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सीएसआईआर
CSIR
भारत का नवाचार इंजन
The Innovation Engine of India

सीएसआईआर - राष्ट्रीय धातुकर्म प्रयोगशाला
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Leading Women of India...

"Nari Shakti"-The versatility of women is much celebrated in today's time. Indian women has proven their adaptability and competence from historical times. These women have eventually inspired several other women to build self-confidence for multitasking. While women is looking for more inclusive environment and equitable growth, quite a few women have led their own fields of work and have broadened the possibilities. Their talent has helped them as well as their organizations in achieving remarkably. This book mentions about such Indian women who have been the leaders, trendsetters or the first-ones in their own field of work. Let us acknowledge some of those women whose perseverance and talent has helped in building a sense of equality and inclusion of women in all spheres of life.









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Women in Railway & Metro

Indian Women who are leading the transformation in the railway and metro sector through their skills determination.

Leading Women of India...

"Mumbai Metro is women friendly transportation and is tipped to be the second lifeline of Mumbai."

An IAS officer who stood first among women candidates in UPSC and ninth overall. As the fist women managing director of the Mumbai Metro Rail Corporation (MMRC) and additional commissioner of the Municipal Corporation of Greater Mumbai, she has contributed to make the India's longest underground Metro line. She's been the driving force of Mumbai Metro-3 that is now known as the new lifeline of the city. Often called as the Metro Women of Mumbai, Ashwini Bhide has been listed as Self Made Women of India (2024). She believes that honest dialogue can solve many problems in execution of ideas. She aims to have more participation of women in changing the environment around us.



IAS ASHWINIBHIDE
FIRST WOMAN MD,
MUMBAI METRO RAIL CORPORATION



JAYA VARMA SINHA
FIRST WOMAN CHAIRMAN OF
THE RAILWAY BOARD

"We are fortunate to be living in times when gender barriers in the physical world are dropping. So let there be no barriers remaining in the mind."

Jaya Varma Sinha is the current Chairman and CEO of Railway Board of the Indian Railways. She assumed office on 1st September 2023 becoming the first female chairman of the Railway Board in its history. Jaya Varma Sinha loves challenges. After securing a good rank in the civil services examination, she chose to join the Indian Railway Traffic Service in 1988, which, to date, requires its staff to be on call around the clock In a career spanning more than 35 years, the 60 year old has worked in operations commercial, IT and vigilance. In her current role in railways, she aims for ensuring the highest safety standards and maximising revenues.



सी.एस.आई.आर.– राष्ट्रीय धातुकर्म प्रयोगशाला

CSIR-राष्ट्रीय धातुकर्म प्रयोगशाला (CSIR-NML) एक प्रमुख भारतीय अनुसंधान संगठन है जो खनिजों, धातुओं और सामग्री के विभिन्न पहलुओं के साथ- साथ वैज्ञानिक अनुसंधान, प्रौद्योगिकी विकास, औद्योगिक सेवाओं और इन क्षेत्रों में मानव संसाधन विकास पर ध्यान केंद्रित करता है। प्रयोगशाला की स्थापना 21 नवंबर, 1946 को श्रीमान सी. राजगोपालाचारी ने की थी और इसे 26 नवंबर, 1950 को पंडित जवाहरलाल नेहरू द्वारा "आशा और भविष्य में विश्वास की भावना" के साथ औपचारिक रूप से उद्घाटन किया गया था। यह प्रयोगशाला देश के वैज्ञानिक और तकनीकी विकास के लिए स्थापित CSIRकी प्रारंभिक प्रयोगशालाओं में से एक है। सीएसआईआर-एनएमएलने 1950 से शुरू होने वाले भारत के औद्योगिक क्रांति में महत्वपूर्ण भूमिका निभाई है, विशेष रूप से खनिज प्रसंस्करण, लौह और इस्पात निर्माण, फेरोलॉय और गैर- लौह धातुओं के निष्कर्षण जैसे क्षेत्रों में, विशेष रूप से मैग्नीशियम। एशिया की सबसे बड़ी क्रीप परीक्षण सुविधा भी 1970 के दशक के प्रारंभ में सीएसआईआर-एनएमएलमें स्थापित की गई थी और आज भी यह एशिया की सबसे बड़ी क्रीप परीक्षण प्रयोगशाला के रूप में गिना जाता है। स्थापना के बाद से सीएसआईआर-एनएमएलने अपने अनुसंधान को प्राथमिक और द्वितीयक संसाधनों से महत्वपूर्ण धातुओं के निष्कर्षण, आयात प्रतिस्थापन के लिए मिश्र धातु विकास,संक्षारण अध्ययन, धातुकर्म प्रक्रियाओं के गणितीय और भौतिक मॉडलिंग, खनिज अनुसंधान, औद्योगिक और शहरी संसाधनों के मूल्य निष्कर्षण और वलोरीकरण, उन्नत सामग्री, महत्वपूर्ण औद्योगिक घटकों की समग्रता मूल्यांकन,और सतह इंजीनियरिंग जैसे क्षेत्रों में विविधता दी है।

