poem Competition, Fancy Dress Competition, and Geet Sangeet program.











National Sports Day 2025 (29th -30th August 2025)

National Sports Day was celebrated to mark the birth anniversary of hockey legend Major Dhyan Chand. A documentary on the life of Major Dhyan Chand was screened on the occasion. Also, a marathon and a was organized for all employees to instill in them the spirit of sports.



84th CSIR-Foundation Day (24th September 2025)

Dr. Sandip Kumar Kar, Executive Director, Research & Development Centre for Iron & Steel , Steel Authority of India Limited, was the chief guest for the main function. As a part of the Foundation Day celebrations, competitions such as Essay writing and Sit and Draw were organized for the wards of employees. The winners were awarded during the function by the chief guest. Ann exhibition of the CSIR-NML technologies was also held.











“Swachhta Hi Seva – 2025”(7th October2025)

“Swachhta Hi Seva” a nationwide cleanliness campaign was celebrated at CSIR-NML. As a part of the event, the Safai Mitras of the laboratory were felicitated.



Vigilance Awareness Week (27th October to 2nd November 2025)

Several programs were conducted as part of the three months' campaign period and as a prelude to Vigilance Awareness Week (VAW 2025) . On the opening day of VAW 2025, all employees took the Vigilance- Integrity Pledge.Lectures on Central Civil Services (Conduct) Rules, Audit & Vigilance aspect in Public Procurement and on administrative aspects were organized. An essay competition was also organised for the employees.








National Metallurgist Day (18th November 2025)

AcSIR-NML Science Club celebrated National Metallurgist Day at CSIR-NML Jamshedpur. Dr. Monojit Dutta, Chief, Product Development Research Group, R&D, Tata Steel Ltd., delivered an expert talk on "Addressing the Future Development of Automotive Steels". A quiz Competition on the theme "Materials Around us" was also organised.





CSIR-NML Foundation Day (26th November 2025)

The Platinum Jubilee (PJ) Celebrations Closing Ceremony was held on the CSIR-NML Foundation Day . The event was graced by the current DG and the first female to hold the position, Dr. N Kalaiselvi. Dr. N Murmu, Director CSIR- Central Mechanical Engineering Research Institute, Durgapur and Shri S K Jha, Former C&MD, Midhani, were also present for the occasion. A video Message by Padma Bhushan Anand Mahindra, Chairman M&M and Mentor, CSIR was received and played during the function. On the occasion of Constitution Day, the Preamble of the Constitution reading ceremony was administered by DG, CSIR. Release of CSIR-NML PJ Video and PJ Souvenir was also done by the dignitaries. Distribution of Institutional, Meritorious Student Awards, elocution and Essay Competition was done in the function by the guests. The felicitation of AcSIR Alumni who were awarded Ph.D degree was also done by DG, CSIR. A MoU Exchange Ceremony with Hindustan Zinc Limited, EnviroServe Technologies Pvt Ltd, Electrotherm India, Renocell Recycling Pvt. Ltd., UNICEL Greens, Lohum, UNDP and Jharkhand State Faculty Development Academy was also organized as the part of the main function. The function formally ended with National Anthem.







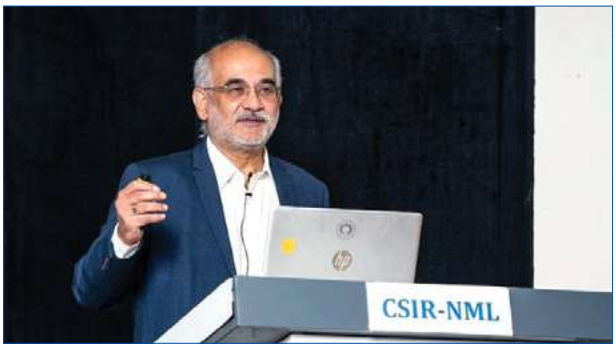






Curtain Raiser Ceremony of IISF 2025 (27th November 2025)

Curtain Raiser Ceremony of India International Science Festival (IISF) 2025 and Science Outreach Programme was held as a preamble to the India International Science Festival (IISF) 2025. Professor Indranil Manna, Vice Chancellor, Birla Institute of Technology (BIT) Mesra, graced the ceremony as the Chief Guest.







Sexual Harassment Prevention Week (10th – 17th December 2025)

Sexual Harassment Prevention Week was observed by organizing several awareness programs for the laboratory staff. Lectures on the POSH Act (Prevention of Sexual Harassment at Workplace Act, 2013) were organized for employees .

Multiple lectures were organised during Sexual Harassment Prevention Week 2025, The objective of these lectures was to spread awareness on the Prevention of Sexual Harassment (POSH) at the workplace Act 2013. Director, CSIR-NML, Controller of Administration, CSIR-NML, Administrative Officer, CSIR-NML, Members of Internal Complaints Committee, CSIR-NML and Nodal Officer-She Box Portal, CSIR-NML delivered talks at CSIR-NML.









New Year Celebration (1st January 2026)

A get-together of the entire staff was organized to present the roadmap for achieving the laboratory's vision and milestones, in the upcoming year. Dr Sandip Ghosh Chowdhury addressed the employees of CSIR-NML on the occasion of the New Year.







National Startup Day Quiz (16th January 2026)

The AcSIR Science Club organized a Quiz Competition to mark the occasion of National Startup Day on the theme "Startup & Entrepreneurship".







Republic Day Celebration 2026

Republic Day was celebrated in the laboratory and residential premises with great enthusiasm. The Director, CSIR-NML, unfurled the national flag at the laboratory. Followed by the March Past of the Security Staff and the musical band performance by the School Children. A cultural program was also organised. The guest of honour, Mr. Manjit Kumar Jha, was felicitated during the program. The staff and their families participated in the national festival in large numbers.



International Women's Day 2026 (6th- 19th March 2026)

International Women's Day was celebrated in CSIR-NML with a variety of programs. Mrs. Mamta Singh, High Court of Jharkhand, Ranchi & Advocate, Civil Court, Jamshedpur, delivered an awareness lecture on POSH Act (Prevention of Sexual Harassment at Workplace Act, 2013). Cultural events and a food fest were organised as a part of the celebration. Ms Smitha Pankaj, Regional Chief Conservator of Forests, Singhbhum, Jamshedpur, Indian Forest Services (2006 Batch) graced the closing function as the chief guest. The Women Janitorial Staff was felicitated by the chief guest and the dignitaries on the dias.











Other Important Events Organised :

Popular Hindi Drama (23rd April 2025)

As the part of Platinum Jubilee Foundation Year celebration, a popular family Hindi play "Surya Ki Antim Kiran Se Surya Ki Pehli Kiran Tak" was staged by national-level artists in CSIR-NML auditorium.





One Day NML Visit Project '' ANVESHANA'' (Phase-2) in association with Jigyasa Program- (08th May 2025)





Hindi Table Workshop (5th -9th May 2025)

Hindi Table Workshops were organised in each department of CSIR-NML to make the promotion of the official language Hindi for use in the everyday official work.

CSIR- One Day as a Scientist Programme (21st to 25th June 2025)



Saawan Mahotsava-2025 (30th June 2025)

The Sawan Mahotsav was celebrated, and a food fest was organized in the residential colony.









13th Prof. S. N. Sinha Memorial Materials and Metallurgy Quiz (8th August 2025)

The Indian Institute of Metals (IIM), Jamshedpur Chapter, is going to organise a Metals & Materials Quiz program, titled “Prof. S. N. Sinha Memorial Materials and Metallurgy Quiz (SNSM3Q-2025)”, for Standard XI and XII students. The annual event is organised in the fond memory of Late Prof. S. N. Sinha, an eminent educationist and past president of the IIM Jamshedpur Chapter. As every year, the event saw enthusiastic participation from school students.





CSIR-Cohort PI-CHeCK- (23rd to 28th August 2025)





Hindi-Week Celebrations-2025 (1st -8th September 2025)

Hindi Week was celebrated with various events, such as Hindi Essay Competition, Hindi Dictation Competition and Hindi Poetry Recitation Competition.









Ekta Diwas Pledge on account of "Rashtriya Ekta Diwas" (National Unity Day)- (31st October 2025)



16th National Voters' Day Pledge- *23rd January 2026)





Important Meetings Organised :

82nd Research Council (RC) Meeting (04th April 2025)

The meeting was held in hybrid mode. Mr. Amarendu Prakash, Chairman SAIL and Chairman RC joined through online platform. Director, CSIR-NML presented about the overall R&D and significant functions, and achievements of the laboratory. 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 deliberated and advised about the current R&D projects and future R&D and technological needs of the country. Multiple technical presentations on the ongoing R&D activities of the laboratories were given by the researchers of the laboratory.





Patent Filing Activity Meeting By CSIR–URDIP and CSIR–IPU (21st-22nd April 2025

A team of Scientists from CSIR–URDIP Pune and CSIR–IPU Delhi visited CSIR–NML Jamshedpur for discussions with Scientists / PIs who have been inventors in various patent applications pending for over the past years, or proposed for filing during FY 2025–2026, and path–forward. The objectives of these discussions were to identify the key issues encountered in regard to patent filings in CSIR–NML till date, and address them through discussions with the concerned Scientists / PIs, and facilitate necessary on–site handholding sessions etc., as may be required. In addition, the team discussed new patent filings proposed during the current year, and extend necessary support for the same from CSIR–URDIP and CSIR–IPU. It iwas also envisaged that, towards the end of the meeting deliberations, several new potential inventions might be identified, which could be taken forward by CSIR–NML to patent filings at the earliest, after due evaluation of Patentability and Techno–Commercial potential by CSIR–URDIP. The following Scientists from CSIR–URDIP and CSIR–IPU attended the discussion meetings on–site at CSIR–NML: CSIR–URDIP Pune (Dr. Dr. Kishore Sreenivasan, Outstanding Scientist and Head; Shri. Abhijeet Dhulap, Senior Technical Officer; Shri. P. Venkataraman, Principal Scientist; Dr. Sivakami Dhulap, Senior Principal Scientist;) CSIR–IPU Delhi (Dr. Kapil Arya, Principal Scientist; Shri. Gaurav Krishnan, Senior Principal Scientist) . CSIR-NML scientists participated in these meeting and the discussions were fruitful to the organization.







Distinguished Visitors

Visit of Commodore Amit Rastogi (Retd), Chairman & Managing Director of National Research Development Corporation (03rd June 2026)

CMD, NRDC visited CSIR-NML research facilities and interacted with the scientific and technical staff of the laboratory.















Visit of Mr. T.V. Narendran, Global CEO and MD, Tata Steel Ltd (25th June 2025)

As a part of the Platinum Jubilee Year Celebration of CSIR-NML, the 4th Platinum Jubilee Lecture delivered by Mr T V Narendran, Global CEO and MD, Tata Steel Ltd, entitled “Industry Research Institutes Collaboration to Meet National Priorities” was held at CSIR-NML Auditorium today. The lecture was followed by a lab visit and a CSIR-NML Technologies demonstration through posters and products.



















Visit of Dr. Vijay Kumar Saraswat, Padma Bhusan, Member Niti Aayog and Member, NITI Aayog, and Chancellor, Jawaharlal Nehru University (2nd July 2026)

Dr. Vijay Kumar Saraswat, Member of NITI Aayog, delivered the fifth Platinum Jubilee lecture at CSIR-NML on "Critical Materials for India's Strategic Future." Commemorating the lab's 75th anniversary, he highlighted the vital role of critical minerals in achieving the Viksit Bharat vision and powering sustainable technologies like EVs and wind turbines. Dr. Saraswat detailed the National Critical Mineral Mission 2025, emphasizing the need for self-reliance amidst global supply challenges. He urged CSIR-NML to lead innovations in circular economy practices, such as waste valorisation and AI integration. The visit concluded with an interactive Q&A and the inauguration of a technology exhibition.



Visit of Shri. Mahendra Kumar Gupta, Joint Secretary (JS) Admin, CSIR (13th October 2025)

Shri Mahendra Kumar Gupta, JS (Admin), CSIR, visited CSIR-NML and interacted with the CSIR-NML scientific, technical and administrative staff of the laboratory. He discussed various initiatives of CSIR in the Administration, as well as suggested solutions to administrative issues of staff. He also graced the cultural program organised by the staff children as the chief guest.















Visit of Dr. N. Kalaiselvi, Secretary, DSIR and Director General, CSIR (26th November 2026)

Dr. (Mrs.) N. Kalaiselvi, Director General of CSIR and Secretary of DSIR, visited CSIR-NML and graced the Platinum Jubilee Foundation Day celebrations of CSIR-NML . During her visit, Dr. Kalaiselvi laid the foundation stones for two critical projects: National Green Hydrogen Mission: One-of-a-kind test facilities and infrastructure aimed at boosting indigenous hydrogen production, and Magnesium Production: A Pilot Plant for the production of Magnesium metal at the Nildih facility. In her address, Dr. Kalaiselvi urged scientists to focus on time-matched technologies and joint ventures with young researchers and startups to achieve the goals of Viksit Bharat 2047.