धातुओं के संसाधन हमेशा दुर्लभ होते हैं और अयस्कों का लाभकारीकरण अपरिहार्य होता है। विशेष रूप से, लौह और इस्पात उद्योगों में, धातु लौह के उत्पादन में वृद्धि बड़ी मात्रा में लौह अयस्क की खपत करती है। परिणामस्वरूप, उच्च ग्रेड के लौह अयस्क की कमी हो जाती है और कम ग्रेड के अयस्क के लाभकारीकरण पर जोर दिया जाता है। प्रयोगशाला ने एक प्रक्रिया विकसित की है जो 83.8% प्राप्ति के साथ 2.77% Al2O3 के एक केंद्रित पदार्थ और 43.2% Fe के साथ अवशेष उत्पन्न करने में सक्षम है जो बैच स्तर पर 1 किलोग्राम/टन संकलक खुराक पर लौह अयस्क के लाभकारीकरण में सक्षम है। उच्च सीमेंट ग्रेड चूना पत्थर की कमी के कारण, वर्तमान में सफेद सीमेंट उद्योग को सीमेंट बनाने के कच्चे माल की कमी का सामना करना पड़ रहा है। उच्च ग्रेड चूना पत्थर जिसमें 0.068% Fe2O3 और 0.015% MnO से कम हो, आमतौर पर इस उद्देश्य के लिए उपयोग किया जाता है। लोहे और इस्पात निर्माण के लिए कम ग्रेड के लौह अयस्क के लिए ड्राई लाभकारीकरण प्रक्रिया प्रौद्योगिकी का विकास प्रयोगशाला का एक अन्य महत्वपूर्ण द्ध्येय है। इस गतिविधि के तहत, दो प्रयोगशाला स्तर के ड्राई विभाजक और प्रयोगशाला स्तर पर लौह अयस्क के ड्राई लाभकारीकरण के लिए एक प्रवाह आरेख -20 मिमी से +0.1 मिमी के आकार के लिए विकसित किए गए हैं। इसके अलावा, वायु तालिका, चुंबकीय विभाजक में लौह अयस्क के फीड आकार को -1 मिमी से नीचे कम करने से 62% Fe या उससे अधिक की सामग्री के साथ प्राप्ति प्रतिशत में वृद्धि हुई है। झारखंड में स्थानीय रूप से lean grade लौह अयस्क (<55% Fe) और non-coking कोयला (<40% F.C) की परित्यक्त मात्रा उपलब्ध है। फेरुगिनस सामग्री में निम्न Fe और उच्च गैंगू सामग्री के कारण, इन कच्चे माल का लाभकारीकरण या इसे एक मूल्य वर्धित उत्पाद में परिवर्तित करना लौह और इस्पात उद्योग के लिए एक चुनौतीपूर्ण कार्य है। इसी तरह, कम फिक्स्ड कार्बन और कोकिंग गुणों की अनुपस्थिति के कारण, lean grade non-coking कोयले के उपयोग में कठिनाई होती है और यह खदानों में अनुपयुक्त रहता है। ऐसे lean

grade कच्चे माल के उपयोग के लिए तकनीकी संभावनाएं आर एंड डी वैज्ञानिकों का विशेष ध्यान आकर्षित करती हैं ताकि इसे एक मूल्य वर्धित उत्पाद में परिवर्तित किया जा सके। इसलिए, प्रयोगशाला द्वारा क्षेत्रीय रूप से उपलब्ध lean grade लौह अयस्क और non-coking कोयले का उपयोग करके DRI के उत्पादन की एक प्रक्रिया विकसित की गई है।