Platinum Jubilee Year
1950 – 2025
प्लैटिनम जुबिली स्थापना दिवस समारोह
Platinum Jubilee Foundation Day Celebrations
26 नवंबर 2025 || 26 November 2025
सीएसआईआर-राष्ट्रीय धातुकर्म प्रयोगशाला, जमशेदपुर • CSIR – National Metallurgical Laboratory, Jamshedpur
Shri Narendra Modi
Hon'ble Prime Minister of India
&
President, CSIR
"Self-reliance is not possible without a strong mining and mineral sector as the two are important pillars of our economy"
Dr. Jitendra Singh
Hon'ble Union Minister
Ministry of Science and Technology
Government of India
&
Vice President, CSIR
"Minerals and Metals Research should focus on economic self-reliance, innovation and sustainable development for Viksit Bharat"





Staff Club Activities

Awareness program on PCOD and PCOS (15th April 2025)

A lecture on PCOD (Polycystic Ovarian Disease) and PCOS (Polycystic Ovary Syndrome) by Dr Ruchita Agarwal, MBBS, MS (G&O) DNB, Apollo Hospital.



Blood Donation Camp (17th June 2025)

CSIR-NML staff club organised a blood donation camp to encourage its employees to donate blood and save lives. 92 units of blood were deposited at Jamshedpur Blood Bank.





Swasth Nari Sashakt Parivar (20th November 2025)

Under the "Swasth Nari Sashakt Parivar" Mission of GOI, an oral, dental and Gynecology examination camp was organised for all the female employees of CSIR-NML



CSIR-NML Outreach Program (11th January 2026)

An outreach program was organized by CSIR-NML Staff Club at Silver Sand Resort (Vrindavan Garden), Jamshedpur. Staff members and staff families participated in the event with enthusiasm.



Football Tournament (15th August 2025)



Tennis Ball Cricket Tournament 2026 (26th January 2026)



Table Tennis & Chess Tournament (22nd February 2026)



Pair Bridge Tournament (22nd February 2026)



Illumination of NML Building during 75th Platinum Jubilee Foundation Day Celebration 2025





Achievements

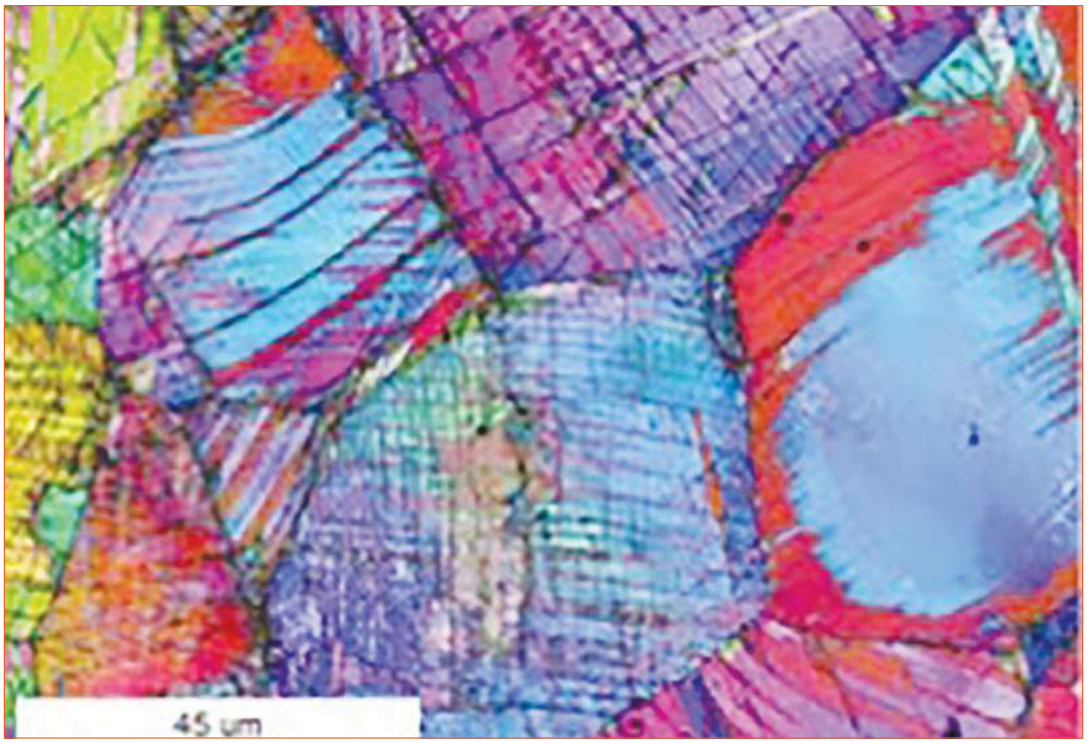
Platinum-Rated Green Building- The New Parliament Building-Sansad Bhawan

The unique build features 9,689 cubic metres of fly ash blended into the concrete mix and construction and demolition waste. Utilising sustainable construction methods, the new facility is engineered to cut energy usage by 30% relative to the legacy building. The infrastructure integrates advanced rainwater harvesting and water recycling systems. Inside, the design celebrates national symbols: the Lok Sabha reflects the Peacock, the Rajya Sabha mirrors the Lotus, and the Central Lounge honors the Banyan tree. A massive 4.5-tonne, 6.5-metre-high Ashoka Emblem stands proudly at the summit.





https://centralvista.gov.in/myths-and-realities.php | https://www.business-standard.com | https://energy.economictimes.indiatimes.com
https://www.cim.io/blog/the-leed-rating-system-explained | https://economictimes.indiatimes.com
https://www.tata.com/newsroom/business/ode-to-india-new-parliament-tata-projects



Deformation-induced defects in austenitic stainless steel

Awards and Recognition

National /International Awards/Recognitions Received

Eminent Engineers Award 2025-26

Dr. KL Sahoo, Scientist G

'Eminent Engineers Award 2025-26' in Metallurgical and Materials Engineering from the Institute of Engineers India (IEI)



IEI Young Engineer's Award 2025

Dr. Avanish Kumar Chandan



National Award for NDT Systems

Dr. Ashish Kumar Panda, Scientist G

National Award for NDT Systems Innovation & Development from Indian Society for Non-Destructive Testing (ISNT) .



National Geoscience Award 2024

Dr. Ranjeet Singh, Scientist F

National Geoscience Award 2024 in Mineral Processing





V. L. KANTHA RAO, IAS
Secretary

GOVERNMENT OF INDIA
MINISTRY OF MINES

No.11/13/2019-M.I[E] 28th May, 2025

Dear Dr Singh

I extend warm congratulations on your selection for the prestigious **National Geoscience Award 2024** in recognition of your significant contributions in the field of Mineral Beneficiation and Sustainable Mineral Development. The award carries a Certificate and a Plaque. My Ministry will communicate the details of the award presentation ceremony in due course.

I am confident that you will continue to make significant contributions to the field of Geosciences.

With regards,

Yours sincerely,

(V. L. Kantha Rao)

Dr. Ranjeet Kumar Singh
Principal Scientist,
CSIR-National Metallurgical Laboratory,
Mangalam City, Adityapur, Jamshedpur-832108

IIM Young Metallurgist Award - 2025

Dr. Ammasi A., Scientist D



INAE Young Engineer Award -2025

Dr. Prem Kumar M, Scientist D



N.M. Sampat National Award 2025

Dr. Mahesh Walunj, Scientist D



National Corrosion Championship Trophy - 2025 for the Best Research

Dr. Mahesh Walunj, Scientist D

New Technologies and Innovation in Corrosion Management organized by Confederation of Indian Industry (CII) and presented during 2nd CII CORTEM- International Summit on Corrosion Technology and Management, 2025 at Chennai Trade Centre, Chennai.



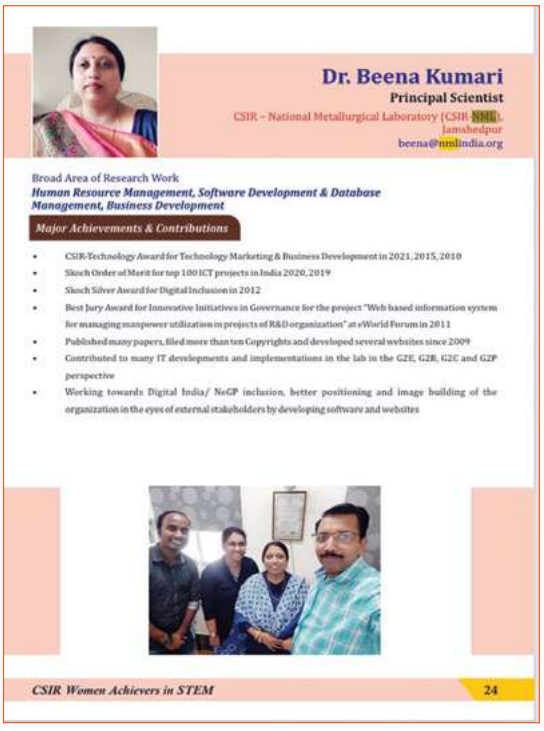
CSIR-NML Women Achievers

Recognition of CSIR-NML Women Achievers in CSIR Women in STEM Compendium by CSIR-NAL (Available at: https://www.nplindia.org/wp-content/uploads/2023/09/CSIR_women_in_STEM_compendium_2023.pdf)











Ms. N. Vasumathi

Principal Scientist

CSIR-National Metallurgical Laboratory (CSIR-NML), Jamshedpur
vasumathi@csircmc.res.in

Broad Area of Research Work

Mineral Processing

Major Achievements & Contributions

- VA. Alekar Award for the Best Technology developed/transferred, 2020
- Recipient of Tamotia Award (Environment category), 2019
- Recipient of Technology Award for most significant CSIR technology, 2014
- Scientific contributions focused on process flow sheet development for low grade ores and recovery of values from tailings by flotation
- Major contribution in pilot-scale column flotation technology demonstration and commercialization of column flotation technology
- Developed new bio-degradable eco-friendly single flotation collector for fine coal and graphite
- Worked on the development and performance evaluation of environment friendly flotation reagents for cement manufacturing
- Surface clay contamination reduction on quartz and feldspar and beach sand heavy minerals using environment friendly natural surfactants
- Contributed to the development of value-added products from mineral/mining wastes/rejects





Dr. Shobhana Dey

Senior Principal Scientist

CSIR – National Metallurgical Laboratory (CSIR-NML), Jamshedpur
sd@nmlindia.org

Broad Area of Research Work

Mineral and Coal Processing, Surface Chemistry

Major Achievements & Contributions

- Recipient of MEAI - NMDC Award for 2020
- NML Best In-house Project 2008
- National Research Foundation (NRF) fellowship provided by South Africa Government in 2008
- Developed dry processing technology for high ash non-coking coal for thermal power plants and DRI application
- Developed process flow sheets for low-grade waste dumped limestone, high siliceous limestone for reducing flux grade material and cement making, respectively
- Expertise in the area of dry beneficiation of low-grade iron ores and coal, development of process flow sheet for industrial minerals, froth flotation, fluid dynamics and enhanced gravity separation etc.
- Significant contribution in R&D studies for producing value-added product from lean grade ores, waste mines dumped and plant reject to conserve the primary resources and protect the environment.



Dr. Pratima Meshram

Principal Scientist

CSIR – National Metallurgical Laboratory (CSIR-NML), Jamshedpur
pratima@nmlindia.org

Broad Area of Research Work

Science, Engineering and Technology in Metal Extraction and Recycling

Major Achievements & Contributions

- Prof. Shilowbhadra Banerjee Award 2010 at CSIR-NML, Jamshedpur
- Indo-Finish Mobility Program Fellowship 2019for research visit at Lappeenranta University of Technology, Finland
- CSIR-Raman Research Fellowship 2021-22 for research at the University of British Columbia, Vancouver
- Initiated first in India work on recycling of nickel-based batteries for rare earth extraction
- Principal inventor in CSIR's first indigenous process for extraction and separation of all metals from mixed chemistry scrap lithium-based batteries
- Published several research papers and filed many patents



Membership of Staff in National/ International Committee(s) /Editorial Board(s)



Dr. Trilochan Mishra, Scientist G

- Inducted as an International Advisory Board member of the International Conference “Innovations, Advances in Material Science for Sustainable Goals (IAMSSG) 2025,".
- Guest of Honour in the inaugural ceremony of the National Seminar on “Frontiers in Chemical Sciences-III” (FCS-III, 2026) held at MSCB University, Baripada, during 10th-11th January, 2026.



Dr. Abhilash, Scientist F

- Member (International Scientific Committee) – International Biohydrometallurgy Council
- Expert Member, Inter-ministerial working group on Critical Metals, Govt of India
- Member (International Scientific Committee) – International Biohydrometallurgy Council
- Expert Member, Inter-ministerial working group on Critical Metals, Govt of India



Dr. Kuldeep Singh Gour, Scientist C

- Editorial Board Member in Advances in Materials
- Guest Editor in Materials MDPI in Special Issue on Advancements in Emerging Semiconductor Materials for Diverse Applications
- National Advisory Board Member in the 2nd International Conference on Academic and Industrial Innovations in Engineering (ICAIIE 2026), 30th - 31st January 2026, Organized by the School of Engineering, PP Savani University, Gujarat, India.



Invited Lectures/Talks Delivered by Staff



Dr. Sarmishtha Palit Sagar, Scientist G

- Plenary Talk on the topic " From CSIR Laboratory to Market, Bridging Research and Implementation" at the 35th National Conference and exhibition on Non-destructive Evaluation (NDE 2025) on 12th December 2025 at the Jio-Convention Centre, Mumbai.



Dr. Sanjay Kumar, Scientist G

- Keynote address entitled “Urban Ore: The Hidden Treasure” in “Technica” fest organised by National Institute of Technology, Jamshedpur on 16th January 2026.
- Keynote address entitled “Granulated Blast Furnace Slag: A Sustainable Cementitious Material” during the industry meet organised by Tata Steel in Hotel Radisson Blue, Ranchi on 17th February 2026.
- Keynote address entitled “Sustainable Energy: Key Materials Requirements and Challenges”, in the Conference Sustainable Energy in India; Balancing Scientific Achievements, Commercial Potential & Socio-Economic Growth, organized by Graduate Women’s College on 11th December 2025.
- Expert lecture entitled “Critical metal Extraction from Secondary resources: A Circular Economy Approach” in the six-day online short course titled "Sustainable Pathways in Critical Mineral Development: From Discovery to Delivery" which is scheduled to be held during 1st - 6th September 2025 organized by IIT-ISM



Dr. Trilochan Mishra, Scientist G

- Invited talk in International Conference on “Innovations, Advances in Material Science for Sustainable Goals (IAMSSG) 2025," during 29th - 31st October 2025.
- Invited talk in MRSI International Conference on Emerging Materials (MRSI-ICEM 2025) conference held at NISER Bhubaneswar during 17th–20th December 2025.
- Keynote lecture in the above national seminar National Seminar on “Frontiers in Chemical Sciences-III” (FCS-III, 2026) held in MSCB University, Baripada.



Dr. Abhilash, Scientist F

- Invited Talk at Australia-India Critical Mineral Hub Symposia held at IIT Hyderabad during 2nd- 4th January 2025 (Capabilities of CSIR-NML in Critical Mineral Processing and Metal Extraction)
- Invited Talk at ANRF-SERB Symposia on Atmanirbhar Bharat at NIAMMT, Ranchi (Topic: Atmanirbhar technologies of CSIR-NML in Waste Utilization) on 22nd March 2025.
- Invited Talk at Critical Minerals Association (India) on Innovation in Rare Earth Elements (REE) and Lithium during 9th –10th October 2025, in Bengaluru
- Invited Talk at BIS-BSI Workshop on “Enhancing Critical Minerals Data Quality and Standards” on 19th – 20th January 2026, New Delhi
- Keynote Speaker at FICCI's Annual Flagship Critical Minerals Summit on 19th February 2026



Dr. Naveena, Scientist E

- Invited Lecture on "From Test Result to Material Performance: Why Interpretation Matters" during Webinar Series on “Mechanical Testing of Metals – Indian Standards, Industry Practices and Emerging Needs.” organized by Bureau of Indian Standards (BIS), during 11th Feb - 18th March 2026.

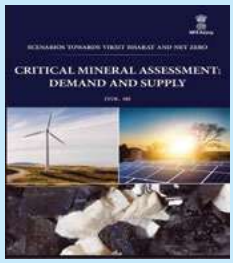
 **Dr. Sreeda P., Scientist D**	• Invited lecture in CSIR-One Day As A Scientist Program – " Career in Science" • Invited lecture in Popular Lecture Series : " Science: A world of Unlimited Possibilities" • Invited lecture on the topic "Intellectual Property Rights- a student perspective" at the *"Protecting Research and Innovation: IPR & Patent Awareness Workshop (PRIIPAW 2026)"* conducted by NIT Jamshedpur from 20th to 24th March 2026
 **Dr. Mudila Dhanunjaya Rao, Scientist C**	Guest Speaker in two-day National Workshop on the occasion of World Meteorological Day at Karim City College, Jamshedpur, on 23rd March 2026
 **Dr. Kuldeep Singh Gour, Scientist C**	• Invited Lecture on "Materials and Interface Engineering Strategies for Emerging Kesterite Thin Film Solar Cells" in "Advances in Materials and Storage Technologies for Energy and Environment (AMSEE 2026)", 30th January 2026, organized by the Department of Physics, School of Advanced Sciences, VIT-AP University, Vellore, India.
 **Dr. Vinod Belwanshi, Scientist C**	• Invited talk under the HBNI Alumni Webinar Series on 26 March 2026 at Homi Bhabha National Institute (HBNI)

Book Chapter (s) / Book Publication / High-Impact-Factor Journal Publication by Staff



Dr. Abhilash, Scientist F

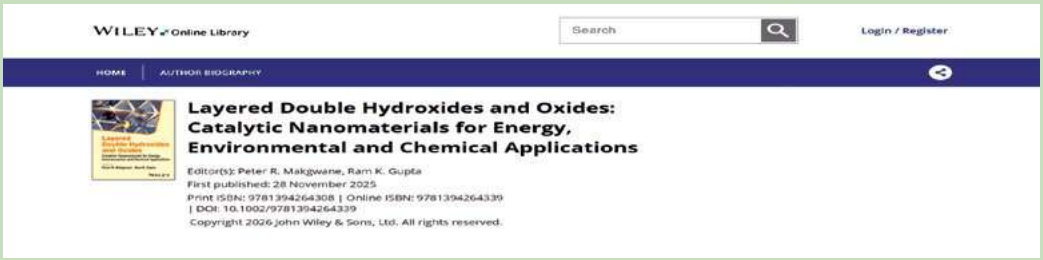
Author to ITI Aayog report, "Scenarios Towards Viksit Bharat and Net Zero - Critical Mineral Assessment" https://niti.gov.in/sites/default/files/2026-02/Scenarios-Towards-Viksit-Bharat-and-Net-Zero-Critical-Mineral-Assessment-Demand-and-Supply.pdf







Dr. Shailendra Kr Jha, Scientist F









Dr. A. P. Murugesan, Scientist F

Selected as one of the six Editor's Choice Articles (2025) Paper: "Effect of Different Strain-Path Cold Rolling on Mechanical Properties, Microstructures and Texture Evolution in Aluminum–Copper– Lithium (AA 8090) Alloy" in Metallography, Microstructure, and Analysis (ASM–Springer);". The article has been made Free Access by the publisher.



Dr. Sreeda P., Scientist D

Book Chapter:

Pallipad Sreeda. "Biomass Utilisation for Meeting Sustainable Development Goals: An Indian Context." *Biomass Processing Technologies for Sustainable Energy and Material Production*. CRC Press, 2026. 21-30.



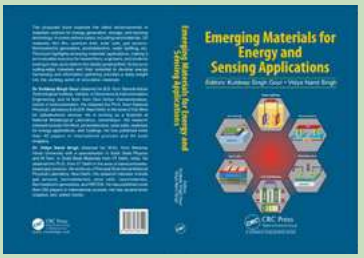
Dr. Kuldeep Singh Gour, Scientist C

Book

- K.S. Gour, VN Singh, Emerging materials for energy and sensing applications, CRC Press, Taylor & Francis Group, 2025, 1-162.

Book Chapter

- S. Rani, M. Kumar, K.S. Gour, G. Rawat, V.N. Singh, Emerging Materials for Energy and Sensing Applications, CRC Press, 2025, 122-138.



Media Appearance/Technical Interviews

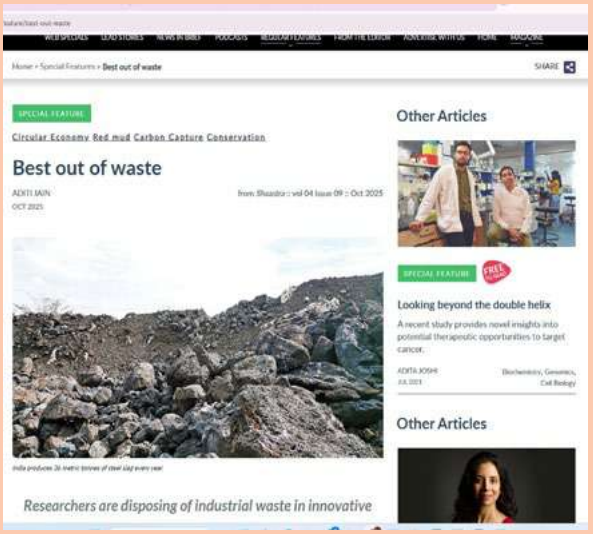


Dr. Abhilash, Scientist F



Dr. Pratima Meshram, Scientist F

IITM Sastra Magazine: https://shaastramag.iitm.ac.in/special-feature/best-out-waste



Revathy's team has found that the sequestration capability of steel slag can be enhanced by decreasing the particle size of slag through grinding.

Scientists are not only working on using waste but also ensuring that it is fully utilised, leaving nothing to be treated or buried. They offer a waste value chain solution to industries. Scientists Pratima Meshram and Abhilash (he uses only one name) from the Jamshedpur-based CSIR-National Metallurgical Laboratory have developed a process that ensures the total utilisation of red mud. In this process, they first recover leftover aluminium from red mud, followed by iron recovery through smelting. Titanium and rare-earth elements are then extracted from the leftover slag. Finally, the residue, which contains calcium silicate and gypsum, is geopolymerised to produce paving blocks and other materials used in the construction industry. Apart from disposing of waste, the process enables the production of iron and aluminium at a cheaper rate, as it does not require mining. It consumes only a fifth of the energy that most normal processes do, and yields rare-earth metals, which are at present mostly imported. While the concentration of rare-earth elements is low per kilogram, the potential is enormous. India, which already has nearly 23 million tonnes of red mud, generates 5 million tonnes of it annually.

High Citation/ High Downloads



Dr Sanjay Kumar, Scientist G

- Total citations on Google Scholar have crossed 9200, and the h-index is 44.
- "Influence of granulated blast furnace slag on the reaction, structure and properties of fly ash based geopolymer" published in Journal of Materials Science 45 (3), 607-615 has crossed 1000 citations on Google Scholar.



Dr. Abhilash, Scientist F

Most Downloaded and Most Cited two papers in Taylor & Francis's Mineral Processing and Extractive Metallurgy Review in 10 years (Overview on extraction and Separation of Rare Earth Elements from Red Mud: Focus on Scandium; Advanced Review for Extraction of Nickel from Primary and Secondary Resources)

Top 2% Scientist cited in Elsevier database 2022-2025 (https://elsevier.digitalcommonsdata.com/datasets/btchxktzyw/3)



Dr. Abhilash, Scientist F

84th CSIR Foundation Day Awards
Meritorious Students Awards

Master Rupam Singh
Ward of Employee :
Mr. Madhusudan Singh

Award Details:

For Securing Admission in IIT, Kharagpur



Master Prateek Prem Purti
Ward of Employee :
Mr. Saban Purti

Award Details:

For Securing 90% Marks in Class X



Miss. Debadrita Pal
Ward of Employee :
Dr. Jagannath Pal

Award Details:

For securing admission in IIT, BHU in 2025

For Securing 90% Marks in each of minimum three science subjects

For Securing 100% marks in any science subject



Miss. Abha Poddar
Ward of Employee :
Dr. Palash Poddar

Award Details:

For Securing 90% Marks in Class X

For securing 100% Marks in any subject in Class X

Miss. Amishi
Ward of Employee :
Mr. Amit Prakash

Award Details:

For Securing 90% Marks in Class X

For securing 100% Marks in any subject in Class X



Master Chirag Kumar Shaw
Ward of Employee :
Mr. Ashok Kr Shaw

Award Details:

For Securing 90% Marks in Class X

Sit & Draw / Essay Competition Awards



Ms. Jeshwitha

Ward of Employee :
Mr. M Udaya Bhashkara Rao

Category:
Nursery to Standard-I

Position: First



Mr. Nabh Srivastava

Ward of Employee :
Mr. Rajiv Ranjan Srivastava

Category:
Standard II to IV

Position: Second



Ms. Anubhavi

Ward of Employee :
Mr. Dayakant Kumar

Category:
Nursery to Standard-I

Position: First



Ms. Snigdha Bagui

Ward of Employee :
Dr. Sumanta Bagui

Category:
Standard II to IV

Position: Third



Ms. Aaradhya Singh

Ward of Employee :
Mr. Saroj Kumar

Category:
Nursery to Standard-I

Position: Second



Ms. Saranya Behera

Ward of Employee :
Mr. R N Behera

Category:
Standard V to VIII

Position: First



Ms. Havyasri

Ward of Employee :
Mr. C. Pakkiraiah

Category:
Nursery to Standard-I

Position: Third



Ms. Anokhi

Ward of Employee :
Mr. Dayakant Kumar

Category:
Standard V to VIII

Position: First



Mr. Prakrit Kumar

Ward of Employee :
Dr. Krishna Kumar

Category:
Standard II to IV

Position: First



Mr. Aaryan Singh Gour

Ward of Employee :
Dr. Kuldeep Singh Gour

Category:
Standard V to VIII

Position: Second



Ms. Pranavi Guguloth

Ward of Employee :
Dr. Krishna Guguloth

Category:
Standard V to VIII

Position: Third



Ms. Rima Kumari Mudi

Ward of Employee :
Mr. Rohit Mudi

Category:
Standard IX & Above

Position: Second



Ms. Priyanka Kumari Mudi

Ward of Employee :
Mr. Rohit Mudi

Category:
Standard IX & Above

Position: First



Ms. S L V Jayashree

Ward of Employee :
Mr. C. Soupramanien

Category:
Standard IX & Above

Position: Third

Essay Competition



Ms. Parvathy A

Ward of Employee :
Dr. Sreeda P

Category:
Standard V to VIII

Position: First



Ms. Navya Srivastava

Ward of Employee :
Mr. Rajiv Ranjan Srivastava

Category:
Standard IX & Above

Position: First



Mr. Saksham Sharma

Ward of Employee :
Dr. Beena Kumari

Category:
Standard V to VIII

Position: Second



Ms. Rima Kumari Mudi

Ward of Employee :
Mr. Rohit Mudi

Category:
Standard IX & Above

Position: Second



Mr. Aadarsh Kumar

Ward of Employee :
Mr. Saroj Kumar

Category:
Standard V to VIII

Position: Third



Ms. Akshita Raj

Ward of Employee :
Mr. Shailendra Kumar

Category:
Standard IX & Above

Position: Third

75th CSIR-NML Foundation Day Awards

Nijhawan Award 2025 : Best publication in the last Calendar year

"Influence of Texture on Anomalous yielding of thermomechanically processed nicket based superalloy 720 Li" by P S M Jena, J K Sahu, S Tripathy, S K Pradhan, B Mahto, N Paulose, Acta Materialia, 281 (2024)



P S M Jena



J K Sahu



S Tripathy



S K Pradhan



B Mahto

Altekar Award: for Best Technology Award in the last financial year

"A Sensing Device for Real Time Zinc Coating Weight Measurement in the Galvanised Line of Steel Wires", by Dr. Tarun Kumar Das and Dr. Sarmishtha Sagar Palit.



Dr. Tarun Kumar Das



Dr. Sarmishtha Sagar Palit.



Prof. S. P. Mehrotra Award :

Dr. Kuldeep Singh Gour, Scientist C

Best Colloquium Speaker "From Materials to Prototype: Strategies for Next-Generation Thin Film Solar Cells"

Prof. P. Ramachandra Rao Award: for Best Employee



Mr. Binay Mohan Kumar Singh, MTS, CSIR-NML Jamshedpur



Mr. G. Jeevanandam, Sr. Technician (3), CSIR-NML Madras Centre, Chennai

Meritorious Students Awards

Mr. Rupam Singh

Name of the Employee :
Mr. Madhusudan Singh

Category:

Secured admission in IIT, KGP in 2025



Miss. Debadrita Pal

Name of the Employee :
Dr. Jagannath Pal

Category:

Secured admission in IIT, BHU in 2025

Secured 90% Marks in each of the minimum three science subjects

Secured 100% marks in a science subject

Essay /Elocution Competition Awards



Mr. Somnath Das

Competition: Essay Competition (Hindi)

Position: First



Dr. Minati Sahu

Competition: Essay Competition (Hindi)

Position: Second



Mr. Prakash Kumar Rajak

Competition: Essay Competition (Hindi)

Position: Second



Dr. M. Dhanunjay Rao

Competition: Essay Competition (Hindi)

Position: Third



Mr. Vikas Kumar

Competition: Essay Competition (English)

Position: Third



Mr. Vedprakash

Competition: Elocution Competition

Position: First



Mr. Subrat Shekhar

Competition: Essay Competition (Hindi)

Position: First



Mr. Manoranjan Kumar Sinha

Competition: Elocution Competition

Position: Second



Competition:

Elocution Competition

Position: Third

Md. Nayeemuddin Ansari

Swachhata Pakhwada 2025 Awards

Essay Competition



Prize:

First

Category:

Hindi

Mr. Gopal Jee



Prize:

Second

Category:

Hindi

Miss Twinkle Kumari



Prize:

Third

Category:

Hindi

Mr. Ravi Kumar



Prize:

First

Category:

English

Miss Prachi Kumari



Prize:

Second

Category:

English

Mr. Subrat Shekhar



Prize:

Third

Category:

English

Miss Nikita Agarwal

Quiz Competition



Prize:

First

Mr. R R Srivastava, Mr. C R Chakraborty



Prize:

Second

Dr. Satyajit Mukherjee, Dr. Animesh Jana



Prize:

Third

Dr. Sanjay Agarwal, Dr. Rachit Ghosh

Extempore Competition



Prize:

First

Dr. Suman Tewary



Prize:

Second

Ms. Chandni Kumari



Prize:

Third

Ms. Tanushree Ghosh

VIGILANCE AWARENESS COMPETITION AWARDS

VIGILANCE AWARENESS PROGRAM 2025

DRAWING COMPETITION



Mr. Arindam Sen (First)



Ms. Prachi Kumari (Second)



Ms. Goutami Mohanti (Third)

ESSAY COMPETITION [HINDI]



Mr. Somnath Das (First)



Mr. Raju Kumar (Second)



Mr. Pravin Anandrao Nagrare (Third)

ESSAY COMPETITION [ENGLISH]



Ms. Prachi Kumari (First)



Dr. Minati Sahu (Second)



Mr. Manoranjan Kumar Sinha (Third)

ELOCUTION COMPETITION [ENGLISH]



Mr. Vedprakash (First)



Mr. Subrat Shekhar (Second)



Mr. Virendra Kumar (Third)



Mr. Akash Pandey (Fourth)

Horticulture Awards 2026

CSIR–National Metallurgical Laboratory Horticulture Team has won several prizes for its entries in the Annual Flower Show 2026, Jamshedpur: First Prize- 8 nos., Second Prize- 15 nos., Third Prize- 5 nos. and a Champion Award in the cut-flower category.



Hindi Diwas Prizes



Miss. Twinkle



Dr. AK Sahu



Miss. Shruti



Mr. Raju



Mr. Viplav Vishal



Mr. Abhishek



This replica of Asoka Pilar 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.

Intellectual Property Rights

Copyrights : Filed or Registered			
S.No	**Title**	**Reg. No**	**Date of Reg.**
1	A website for conference mangement system : User Registration, Speakers, Sponsors, Payment Processing and User Database Management	2025021573	08-Sep-2025
2	Model Design of an integrated Urban Ore Recycling Plant	—-	—-

Designs: Filed or Registered			
S.No	**Title**	**Reg. No**	**Date of Reg.**
1	Manual cum semi-automatic lid arrangement for the pit furnance assembly		

Patent Applications Filed in India				
S.No	**Title**	**Inventors**	**Filing Date**	**Appl. No.**
1	Rotary Coating System for Galvanizing, Sol-Gel Dipping and Electrodeposition Process	Walunj Mahesh Gulab, Yenni Usha, Nimai Haldar	09-Apr-2025	202531035316
2	A process for Fe-based medium-entropy alloy with enhanced strength-ductility synergy	Vikas Shivam, Shubhada Kar, Gaurav Kumar Bansal, Avanish Kumar Chandan, Gopi Kishor Mandal, Vikas Chandra Srivastava	13-Oct-2025	202511098901
3	An Apparatus and a Process for the Preparation of Highly Metallised Low Sulphur Bio Sponge Iron	Madhurai Malathi, Dayanand Paswan, Alok kumar Meher	24-Feb-2026	202611022147
4	Development Of Magneto Strictive Heusler-Amorphous-Nanostructured System And A Process For Preparation Thereof	Ashis Kumar Panda, Somnath Das, Premkumar Murugaiyan, Rajat Kumar Roy, Abhishek Kumar Singh, Nimal Haldar	03-Mar-2026	202611025442

Patents Granted in India				
S.No	**Title**	**Inventors**	**Comp. Filing Date**	**Appl. No.**
1	A Process for Production of Highly Metallised Directly Reduced Iron (DRI) from Mill Scale and Lean Grade Non-Coking Coal in Tunnel Kiln	Dayanand Paswan, Madhurai Malathi, Debajyoti Bandyopadhyay, Madan Mohanasundaram, Ammasi Ayyandurai, Sarbeswar Thatoi	08-Jan-2019	201911000836
2	A Process For The Preparation Of High Induction Fe-Based Amorphous And Nanocomposite Alloy Strip	Premkumar Murugaiyan, Rajat Kumar Roy, Ashis Kumar Panda, Amitava Mitra	22-Jan-2019	201911002609
3	Medium Manganese High Strength-Ductility Steel Sheet And Process For Preparation Thereof	Biraj Kumar Sahoo, Avanish Kumar Chandan, Gaurav Kumar Bansal, Bandari Ravi Kumar, Sandip Ghosh Chowdhury, Anjana Deva, Biswajit Sarkar	01-Sep-2020	202011037771
4	A Process For Oxidative Dissolution Of Copper From Sulfides Using Surfactant Assisted Chlorine Leaching	Rajanikant Choudhari, Devarata Mishra, Shivendra Sinha, Shaurabh Shekhar, Kamlakanta Sahu, Archana Agrawal	05-Oct-2021	202111045216



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



Atomizer Facility

SCI - Publications

1. Abhilash; Maheswari, MU; Reddy, KR; Aminabhavi, TM; Aravindan, V; Meshram, P, Recycling strategies for renewable graphite and other carbon nanomaterials from used batteries: A review, JOURNAL OF CLEANER PRODUCTION, 2025, 493, 144871, 10.1016/j.jclepro.2025.144871
2. Abhilash; Shrivastava, SK; Rahman, MR; Meshram, Pratima, Red Mud Neutralisation by CO2 Promotes Alkali Recovery and Higher Scandium Extraction, WASTE AND BIOMASS VALORIZATION, 2025, 16, 1989, 1997, https://doi.org/10.1007/s12649-024-02791-y
3. Aldbea, FW; Vazques-Vazquez, C; Abobaker, MA; Alsteeni, AY; Saad, A; Sharma, A; Singh, PK; Diantoro, M; May, M; Abdullah, T; Edhirej, A; Aldosari, SM; Kraini, M Structural and optical properties of α aluminum oxide prepared by sol-gel method, CURRENT APPLIED PHYSICS, 2025, 71, 85, 90, 10.1016/j.cap.2024.12.008
4. Alex, TC; Kailath, AJ; Kumar, R Influence of mechanical activation on boehmite (γ-AlOOH) to γ-Al2O3 transformation: differential scanning calorimetric (DSC) analysis, JOURNAL OF ALLOYS AND COMPOUNDS, 2025, 1037, 182083, 10.1016/j.jallcom.2025.182083
5. Alex, TC; Singla, R; Sahoo, DP; Mehta, KD; Kumar, S, Avenues of resources efficiency enhancement in iron and steel production, MINERALS ENGINEERING,2025,222, 109160, 10.1016/j.mineng.2024.109160
6. Ammasi, A; Pal, J, Utilisation of Jhama coal as a carbon source in hematite ore pelletising, CANADIAN METALLURGICAL QUARTERLY, 2025, 10.1080/00084433.2025.2575237
7. Ammasi, A; Prasad, A; Kumar, S, Tailoring of Solidification and Crystallization Behavior of Blast Furnace Slag for Developing Glass-Ceramics During Melt Cooling, JOURNAL OF SUSTAINABLE METALLURGY, 2025, 11, 1, 616, 627, 10.1007/s40831-025-01007-4
8. Andavarapu, Mohana Rao; Prasad, R, Efficient beneficiation of difficult-to-wash Indian low volatile coking coal fines through Magotteaux flotation, INTERNATIONAL JOURNAL OF COAL PREPARATION AND UTILIZATION, 2025, 10.1080/19392699.2025.2529405
9. Ansari, Mohd Furkan; Bansal, G.K.; Mandal, Gopi Kishor; Bhattacharyya, Abir, Role of annealing conditions prior to cold rolling on microstructure and tensile deformation behavior of a medium-Mn steel, MATERIALIA, 2025, 42, 102502, https://doi.org/10.1016/j.mtla.2025.102502
10. Anuraag, NS; Kumar, U; Pradhan, S; Shaw, SK; Sharma, A; Sinha, I; Prasad, NK, Rhombohedral phase high-entropy alloy of AlMnCuZnBi as a photo-Fenton catalyst for methyl orange degradation, JOURNAL OF ALLOYS AND COMPOUNDS,2025,1010,177142, https://doi.org/10.1016/j.jallcom.2024.177142
11. Arif, SM; Bar, HN; Ghosh, M; Hazra, B; Ghorai, S; Mandal, D, Impact of Quenching and Partitioning Time on Microstructures, Mechanical and Fatigue Properties of High-Strength Steel, TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS, 2025, 78, 9, 214, 10.1007/s12666-025-03698-5
12. Arif, SM; Bar, HN; Sahoo, BK; Chaudhary, C; Mandal, D, Effect of Quench and Partitioning Treatment on Microstructure, Tensile Properties, and Low Cycle Fatigue Behavior of Low-Carbon High Strength Steel, JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE, 2025, 34, 18, 19933, 19944, 10.1007/s11665-025-10737-1
13. Arohi, AC; Nayak, P; Punyamanthula, KK; Ramesh, S; Tarafder, S; Frenzel, J; Sen, I, Processing-microstructure-functional properties correlation for NiTi-based pseudoelastic shape memory alloy, JOURNAL OF MATERIALS SCIENCE, 2025, 60, 20, 8515, 8535, 10.1007/s10853-025-10894-7
14. Austen, IC; Chennakesavulu, K; Reddy, GR; Vasumathi, N; Kumari, A; Gharai, M; Kumar, TA; Kumar, TVV, Utilizing a sustainable surfactant from Cucurbita pepo seeds for eco-friendly flotation of non-coking coal in sustainable energy applications, BIOMASS CONVERSION AND BIOREFINERY, 2025, 15, 17, 24465, 24481, https://doi.org/10.1007/s13399-024-05359-x