प्रयोगशाला अपने अत्याधुनिक कोयला वर्णन प्रयोगशाला का उपयोग करते हुए कोकिंग और नॉन-कोकिंग कोयले की आरएंडडी कार्य और गुणवत्ता मूल्यांकन करती है, जिसमें बैंड द्वारा बैंड विश्लेषण और सीम समग्र विश्लेषण के माध्यम से रासायनिक वर्णन होता है। पिछले 10 वर्षों में, सीएसआईआर-एनएमएल ने कोयला पर कई परियोजनाओं को अंजाम दिया है और एक महत्वपूर्ण परियोजना "रांची के CMPDI द्वारा प्रायोजित तेल ऐग्लोमरेशन के माध्यम से वॉशरी ग्रेड कोकिंग कोयला और उच्च राख नॉन कोकिंग कोयले से राख सामग्री को कम करना" पर काम किया है। इस परियोजना के माध्यम से, एक पायलट स्तर प्रक्रिया संयंत्र विकसित किया गया है जो विभिन्न कोयलों की राख सामग्री को 22% से 8% तक कम कर सकता है। इसके लिए मगद, केडला, टोपा, राजरप्पा (झारखंड मूल) आदि सात विभिन्न मूलों के कोयले का उपयोग किया गया है। प्रयोगशाला CCL के राजरप्पा, केडला, काठारा, स्वांग क्षेत्र (झारखंड क्षेत्र) के विभिन्न लोडिंग पॉइंट्स से धोए गए कोकिंग कोयले के नमूनाकरण, तैयारी और विश्लेषण के कार्य में भी संलग्न है, जिसे SAIL और RINL स्टील प्लांट को आपूर्ति के लिए किया जाता है।

अपघाटन धातुकर्म सीएसआईआर -राष्ट्रीय धातुकर्म प्रयोगशाला की पहली गतिविधियों में से एक था। इस क्षेत्र में किए गए कुछ अग्रणी कार्यों में रोटरी भट्टी में स्पंज आयरन का उत्पादन, मैग्नीशियम धातु के निष्कर्षण के लिए पिजियन प्रक्रिया, समुद्री गांठों से निकल और कोबाल्ट का निष्कर्षण, आदि शामिल थे।

देश की आवश्यकताओं के साथ संरेखित होते हुए,ये गतिविधियाँ कई प्रमुख कार्यक्रमों में बदल गई हैं, जैसे कि प्राथमिक और द्वितीयक संसाधनों से महत्वपूर्ण धातुओं का निष्कर्षण, शहरी खनिज खनन, हरित इस्पात उत्पादन, और कचरे का मूल्यांकन।

महत्वपूर्ण धातुएं, जिनमें दुर्लभ पृथ्वी तत्व भी शामिल हैं, देश की आवश्यकता हैं क्योंकि रक्षा, अंतरिक्ष, गतिशीलता, नवीकरणीय ऊर्जा जैसे क्षेत्रों के उत्पाद विकास उन पर निर्भर करते हैं। वर्तमान में भारत 90% से अधिक महत्वपूर्ण धातुओं का आयात कर रहा है। 2023 में, खनिज मंत्रालय ने भारत के लिए महत्वपूर्ण 30 खनिजों की सूची जारी की। इन 30 खनिजों में से, सीएसआईआर- एनएमएलने 16 खनिजों/धातुओं पर शोध किया है और इसे इस क्षेत्र में तकनीक प्रदान करने में सक्षम एक शोध संस्थान माना जाता है। सीएसआईआर-एनएमएलने पहली स्वदेशी सोडियम धातु तकनीक विकसित की है जिसे पायलट किया गया है। महत्वपूर्ण धातु पर कार्यक्रम में टंगस्टन, मैग्नीशियम, सोडियम, वैनेडियम, स्कैंडियम, दुर्लभ पृथ्वी तत्व, लिथियम, कोबाल्ट, निकल और कई अन्य पर ध्यान केंद्रित किया गया है। इन विकासों में से कई को उद्योगों द्वारा समर्थन दिया जाता है। सीएसआईआर- एनएमएल" महत्वपूर्ण धातुओं का मानचित्रण और दोहन" पर CSIR मिशन मोड परियोजना में भाग ले रहा है। इसके अलावा, 100 किलोग्राम/दिन के पैमाने पर मैग्नीशियम का उत्पादन करने के लिए एक पायलट संयंत्र संशोधित पिजियन प्रक्रिया का उपयोग करते हुए स्थापित किया जाएगा, जो आसवन सुविधा के साथ एकीकृत होगा।