15. "Badkoobeh, Farzad; Raygan, Shahram; Rassizadehghani, Jafar; Kwak, Tae-Yang; Kim, Bong-Hwan; Chandan, Avanish Kumar; Bansal, Gaurav Kumar"Unraveling the role of subcritical annealing time before intercritical annealing of a cold-worked Ni-Cr-Mo-V alloy steel: Phase transformations and mechanical properties, JOURNAL OF ALLOYS AND COMPOUNDS, 2025, 1010, 178305, 10.1016/j.jallcom.2024.178305

16. Bagui, S; Singh, CV; Mahato, B; Vijay, R Creep deformation behavior of an oxide dispersion strengthened modified iron aluminide alloy, INTERMETALLICS, 2025, 184, 108860, https://doi.org/10.1016/j.intermet.2025.108860W

17. Banerjee, T; Kundu, Rajen, Compatibility of Li Alloy Anodes with Solid-State Electrolytes: An Evaluation, ACS APPLIED ENERGY MATERIALS,2025, 8, 12, 7780, 7804, 10.1021/acsaem.5c00373

18. Behera, G; Kar, MK; Chakladar, S; Önal, MAR; Borra, CR Recovery of alumina and soda from a titanium-rich bauxite residue: a phase evolution study, CANADIAN METALLURGICAL QUARTERLY, 2025, 10.1080/00084433.2025.2571301

19. Bharti, A; Dey, R; Sivaprasad, S; Tarafder, S; Bhattacharyya, A Deformation response and microstructure evolution in 304LN stainless steel subjected to multiaxial fatigue loading under different strain paths, INTERNATIONAL JOURNAL OF PRESSURE VESSELS AND PIPING, 2025, 214, 105452, 10.1016/j.ijpvp.2025.105452

20. Bharti, A; Maharaja, H; Mishra, S; Sivaprasad, S; Bhattacharyya, A Effect of strain amplitude on low-cycle fatigue behavior of an alpha Cu-Zn alloy, MATERIALS TODAY COMMUNICATIONS, 2025, 48, 113267, 10.1016/j.mtcomm.2025.113267

21. Chaithanya, PVS; Jena, PSM; Pradhan, SK; Singh, R; Sahu, JK, Influence of γ'-Ni3(Al, Ti) precipitate morphology and lattice misfit on the oxidation behavior of Ni-based superalloy IN740H, CORROSION SCIENCE, 2025, 257, 113268, 10.1016/j.corsci.2025.113268

22. Chaithanya, PVS; Jena, PSM; Pradhan, SK; Singh, R; Sahu, JK, On the Dominance of Grain Size Over Grain Boundary Character in Determining the Oxidation Behavior of Ni-Based Superalloy IN740H, JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE, 2025, 34, 18, 19992, 20005, 10.1007/s11665-025-10763-z

23. Chakladar, S; Banerjee, R; Mohanty, A; Chattopadhyay, SK; Chakravarty, S Extractability, and occurrence of rare earth elements in bottom ash through sequential leaching and pre-treatment, ENERGY SOURCES PART A-RECOVERY UTILIZATION AND ENVIRONMENTAL EFFECTS, 2025, 47, 1, 10, 20, https://doi.org/10.1080/15567036.2024.2433705

24. Chakraborty, Jay; Sanket, Kumar; Srikar, S.; Nambissan, P. M. G.; Chandan, A. K.; Jena, P.S.M. Lattice distortion in nanocrystalline Fe powder studied by positron annihilation and X-ray diffraction, PHILOSOPHICAL MAGAZINE, 2025, 105, 9-10, 546, 576, https://doi.org/10.1080/14786435.2024.2434672

25. Chakraborty, R; Mandal, M; Mohanty, I; Bagui, S; Kumar, NSS; Raju, KVV; Saha, P, The Effect of Process Parameters and Post-fabrication Heat Treatment on the Microstructure and Mechanical Properties of Martensitic Steel SS420 Developed through Laser Powder Bed Fusion Technique, JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE, 2025, 34, 21, 25581, 25592, 10.1007/s11665-025-11168-8

26. Chandan, AK; Sahoo, BK; Bansal, GK; Ghosh, M Root Cause Analysis for the Failure of an Air Compressor Impeller, TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS, 2025,78, 1, 23, 10.1007/s12666-024-03534-2

27. Chandan, AK; Sahoo, BK; Garg, A; Meena, LK; Bansal, GK; Munda, P; Ghosh, M, Discerning the degradation and failure mechanism of T91 grade reheater tube through integrated experimental and simulation approach, ENGINEERING FAILURE ANALYSIS, 2025, 176, 109621,10.1016/j.engfailanal.2025.109621

28. Chandel, SS; Lavakumar, A; Randhawa, NS; Singh, PK, Unique hot stage modification technique to enhance cementitious properties of electric arc furnace steel slag, JOURNAL OF ENVIRONMENTAL MANAGEMENT, 2025, 376, 124398, 10.1016/j.jenvman.2025.124398

29. Chandel, SS; Singh, PK; Randhawa, NS Enhancing recycling potential: Thermodynamic and non-isothermal kinetics of solid state carbothermic reduction of electric arc furnace slag, THERMAL SCIENCE AND ENGINEERING PROGRESS, 2025, 65, 103941, 10.1016/j.tsep.2025.103941

30. Chaurasia, PK; Barik, BK; Das, Atanu;De, Amitava Evaluating porosity formation in gas metal arc directed energy deposition of an aluminium alloy, WELDING IN THE WORLD, 2025, 30, 1, 14, 24, https://doi.org/10.1177/13621718241298851

31. Dak, G; Guguloth, K; Bhattacharyya, A; Kumar, P; Pandey, C, Failure Study of Creep and High-Temperature Tensile Tested Tungsten Inert Gas Welded P92 Steel and AISI 304L Steel Dissimilar Weld Joints, JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE, 2025, 34, 1, 658, 685, https://doi.org/10.1007/s11665-023-09070-2

32. Dak, G; Guguloth, K; Sirohi, S; Adin, MS; Pandey, C, Creep and High-Temperature Tensile Deformation Behavior of the TIG Welded P92/304L Dissimilar Steel Weld Joints, JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE, 2025, 34, 11, 10659, 10684, https://doi.org/10.1007/s11665-024 09872-y

33. Das, Abhinaba, Samanta Roy Choudhury, A. & Bhattacharya, P., Ti3C2-Mxene-dispersion and morphology controlled battery-type nickel cobalt sulphide based nanocomposites for the application as aqueous asymmetric supercapacitor with improved rate, DISCOVER NANO, 2025, 20, 1, 216, https://doi.org/10.1186/s11671-025-04396-3

34. Das, Atanu; Kumar, A; Bagui, S; Singh, CV; Haldar, N; Vajpai, S; Srivastava, VC; Mandal, GK Effect of process parameters and orientation on the tensile and low cycle fatigue properties of low-carbon steel builds manufactured by directed energy deposition-gas metal arc process, WELDING IN THE WORLD, 2025, 69, 957, 971, https://doi.org/10.1007/s40194-024-01873-8

35. Das, M; Kumar, S; Singh, PK; Ghosh, M Correlating Microstructure with Mechanical Properties for Different Regions of Dissimilar Metal-Welded Joints, JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE, 2025, 34, 22, 26478, 26491, 10.1007/s11665-025-11282-7

36. Das, Rupa; Kumari, P; Kumar, K; Kundu, Rajen; Sahu, R, From Fossil Fuel to Functional Electrode: An Outlook on Coal-Derived Anodes for Energy Storage Devices, ENERGY & FUELS, 2025, 39,3,6,17234, 17257, 10.1021/acs.energyfuels.5c03677

37. Das, Rupa; Kumari, P; Kumar, K; Sen, A; Arif, M; Mediboyana, H; Bag, SS; Sahu, R; Kundu, Rajen Nitrogen and Sulfur Co-doped Graphene Quantum Dots: A Strategy for Utilizing Coal as a Precursor for Functional Material, CHEMISTRYSELECT, 2025, 10, 43, e04949, 10.1002/slct.202504949

38. Das, S; Kumar, S; Pradhan, SK; Bandyopadhyay, TK; Mandal, S Implications of the microstructure on strength-ductility synergy in a novel B2-strengthened medium manganese advanced high strength steel MATERIALS SCIENCE AND ENGINEERING A-STRUCTURAL MATERIALS PROPERTIES MICROSTRUCTURE AND PROCESSING, 2025, 924, 124398, 10.1016/j.msea.2025.147798

39. Das, S; Mahato, DK; Panda, AK, Detection of carburization and defective weld in austenitic stainless steel using magneto-impedance arrayed sensor, JOURNAL OF MAGNETISM AND MAGNETIC MATERIALS, 2025, 615, 172811, 10.1016/j.jmmm.2025.172811

40. Das, S; Mahato, DK; Panda, AK; Murugaiyan, P; Roy, RK, Impact of chemical etching on stress induced magnetic anisotropy of amorphous microwires, JOURNAL OF MAGNETISM AND MAGNETIC MATERIALS, 2025, 633, 173547,10.1016/j.jmmm.2025.173547

41. Das, S; Mahato, DK; Panda, AK; Murugaiyan, P; Roy, RK, Impact of parametric controls and spatial flux distribution on the arrayed microwires of a giant magneto-impedance (GMI) sensor, PHYSICA SCRIPTA, 2025, 100, 7, 75916, 10.1088/1402-4896/add96f

42. Das, S; Mohanta, S; Kumar, A; Mishra, D; Sahu, KK, Extraction of vanadium from pet-coke gasification cinder part 1: Leaching kinetic studies in sulphuric acid medium, JOURNAL OF MINING AND METALLURGY SECTION B-METALLURGY,2025, 61, 3, 333, 344, 10.2298/JMMB250319026D

43. Das, TK; Dutta, C; Das, PK; Rajput, R; Bhakat, NK; Bhave, K; Sagar, SP, Real-Time In-Process Measurement and Control of Zinc Coating Weight: Assessing Eddy Current Sensor Proficiency in Industrial Applications, IEEE SENSORS JOURNAL, 2025, 25, 1, 1527, 1534,10.1109/JSEN.2024.3492253

44. Dash, A; Bansal, GK; Soni, S; Kurapati, GK; Kamaraj, A, Interplay Between Inclusion Evolution, Tensile Properties, and Volumetric Energy Density During Additive Manufacturing of 316L Stainless Steel, METALLURGICAL AND MATERIALS TRANSACTIONS B-PROCESS METALLURGY AND MATERIALS PROCESSING SCIENCE, 2025, 56, 6, 6198, 6211, 10.1007/s11663-025-03772-9

45. Dey, S; Chattoraj, I; Sivaprasad, S, Effect of pitting corrosion on fatigue life of T6 and T73 of 7075 aluminum alloy, INTERNATIONAL JOURNAL OF FATIGUE, 2025, 200, 109073, https://doi.org/10.1016/j.ijfatigue.2025.109073

46. Dubey, P Durable anti-icing copper-based alloy coating grown by the HVOF method, COLLOIDS AND SURFACES A-PHYSICOCHEMICAL AND ENGINEERING ASPECTS,2025, 725, 137730, 10.1016/j.colsurfa.2025.137730

47. Gangwar, A; Alla, SK; Sharma, A; Verma, M; Shaw, SK; Das, T, Mesoporous ZnO integrated CeF3 nanoparticles for X-ray PDT, SOLID STATE SCIENCES, 2025, 163, 107918,10.1016/j.solidstatesciences.2025.107918

48. Gaur, V; Vashishtha, P; Sahoo, BK; Bandari, RK; Das, R, Effect of Cryo-Rolling on the Microstructural Evolution and Mechanical Properties of Ti-6Al-4V Alloy, MATERIALS, 2025, 18, 23, 5296, 10.3390/ma18235296

49. Ghosh, D; Maharana, S; Panda Asit Baran, Bio-inspired nickel–iron-based organogel: an efficient and stable bifunctional electrocatalyst for overall water splitting at high current density, NANOSCALE, 2025, 17, 20, 12880, 12893, https://doi.org/10.1039/D5NR00589B

50. Gorain, NC; Walunj, MG; Soni, MK; Kumar, BR Effect of continuous annealing process on various structure parameters of martensite of dual-phase steels (vol 20, 29, 2020), ARCHIVES OF CIVIL AND MECHANICAL ENGINEERING, 2025, 25, 5-6, 288, 10.1007/s43452-025-01314-3

51. Halder, AK; Ghosh, R; Sahoo, B; Walunj, MG; Kumar, RR; Pathak, L; Pais, RS; Mandal, GK; Chakraborty, A; Mondal, A, Evaluation of High Temperature Phase Transformation, Deformation, and Corrosion Performance of Hot Dip Al-7Si-X (X=Mg, Cu, Sr, Sc) Alloy Coatings on Steel, JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE, 2025, 34, 23, 27664, 27679, https://doi.org/10.1007/s11665-025-11395-z

52. Hazra, A; Hossain, SM; Pramanick, AK; Ray, M Spontaneous Interfacial Alloying in Au@Ag Core@Shell Nanoparticles: Unraveling the Impact on Plasmonic Absorption, JOURNAL OF PHYSICAL CHEMISTRY C 2025, 129, 24, 10995, 11003, https://pubs.acs.org/doi/10.1021/acs.jpcc.5c02401

53. Husain, Md Murtuja; Munda, Parikshit; Rajinikanth, V.; Roy, Rajat Kumar, Metallurgical Failure Investigation of Boiler Bed Coil Tubes made of Carbon Steel of a Thermal Power Plant, JOURNAL OF FAILURE ANALYSIS AND PREVENTION, 2025, 25, 413, 428, 10.1007/s11668-025-02110-0

54. Jha, A; Chakladar, S; Patra, D; Chakravarty, S, Study of mineralogy and distribution of rare earth elements in coal block of Eastern Coalfield, India, INTERNATIONAL JOURNAL OF COAL PREPARATION AND UTILIZATION 2025, 45, 5, 969, 989, https://doi.org/10.1080/19392699.2024.2363859

55. Jha, G; Soren, S; Mehta, KD, A pilot-scale beneficiation study for removal of alumina and silica prior to metallurgical sintering, SADHANA-ACADEMY PROCEEDINGS IN ENGINEERING SCIENCES, 2025, 50,1, 41, 10.1007/s12046-025-02702-4

56. Kalshyan, RK; Mohanasundaram, M; Chowdhury, GM; Ghorai, S, Synthesis of calcium ferrite using microwave susceptor heating, CANADIAN METALLURGICAL QUARTERLY, 2025, 64, 4, 1803, 1813, https://doi.org/10.1080/00084433.2024.2430058

57. Kar, S; Shivam, V; Bagui, S; Mahato, B; Srivastava, VC; Mandal, GK Promising room to high temperature properties in a novel Ni-Fe-Cr-based medium entropy alloy prepared using commercial-grade materials, JOURNAL OF ALLOYS AND COMPOUNDS, 2025, 1032, 181118, https://doi.org/10.1016/j.jallcom.2025.181118

58. Karade, VC; Gour, Kuldeep Singh; He, MR; Jang, J; Enkhbat, T; Lee, MW; Kim, J; Sutar, SS; Dongale, TD; Ellingson, RJ; Yun, JS; Kim, JH; Park, J Machine Learning Drives a Path to Defect Engineering for Suppressing Nonradiative Recombination Losses in Cu2ZnSn(S,Se)4 Solar Cells ACS APPLIED MATERIALS & INTERFACES, 2025, 17, 24, 35382, 35395, https://pubs.acs.org/doi/10.1021/acsami.5c01764

59. Karri, M; Verma, A; Singh, JB; Singh, CV, Effect of borosilicate glass environment on creep behaviour of alloy 690 at temperatures over 800-1000 °C, JOURNAL OF MATERIALS SCIENCE, 2025, 60, 4, 8, 25114, 25133, 10.1007/s10853-025-11751-3

60. Khatri, N; Berwal, S; Singh, B; Tewary, S; Manjunath, K; Goel, S, Single-step precision manufacturing of ZnSe lenses for FLIR thermal imaging: From atomic insights to lab-scale fabrication and integration JOURNAL OF MANUFACTURING PROCESSES, 2025, 142, 468, 481, 10.1016/j.jmapro.2025.03.082

61. Kishor, M; Kaushik, P; Ramavajjala, AK; Nahid, SAG; Modalavalasa, VK; Gorja, SR; Rao, AKP, Catalytic-Role of Sr on the Evolution of Fe-rich Phases in Recycled Al-Si-Fe Alloys, JOM, 2025,7,7, 1,1, 8309, 8318, 10.1007/s11837-025-07618-2

62. Kishore, K; Chandan, AK; Mukhtarova, K; Kumar, S; Das, A; Arora, KS; Kawasaki, M; Gubicza, J; Chowdhury, SG Non-monotonic plasticity and hardness evolution of an additively manufactured 316L stainless steel at very high shear strains, MATERIALS SCIENCE AND ENGINEERING A-STRUCTURAL MATERIALS PROPERTIES MICROSTRUCTURE AND PROCESSING, 2025, 935, 148354,10.1016/j.msea.2025.148354

63. Kishore, K; Patra, S; Chandan, AK; Mishra, V; Sahoo, BK; Aamir, M; Mishra, G; Arora, KS, Simultaneous Improvement in Load-Bearing Capacity and Energy Absorption of Resistance Spot-Welded Medium Mn Steel: An Integrated Simulation and Experimental Approach, METALLURGICAL AND MATERIALS TRANSACTIONS A-PHYSICAL METALLURGY AND MATERIALS SCIENCE, 2025, 56, 5, 1838, 1857, 10.1007/s11661-025-07748-x

64. Kumar, A; Bag, S; Srivastava, VC, Bi-directional scanning strategies for residual stress management by tailoring microstructural evolution in directed energy deposition of 9Cr-1Mo steel, JOURNAL OF MATERIALS PROCESSING TECHNOLOGY, 2025, 341, 118906, https://doi.org/10.1016/j.jmatprotec.2025.118906

65. Kumar, A; Bag, S; Srivastava, VC, Role of inter-layer dwell time on residual stress generation of a thin wall structure by directed energy deposition of ferritic steel, MATERIALS CHEMISTRY AND PHYSICS, 2025, 340, 41, 130807, 10.1016/j.matchemphys.2025.130807

66. Kumar, A; Das, D; Raj, ND; Bag, S; Srivastava, VC, Comparison of Machine Learning Performance for the Prediction of Melting Efficiency and Bead Geometry in wire Arc Additive Manufacturing Process, ARCHIVES OF METALLURGY AND MATERIALS, 2025, 70, 1, 29, 38, 10.24425/amm.2025.152503

67. Kumar, A; Guguloth, K; Pandey, SM; Sirohi, S; Swierczynska, A; Fydrych, D; Pandey, C Microstructure degradation and creep failure study of the dissimilar metal welded joint of heat-resistant steel and Inconel 617 alloy tested at 650 °C and applied stress range of 100-150 MPa, INTERNATIONAL JOURNAL OF PRESSURE VESSELS AND PIPING, 2025, 214, 105370, 10.1016/j.ijpvp.2024.105370

68. Kumar, A; Kumar, A; Kumar, S, Defect Healing Mechanism in Fe-Cr-Ni Single Crystal Alloy Under Multiaxial Cyclic Loading: A Molecular Dynamics Simulation-Based Study, FATIGUE & FRACTURE OF ENGINEERING MATERIALS & STRUCTURES, 2025, 48, 10, 4375, 4390, 10.1111/ffe.70042

69. Kumar, A; Kumar, A; Kumar, S, Nanostructure Evolution and Rupture Mechanisms in Layered Fe-Cr-Ni Alloy under Multiaxial Tensile Deformation: A Molecular Dynamics Study, JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE, 2025,34, 21, 24542, 24555,10.1007/s11665-025-11055-2

70. Kumar, A; Kumar, S; Kumar, A; Sharma, S, Prediction of creep degradation in Fe-Cr-Ni single-crystal alloys for high-temperature applications: a molecular-dynamics and machine-learning approach, MECHANICS OF TIME-DEPENDENT MATERIALS, 2025, 29, 1, 8, https://doi.org/10.1007/s11043-024-09745-w

71. Kumar, A; Soni; Mishra, SK, Al-Cr-Si-N coating: Substrate temperature effect on mechanical and scratch behaviour, SURFACE ENGINEERING, 2025, 41, 6, 684,694, 10.1177/02670844251356711

72. Kumar, G; Kumar, A; Nandan, G; Mukherjee, S; Kumar, A; Bar, HN Monotonic deformation behavior of SA333 Gr-6 steel: Dynamic strain aging, INTERNATIONAL JOURNAL OF PRESSURE VESSELS AND PIPING, 2025, 216, 105511, .10.1016/j.ijpvp.2025.105511

73. Kumar, K; Kundu, Rajen, Impact of Different Lithiation Mechanisms Across Transition Metal Oxide Anodes on Performances for High-Energy Lithium-Ion Batteries, CHEMICAL RECORD, 2025, 25, 10, e202500182, 10.1002/tcr.202500182

74. Kumar, Kundan; Kundu, Rajen, Boosting the Performance of a Highly Cobalt-Doped Na3V2(PO4)3/C Nanocomposite via a Dual Doping Strategy for High-Performance SIB Cathodes ACS APPLIED ELECTRONIC MATERIALS, 2025, 7, 8, 3363,3371, 10.1021/acsaelm.5c00065

75. Kumar, Kundan; Kundu, Rajen, Enlightenment of the Underestimated Parameters for a Fast-Charging Energy-Dense Anode for Lithium-Ion Batteries: An Outlook, ENERGY & FUELS, 2025, 39, 18, 8354, 8368, 10.1021/acs.energyfuels.5c00335

76. Kumar, Nikhil; Bhattacharya, Pallab; Jana, Animesh; Kumar, Sunil, Synergism induced multifunctional electroactivity of Co-Ni bimetallic metal-organic frameworks towards oxygen evolution reaction and supercapacitors, INORGANIC CHEMISTRY COMMUNICATIONS, 2025, 177, 114445, https://doi.org/10.1016/j.inoche.2025.114445

77. Kumar, P; Chakravarty, S; Majumder, AK, Relationship between petrological characteristics and gross calorific value of coal, FUEL, 2025, 380, 133180, https://doi.org/10.1016/j.fuel.2024.133180

78. Kumar, P; Tyeb, MH; Mishra, S; Chakravarty, S; Majumder, AK, Limitations Associated with Proximate Analysis-Based Gross Calorific Value Modeling for Coals, MINERAL PROCESSING AND EXTRACTIVE METALLURGY REVIEW, 2025, 46, 3, 362, 373, https://doi.org/10.1080/08827508.2024.2334962

79. Kumar, R; Mandal, SK; Kumar, D; Kumar, S, Enhancing the thermal property and biocompatibility of hydroxyapatite nanocomposites reinforced with reduced graphene oxide for biomedical applications, CERAMICS INTERNATIONAL, 2025, 51, 25, 45044, 45060, 10.1016/j.ceramint.2025.07.224

80. Kumar, S; Kumar, N; Meena, LK; Kumar, A; Kumar, R; Yadav, VS; Pandey, LM Atomistic simulation and experimental study of water induced iron corrosion and its prevention mechanism: Estimation of excess pair entropy and atomic charge migration at interface, SURFACES AND INTERFACES, 2025, 74, 107647, 10.1016/j.surfin.2025.107647

81. Kumar, S; Sahu, RK, External electric field induced atomic charge migration and surface degradation of CsPbI3: A reactive molecular dynamics simulation based study, MATERIALS CHEMISTRY AND PHYSICS, 2025, 333, 130350, 10.1016/j.matchemphys.2024.130350

82. Kumari, P; Das, Rupa; Kumar, K; Kundu, Rajen, Compatibility of Hard Carbon Anode in Li/Na-Ion Batteries: Precursor and Performance Insights, ACS APPLIED ELECTRONIC MATERIALS, 2025, 7, 19, 8800, 8820, 10.1021/acsaelm.5c01488