शहरी अयस्क दुनिया भर में सबसे तेजी से बढ़ने वाले द्वितीयक संसाधन हैं। कुछ महत्वपूर्ण शहरी अयस्कों में ई-कचरा, बैटरी, सीएफएल बल्ब, घरेलू उपकरण आदि शामिल हैं। भारत ई-कचरे का पांचवां सबसे बड़ा उत्पादक है। वर्तमान में, देश में व्यक्तिगत कीमती धातुओं के निष्कर्षण और ई-कचरे के सुरक्षित पुनर्चक्रण के लिए कोई स्वदेशी तकनीक मौजूद नहीं है। वर्तमान में, ई-कचरे के पुनर्चक्रण को अनियमित क्षेत्र के डिस्मैंटलर्स द्वारा पर्यावरणीय रूप से असुरक्षित तरीके से संभाला जाता है। इस संस्थान ने देश का पहला शहरी अयस्क पुनर्चक्रण केंद्र स्थापित किया है और ई-कचरे से कीमती धातुओं,महत्वपूर्ण धातुओं के निष्कर्षण के लिए कई प्रक्रियाओं को विकसित किया है। विभिन्न उद्योगों को बड़ी संख्या में तकनीकों का हस्तांतरण किया गया है। इलेक्ट्रिक वाहनों, स्मार्टफोन और अन्य पोर्टेबल इलेक्ट्रॉनिक्स में रिचार्जेबल लिथियम-आयन बैटरियों के उपयोग में वृद्धि के कारण लिथियम की वैश्विक मांग निकट भविष्य में काफी बढ़ने वाली है। भारत में प्राथमिक रूप में लिथियम का बहुत ही सीमित संसाधन है और यह पूरी तरह से आयात पर निर्भर करता है। चूंकि भारत स्मार्टफोन और इलेक्ट्रिक वाहनों के लिए सबसे बड़े बाजारों में से एक के रूप में उभर रहा है, लिथियम की मांग बढ़ने वाली है। इसलिए द्वितीयक संसाधनों से लिथियम के निष्कर्षण के लिए स्वदेशी तकनीक विकसित करने की गंभीर आवश्यकता है। सीएसआईआर-एनएमएलने इस क्षेत्र में कई तकनीकों का विकास और हस्तांतरण किया है। बेंच स्केल पर हाइब्रिड हाइड्रोमेटलर्जिकल विधि द्वारा धातुओं की वसूली के लिए कार बैटरियों के पुनर्चक्रण पर एक व्यवहार्यता स्थापित की गई है जहां विद्युत सामग्री मुख्य रूप से Mn-आधारित थी। हाल ही में, लिथियम बैटरियों के पुनर्चक्रण के लिए 1 टन/दिन की इनपुट क्षमता वाला एक पायलट संयंत्र स्थापित किया गया है, जिसका उद्घाटन डॉ. वी. के. सरस्वत, सदस्य, नीति आयोग द्वारा किया गया था। एक और गतिविधि जो की जा रही है वह सौर पैनलों के पुनर्चक्रण है।

दुर्लभ पृथ्वी एक बहुत ही महत्वपूर्ण सामरिक सामग्री है, लेकिन भारत के पास प्राथमिक संसाधन नहीं हैं और पूरी तरह से आयात पर निर्भर है। नीति आयोग ने फ्लाई ऐश और रेड मड जैसे द्वितीयक संसाधनों से दुर्लभ पृथ्वी के निष्कर्षण की संभावनाओं को देखने के लिए एक समिति का गठन किया है। हमें रेड मड से दुर्लभ पृथ्वी सहित अधिकतम मूल्य निकालने और अवशेष के उपयोग के लिए पायलट पैमाने पर एक व्यापक तकनीक विकसित करने की जिम्मेदारी सौंपी गई है। इस कार्यक्रम में तीन शोध संस्थान और तीन उद्योग भाग ले रहे हैं।

हाल ही में हमने हरित इस्पात पर गतिविधियाँ शुरू की हैं और हाइड्रोजन आधारित DRI का अध्ययन कर रहे हैं। वर्तमान में अभिक्रिया गतिकी अध्ययन प्रगति पर हैं। इस क्षेत्र में एक अन्य गतिविधि जो शुरू की गई है वह है MOF का उपयोग करके कार्बन का संग्रहण और पकड़। एक परियोजना CSIR CCU मिशन के तहत शुरू की गई थी। MOF की उपयुक्तता का परीक्षण भोपाल में RKDF विश्वविद्यालय में पायलट पैमाने पर किया गया है, जिसने कार्बन के अच्छे अवशोषण का परिणाम दिया है।