83. Kumari, P; Kundu, Rajen, Heteroatom-Doped Graphene Quantum Dots: Recent Advancements in Energy Storage, Optical, and Optoelectronic Applications, CHEMISTRY-AN ASIAN JOURNAL, 2025, 20, 22, 10.1002/asia.70293

84. Kumari, P; Kundu, Rajen, Outlook of Doping Engineering in NMC and LMNO Cathode Materials for Next-Generation Li-Ion Batteries, ENERGY & FUELS, 2025, 39, 23, 10933, 10966, 10.1021/acs.energyfuels.5c01527

85. Lakshmi, T; Ali, AMB; Mundari, NDA; Mishra, T; Aman, N Integration of Cu2O-NiTiO3 as an efficient p-n heterojunction visible light photocatalytic system for the simultaneous removal of Cr (VI) and Alizarine Cyanine Green dye, MATERIALS RESEARCH BULLETIN, 2025, 183, 113213, 10.1016/j materresbull.2024.113213

86. Lee, JC; Kurniawan, K; Suh, YJ; Pandey, BD, Uses of H2 and CO2 gases in hydrometallurgical processes: Potential towards sustainable pretreatment, metal production and carbon neutrality, HYDROMETALLURGY, 2025, 234, 106468, 10.1016/j.hydromet.2025.106468

87. Maurya, A; Qu, YT; Gour, KS, Advancements in AgBiS2 thin film solar cells: strategies, challenges, and perspectives, JOURNAL OF PHYSICS-ENERGY, 2025, 7, 4, 42006, 10.1088/2515-7655/adf7da

88. Mayuri, S; Jha, NS; Jha, SK; Sharma, P Enhanced Electrochemical Detection for DNA Hybridization on Core-Shell Magnetic Silica Sphere Gold Nanoparticles, LANGMUIR, 2025, 41, 40, 27051, 27063, 10.1021/acs.langmuir.5c01401

89. Meshram, Pratima; Agarwal, N; Abhilash, A review on assessment of ionic liquids in extraction of lithium, nickel, and cobalt vis-à-vis conventional methods, RSC ADVANCES, 2025, 15, 11, 8321, 8334, 10.1039/d4ra08429b

90. Meshram, Rohit B, Sahoo, K.L., Yadav, G.D.; Marathe, Kumudini V. The Environmental Footprint of the Calcination Process in the Steel Industry Process Integration and Optimization for Sustainability, 2025, 9, 1327, 1338, https://doi.org/10.1007/s41660-025-00511-0

91. "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, 2025, 16,3, 69, 86, 10.1615/SpecialTopicsRevPorousMedia.2024051210

92. Meshram, Rohit B; Sahoo, KL; Yadav, GD; Marathe, KV, Life Cycle Assessment of Oxygen and Nitrogen Production in Iron and Steel Industry and Its Regional Comparison, TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS, 2025, 78, 6, 132, 10.1007/s12666-025-03610-1

93. Mishra, Surya Prakash; Kamaraj, Ashok; Rajinikanth, V; Rahul, MR A, computer vision-based approach for identification of non-metallic inclusions in the steel industry products, JOURNAL OF INDUSTRIAL INFORMATION INTEGRATION, 2025, 46, 100860,10.1016/j.jii.2025.100860

94. Modalavalasa, Uday Bhaskara Rao; Murugaiyan, P; Jana, A; Krishna, KG; Saket, RK Self-supported dealloyed nickel-amorphous ribbons for enhanced electrocatalysis MATERIALS LETTERS, 2025, 399, 139099, 10.1016/j.matlet.2025.139099

95. Mohanasundaram, M; Vasan, AK; Dhopte, SM; Sheikh, RR; Seth, D; Meshram, Rohit B, Life cycle environmental impacts of the electrothermal magnesium production: a comparative assessment with the Pidgeon and electrolysis methods, JOURNAL OF MATERIAL CYCLES AND WASTE MANAGEMENT, 2025, 27, 5, 3266, 3277, 10.1007/s10163-025-02282-9

96. 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, 2025, 45, 10, 2358, 2374, https://doi.org/10.1080/19392699.2024.2424769

97. Mohapatra, C; Ayushi, S; Sarma, R; Sharma, A; Meena, SS; Pataniya, PM; Sumesh, CK; Prasad, NK, Zr substituted (Fe3C/γ-Fe2O3)@C/NF as a high-performance electrocatalyst for sustainable water splitting and H2 production, CERAMICS INTERNATIONAL, 2025, 51, 27, 52649, 52661, 10.1016/j.ceramint.2025.09.022

98. Mohapatra, C; Pradhan, S; Ayushi, S; Sharma, Ankur; Sumesh, CK; Prasad, NK, Zr-substituted maghemite catalyst for water splitting activity, INTERNATIONAL JOURNAL OF HYDROGEN ENERGY, 2025,143, 213, 222, https://doi.org/10.1016/j.ijhydene.2025.05.378

99. Moulali, D; Kumar, A; Guguloth, K; Sirohi, S; Tyagi, CS; Natu, H; Pandey, C, Laser welding on 10 mm thick grade 92 steel for USC applications: microstructure and mechanical properties, ARCHIVES OF CIVIL AND MECHANICAL ENGINEERING, 2025, 25, 2, 90, 10.1007/s43452-025-01144-3

100. Mukherjee S; Panda M; Nath SK; Meshram P; Meshram Rohit B. CO2 sequestration through mineral carbonation for building material Environmental Progress & Sustainable Energy, 2025, 70308, https://doi.org/10.1002/ep.70308

101. Murugesan, A. P.; Kumar, Ashok; Humane, Manoj, Efect of Diferent Strain-Path Cold Rolling on Mechanical Properties, Microstructures and Texture Evolution in Aluminum–Copper–Lithium (AA 8090) Alloy, Metallography, Microstructure, and Analysis, 2025, 14, 20, 43, https://doi.org/10.1007/s13632-024-01159-x

102. Murugesan, AP; Kumar, A; Humane, M, Effect of Downstream Processing on Mechanical Properties, Microstructures, and Evolution of Texture in Aluminum-Copper-Lithium (AA 2199) Alloy, TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS, 2025, 78,8, 199, 10.1007/s12666-025-03648-1

103. Nag, A; Gandhi, D; Jayabalan, B; Premkumar, M; Pathak, A; Bijalwan, P; Bhagat, AN; Bhadu, M Stress induced MnZn ferrite synthesis from pickling plant by-product of steel industry JOURNAL OF THE AUSTRALIAN CERAMIC SOCIETY, 2025, 61, 5, 1979, 1994, https://doi.org/10.1007/s41779-025-01221-z

104. Nanda, AK; Kumar, P; Poddar, P; Sivasubramanian, J; Basu, A; Gupta, G; Singh, SS; Gupta, M; Ganguly, S Influence of Sn and Al contents on the microstructure evolution and mechanical performance of stir-cast Mg-3.0Al-0.5Si alloy, JOURNAL OF MATERIALS SCIENCE, 2025,60, 23, 9758, 9790, https://doi.org/10.1007/s10853-025-10975-7

105. Naveena; Mathew, MD; Komazaki, SI Review of impression creep test: a small-scale testing method for evaluation of creep properties of materials, FRONTIERS IN MATERIALS, 2025, 12, 1599729, https://doi.org/10.3389/fmats.2025.1599729

106. Nayak, D; Nayak, S; Ammasi, A; Sathish, R; Dash, N; Rath, SS, Biochar as a sustainable alternative to conventional carbon additives in iron ore pelletization, FUEL, 2025, 402, 136063, 10.1016/j.fuel.2025.136063

107. Pal, AS; Godha, A; Sharma, A; Pimple, SY; Singh, A; Billare, P; Makineni, SK; Knowles, KM; Basu, J, Chessboard-like nanostructure evolution in Li0.48Nd0.5TiO2.99 perovskites and its effects on electrochemical properties, JOURNAL OF THE AMERICAN CERAMIC SOCIETY, 2025, 108,7, 10.1111/jace.20488

108. Panigrahi, M; Ganguly, RI; Sapkal, S; Dash, RR; Panda, HS, Exploration of dielectric and ferroelectric properties of waste fly ash/kaolin composite: synergistic effect on impedance and polarizability, JOURNAL OF MATERIALS SCIENCE-MATERIALS IN ELECTRONICS, 2025, 36, 22, 1408, 10.1007/s10854-025-15463-x

109. Panigrahi, MK; Ganguly, RI; Dash, RR, Performance of Dielectric Material Thermal Power Plant Waste, JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE, 2025, 34, 22, 26092, 26097, 10.1007/s11665-025-11413-0

110. Parween, R; Rani, K; Panda, R; Sharma, A; Ambade, B; Jha, MK, Hydrometallurgical separation and purification to recover iron (Fe), copper (Cu), nickel (Ni), lithium (Li), cobalt (Co), and manganese (Mn) metals from the leach liquor of discarded LIBs, SEPARATION AND PURIFICATION TECHNOLOGY, 2025, 364, 132325, 10.1016/j.seppur.2025.132325

111. Parween, R; Rani, K; Panda, R; Yoo, K; Alorro, RD; Ambade, B; Jha, MK Kinetics of metals dissolution from EV batteries for the development of sustainable technology, MINERALS ENGINEERING, 2025, 232, 109512, 10.1016/j.mineng.2025.109512

112. Pradhan, P; Dey, S; Manna, K; Panda, AB; Pal, S, In situ synthesis of a photocatalyst using TiO2 QDs-immobilized functionalized galactomannan for degradation of organic pollutant, JOURNAL OF WATER PROCESS ENGINEERING, 2025, 69, 106617, https://doi.org/10.1016/j.jwpe.2024.106617

113. Pradhan, SK; Belyakov, A; Satapathy, DK; Tripathy, S; Sahoo, BK; Chowdhury, SG, On stereological analysis of grain boundary character distribution in post-annealed LPBF 316L stainless steel, MATERIALS LETTERS, 2025, 395, 138730, 10.1016/j.matlet.2025.138730

114. Pratihar, B; Jana, A; De, S, Interaction of Borophene and Cobalt Phosphate for Electrocatalytic Urea Oxidation Reaction, CHEMCATCHEM, 2025, 17, 14, 10.1002/cctc.202500421

115. Pratihar, B; Jana, A; De, S, Plasmon-Enhanced, Electrocatalytic Oxygen Evolution Reaction by Au Nanoparticles-Supported Borophene Nanosheets, CHEMCATCHEM, 2025, 17, 23, 10.1002/cctc.202501200

116. Rahman, A; Husain, MM; Prasad, N, Evaluation of the microstructure, mechanical properties, corrosion resistance, and cytocompatibility of stir-cast Ca- and Zn-modified WE43 nanocomposites for biodegradable orthopedic implants, JOURNAL OF ALLOYS AND COMPOUNDS, 2025, 1037, 182336, 10.1016/j.jallcom.2025.182336

117. Rai, RK; Sahu, VK; Pradhan, SK; Sahoo, BK; Maji, P; Tripathy, S; Chowdhury, SG; Rajinikanth, V, On the influence of deformation schedule and finish rolling temperature on the microstructure and micro-texture evolution during hot rolling of Fe-3 wt% Si steel, MATERIALS TODAY COMMUNICATIONS, 2025, 46, 112613, 10.1016/j.mtcomm.2025.112613

118. Rani, K; Panda, R; Sharma, A; Meher, AK; Ambade, B; Yoo, K; Jha, MK, Hydrometallurgical Recovery of Critical Metal Indium from Scrap LCD Panels, MINERALS, 2025,15, 10, 1084, 10.3390/min15101084

119. Rao, AU; Tiwari, SK; Dubey, P; Saxena, V; Chawla, AK, Impact of working pressure on the crystallinity and mechanical properties of vanadium nitride coatings deposited in helium/nitrogen reactive plasma, JOURNAL OF VACUUM SCIENCE & TECHNOLOGY A, 2025, 43, 4, 43102, 10.1116/6.0004513

120. Rao, Mudila D; Singla, R; Meshram, RB, Recycling of silicon and silver from end-of-life crystalline-Si solar PV cells, CANADIAN METALLURGICAL QUARTERLY, 2025, 10.1080/00084433.2025.2569224

121. Rao, SP; Sivaprasad, S; Bar, HN; Dey, PP, Experimental investigation and computational modelling of 304LN stainless steel under constant and variable strain path multiaxial loading conditions, INTERNATIONAL JOURNAL OF FATIGUE, 2025, 190, 108581, https://doi.org/10.1016/j.ijfatigue.2024.108581

122. Ravi, R; Mahato, A; Murugaiyan, PK; Meena, LK; Dubey, P, Investigation of corrosion and wear performance of Fe50(Cr-Mo)25(B0.5C0.4Si0.1)25 amorphous alloy coatings: Flakes size perspective, MATERIALS TODAY COMMUNICATIONS, 2025, 49, 113988, 10.1016/j.mtcomm.2025.113988

123. Rizwee, M; Kumar, D; Husain, MM, Impact of Heat Treatment on Microstructure and Mechanical Characteristics of Laser Powder Bed Fused Ti-6Al-4V Alloy: A Comprehensive Investigation JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE, 2025, 34, 18, 20223, 20239, 10.1007/s11665-025-10663-2

124. Rizwee, M; Kumar, R; Kumar, S; Kumar, D, Mechanical Characterization of 3D-Printed Polylactic Acid (PLA) Through Molecular Dynamic Simulation, JOURNAL OF POLYMER SCIENCE, 2025, 63, 1, 22680, 2692, 10.1002/pol.20250225

125. Roy, RK; Murugaiyan, P; Sahoo, BK; Kurapati, GK; Panda, AK; Dubey, P; Mishra, D, Impacts of powder size on amorphous-crystalline transition behaviours in gas atomized Fe-rich alloy powders, POWDER TECHNOLOGY, 2025, 464, 121199, 10.1016/j.powtec.2025.121199

126. Roy, S; Ghorai, D; Mukherjee, A; Mondal, SK; Dubey, S; Sau, M; Ghosh, S; Das, T Haloindole Carboxaldehyde as an Emerging Precursor for the Synthesis of Versatile Essential Skeletons, CHEMISTRYSELECT, 2025, 10, 23, e02427 https://doi.org/10.1002/slct.202502427

127. Sahoo, A; Kumar, S, Hydrogen generation via thermochemical decomposition of lithium hydride nano-particle in the presence of water: A temperature-accelerated reactive molecular dynamics and density functional theory based study, INTERNATIONAL JOURNAL OF HYDROGEN ENERGY, 2025, 182, 151824, 10.1016/j.ijhydene.2025.151824

128. Sahoo, Monica; Hower, JC; Chalavadi, G Geochemical perspectives of the rare earth elements and yttrium in some Permian and Paleogene coals of India: A review INTERNATIONAL JOURNAL OF COAL GEOLOGY, 2025, 308, 10483, 10.1016/j.coal.2025.104831

129. Sahu, Minati; Ghosh, A; Das, A; Ghosh, M; Sagar, SP, Impact of wire feed rate on mechanical properties of GMA Welded joints: a qualitative evaluation using nonlinear ultrasonic technique, NONDESTRUCTIVE TESTING AND EVALUATION, 2025, 10.1080/10589759.2025.2551089

130. Sahu, Minati; 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, 2025, 40, 3, 932, 953, https://doi.org/10.1080/10589759.2024.2335528

131. Sahu, Vikash Kumar, Tripathy, Snehashish, Jena, P.S.M.; Krishna, M. Vamsi; Chowdhury, SG; Mandal, GK "On the experimental validation of a local equilibria based framework for design of Fe-C-Cr alloys exhibiting predicted partitioning behaviour during pearlite formation", Materials Characterization, 2025, 225, 115143, https://doi.org/10.1016/j.matchar.2025.115143

132. Sahu, Vikash Kumar; Tripathy, S; Chowdhury, SG; Mandal, GK, On the Local Equilibria Based Re-assessment of Eutectoid Transformation Mechanisms in Fe-C-Cr Alloys, TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS, 2025, 78, 12, 258, 10.1007/s12666-025-03716-6

133. Sahu, Vikash Kumar; Tripathy, S; Jena, PSM; Chowdhury, SG; Mandal, GK, Computational thermodynamics aided design of Fe-C-Mn alloy exhibiting steady state pearlite growth without substitutional partitioning, MATERIALS LETTERS, 2025, 398, 138907, https://doi.org/10.1016/j.matlet.2025.138907

134. Salot, M; Santhy, K; Mandal, D; Pramanick, AK; Rajasekaran, B; Avasthi, G; Chaudhury, SK, A study on the kinetics and structure of tungsten oxide nanopowder synthesized by an electrochemical oxidation process/ INTERNATIONAL JOURNAL OF APPLIED CERAMIC TECHNOLOGY, 2025, 22, 3, 10.1111/ijac.15080

135. Salot, M; Santhy, K; Naganaboina, VR; Singh, SG; Pramanick, AK; Mandal, D; Avasthi, G; Chaudhury, SK, On improved inorganic gas-sensing characteristics of microwave-treated tungsten oxide quantum dots at room temperature, INTERNATIONAL JOURNAL OF APPLIED CERAMIC TECHNOLOGY, 2025, 22, 3, e15033, 10.1111/ijac.15033

136. Salot, M; Santhy, K; Singh, SG; Pramanick, AK; Mandal, D; Avasthi, G; Chaudhury, SK, Effect of microwave treatment on supercapacitance characteristics of WO3 quantum dots synthesized by electrolysis, BULLETIN OF MATERIALS SCIENCE, 2025, 48, 4, 145,10.1007/s12034-025-03509-z

137. Santhy, K; Thorat, S; Pukale, P; Salot, M; Avasthi, G; Mandal, D; Pramanick, AK; Singh, SG; Chaudhury, SK, A new eco-friendly process for the synthesis of Al-doped ZnO Nanopowder: Structure and supercapacitance characteristics CERAMICS INTERNATIONAL, 2025, 51, 23, 40565, 40581, 10.1016/j.ceramint.2025.06.295

138. Santhy, K; Thorat, S; Pukale, P; Salot, M; Avasthi, G; Mandal, D; Pramanick, AK; Singh, SG; Chaudhury, SK, Eco-friendly synthesis of high-purity nanocrystalline ZnO powder for supercapacitance applications, CERAMICS INTERNATIONAL, 2025, 51, 13, 17657, 17670, 10.1016/j.ceramint.2025.01.538

139. Sayari, F.; Mansour, N.B.; Kraini, M.; Wederni, M.A.; Hjiri, M.; Aouaini, F.; Sharma, Ankur; Mir, L. E., Investigation into the Characteristics of Nanoporous Carbon/Silica-Nickel Nanocomposite for high-frequency Applications, JOURNAL OF INORGANIC AND ORGANOMETALLIC POLYMERS AND MATERIALS, 2025, 35, 98, 108, https://doi.org/10.1007/s10904-024-03208-y

140. Sen, A; Kumari, P; Kundu, Rajen, Regeneration of Spent LIB Electrode Materials: An Outlook from Lab-Scale Feasibility to Industrial Integration, ENERGY & FUELS, 2025, 39, 29, 13879, 13904, 10.1021/acs.energyfuels.5c02037

141. Sengupta, Shantanu and Phenome India Consortium, Study research protocol for Phenome India-CSIR Health Cohort Knowledgebase: A prospective multi-modal follow-up study on a nationwide employee cohort, BIOLOGY METHODS AND PROTOCOLS, 2025, 10, 1, bpaf06, https://doi.org/10.1093/biomethods/bpaf061

142. Sharan, BB; Chand, P; Shanmugam, NS; Krishna, KG, 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, 2025, 34, 11, 9986, 10004 https://doi.org/10.1007/s11665-024-09870-0

143. Sharma, A; Das, A; Jangid, MK; Saha, D; Gandharapu, P; Mukhopadhyay, A Suppressing, Irreversible Capacity Loss and Improving Stability during High Voltage Cycling of Li-Ion Battery Cathodes via a Carefully Designed "Formation Cycle" Protocol, JOURNAL OF THE ELECTROCHEMICAL SOCIETY, 2025, 172, 2, 20531, 10.1149/1945-7111/adb650

144. Singh, CV; Bagui, S; Siefert, J; Tarafder, S, Effect of Service Exposure on Creep Crack Growth Nature of P91 Steel, METALLURGICAL AND MATERIALS TRANSACTIONS A-PHYSICAL METALLURGY AND MATERIALS SCIENCE, 2025, 56, 6, 1964, 1970, 10.1007/s11661-025-07776-7

145. Singh, D; Choudhary, S; Sharma, S; Paul, AK; Singh, M; Nain, S; Kumar, N; Singh, V, C-N/N-N, Bonds Formation to Access [1,2,3] Triazolopyrido[3,4-b]indoles and [1,2,3]Triazolo[1,5-a]pyridines, CHEMISTRY-AN ASIAN JOURNAL, 2025, 20, 8, e202401453, 10.1002/asia.202401453

146. Singh, N; Kang, HN; Jyothi, RK; Jha, MK; Pasupuleti, KS; Lee, JY, Hydrometallurgical Approach to Recover Vanadium and Aluminum from the Sulfuric Acid Manufacturing Spent Catalyst, MINERAL PROCESSING AND EXTRACTIVE METALLURGY REVIEW, 2025, 46, 8, 865, 876, 10.1080/08827508.2025.2456027

147. Singh, RK; Patel, P; Chattoraj, N; Belwanshi, V; Mishra, R, Enhancing pressure sensor performance through diaphragm geometry optimization for subsonic applications, MICROSYSTEM TECHNOLOGIES-MICRO-AND NANOSYSTEMS-INFORMATION STORAGE AND PROCESSING SYSTEMS, 2025,3, 1, 12, 3603, 3623, 10.1007/s00542-025-05918-w

148. Singh, V; Singla, G; Kansay, V; Sharma, VD; Bhatia, A; Kumar, N; Bera, MK, Luminescent bioplastic nanocomposite based on N, K, Ca-doped carbon quantum dots derived from ice plant flower extract for applications in quantum dot-based optical displays, CARBON LETTERS, 2025, 35, 3, 1167, 1185, 10.1007/s42823-024-00845-8

149. Singla, G; Bera, MK; Hait, P; Basu, S; Isha; Yogi, AK; Kumar, N; Selvaraj, M; Assiri, MA; Chakrabarti, S, Impact of biosynthesized heteroatom-doped α-MnO2 nanocatalyst loading on the performance of nanocomposite bio-sponge air electrode for wearable and biodegradable zinc-air batteries, JOURNAL OF ENERGY STORAGE, 2025, 134, 118110, 10.1016/j.est.2025.118110

150. Sukhbaatar, T; Piton, R; Giusti, F; Arrachart, G; Duvail, M; Kumari, A; Daware, S; Gupta, S; Goverapet, S; Sahu, SK; Rai, B; Pellet-Rostaing, S, Lipophilic EDTA-based ligands in different diluents for the extraction of rare earths: Preliminary results with Nd(III), Dy(III) and Pr(III) in chloride and nitrate media, HYDROMETALLURGY, 2025, 231, 106415, https://doi.org/10.1016/j.hydromet.2024.106415

151. Tyagi, K; Bhatt, MK; Jain, V; Mishra, G; Pramanik, S; Bhattacharya, A; Bagui, S; Murugesan, AP; Ghosh, A; Patra, S, Strategy to improve strength-ductility together in a 2101 lean duplex stainless steel, MATERIALS SCIENCE AND ENGINEERING A-STRUCTURAL MATERIALS PROPERTIES MICROSTRUCTURE AND PROCESSING, 2025, 941, 148612, https://doi.org/10.1016/j.msea.2025.148612

152. Walunj, Mahesh Gulab; Pathak, LC; Parida, S; Raja, VS, Hot dip galvanization of DP 980 steel sheet using iron based sol pre-layer and its corrosion performance, SURFACE & COATINGS TECHNOLOGY, 2025, 504, 130807, 10.1016/j.surfcoat.2025.132042

153. Walunj, Mahesh Gulab; Pathak, LC; Parida, S; Raja, VS, Superhydrophobic galvannealed coating on DP980 steel by in-situ generation of Zn-Fe-Ti intermetallic phases: A new approach, SURFACE & COATINGS TECHNOLOGY, 2025, 517, 132837, 10.1016/j.surfcoat.2025.132837





"Coming Together is The Beginning.
Keeping Together is Progress.
Working Together is Success"

- Henry Ford

Our Temple Our Laboratary



"Success is not final, failure is not fatal : It is the courage to continue that counts."

-Winston Churchill

Acknowledgment

We sincerely thank all who have extended their generous support, advice and help, in the preparation of the Annual Report 2025-2026. The effort of each and every person who has contributed in the making of this report is hereby acknowledged. We are grateful for the timely submission of data and for the support provided by the scientific and technical staff, Heads of various Divisions, Administration, Finance and Accounts and Stores & Purchase. We are gratified by all your efforts to go beyond your individual problems at hand and work towards achieving the broader, organizational goal to prepare and release this report on time. You have made our job easier and results more effective. Last but not the least, we are grateful to M/s. Kailash Printers for the timely publishing of this good quality Report.

Giving us feedback, keeping in touch:

We want to hear from you, whether it is a constructive suggestion or a critical observation or any other feedback that you have about this Report.

Please contact us at +91-657 2345209/director.nml@csir.res.in

Or stop in at CSIR-National Metallurgical Laboratory,
Jamshedpur, Jharkhand, India-831007.

ISSN 0972-4273



CSIR-National Metallurgical Laboratory

Jamshedpur - 831007, India

Phone : 91-657-2345028 /2345000-001, Fax : 91-657-2345213

e-mail : director.nml@csir.res.in, Website : www.nmlindia.org

Published by : Director, CSIR-National Metallurgical Laboratory, Jamshedpur-831007, India