एक अन्य क्षेत्र जहां सीएसआईआर-एनएमएलको अंतरराष्ट्रीय स्तर पर मान्यता प्राप्त है वह है औद्योगिक कचरे के थोक मात्रा के उपयोग में। हम धातु मूल्यों को निकालने और गैर-धातु अवशेषों को सीमेंटयुक्त बाइंडर के रूप में उपयोग करने के लिए स्लैग के गर्म अवस्था संशोधन पर काम कर रहे हैं। इस क्षेत्र में, हम एलडी स्लैग के अपघटन पर काम करने की भी योजना बना रहे हैं, जहां स्लैग के प्रत्येक घटक को धातु मूल्यों के रूप में निकाला जाएगा। भू-बहुलकीकरण तकनीक का उपयोग करके औद्योगिक कचरे से निर्माण और भवन सामग्री का विकास। भू-बहुलकीकरण प्रक्रिया द्वारा, एल्यूमिना-सिलिकेट कचरे को सीमेंटयुक्त सामग्री में परिवर्तित किया जा सकता है, लेकिन यह प्रक्रिया पारंपरिक पोर्टलैंड सीमेंट की तुलना में 80% कम CO_2 का उत्सर्जन करती है और इसे हरित माना जाता है। उद्योग को दी गई तीन तकनीकें हैं फ्लाई ऐश से भू-बहुलक सीमेंट, विभिन्न औद्योगिक कचरे से पाविंग ब्लॉक्स और फ्लाई ऐश और स्लैग मिश्रण से त्वरित सड़क मरम्मत सामग्री। वर्तमान में टीम CSIR-First कार्यक्रम के तहत आत्म-उपचार भू-बहुलक पर काम कर रही है।

सीएसआईआर- एनएमएलका मिश्र धातु विकास और सामग्री इंजीनियरिंग एक अन्य महत्वपूर्ण क्षेत्र है। इस क्षेत्र के तहत रक्षा से लेकर बायोमटेरियल अनुप्रयोगों तक की विभिन्न अनुप्रयोगों के लिए नई मिश्र धातु विकास करना प्रमुख ध्यान केंद्रित है। प्रयोगशाला ने मौजूदा सुपर मिश्र धातुओं के विकल्प के रूप में एक अवक्षेपण कठोर रचना वाली जटिल मिश्र धातु (CCAs) को डिज़ाइन और विकसित किया है,हाइड्रोजन भंडारण अनुप्रयोगों के लिए उच्च एंट्रोपी मिश्र धातु, उच्च बैलिस्टिक शक्ति कवच इस्पात, बायोमेडिकल अनुप्रयोगों के लिए Zr आधारित बायोकम्पैटिबल मिश्र धातु शामिल हैं। प्रयोगशाला उद्योगों को शेष जीवन मूल्यांकन, संरचनात्मक अखंडता मूल्यांकन, स्वास्थ्य निगरानी और इंजीनियरिंग घटकों के विफलता विश्लेषण में महत्वपूर्ण सेवाएं भी प्रदान करता है। तेल, बिजली, अंतरिक्ष, नौसेना, रक्षा और परमाणु जैसे कई औद्योगिक क्षेत्र इस डोमेन में कई कार्यक्रमों के भागीदार हैं।

प्रयोगशाला के देश के सामाजिक-आर्थिक विकास के लिए योगदान उल्लेखनीय हैं। सीएसआईआर-एनएमएलने समाज तक पहुँचने के लिए कई कार्यक्रम शुरू किए हैं। प्रयोगशाला ने देश के कारीगरों की समृद्धि और लाभ के लिए लगातार प्रयास किए हैं, पारंपरिक तकनीक को उन्नत करके और धात्विक सामग्रियों से जुड़ने वाले कारीगरों के लिए उपयुक्त नवाचारों को लागू करके। सीएसआईआर-एनएमएलने ऊर्जा-कुशल और पर्यावरण के अनुकूल कोक-आधारित पीतल और घंटी धातु पिघलने वाली भट्टी विकसित की है, जिसके पारंपरिक भट्टियों पर कई फायदे हैं। प्रयोगशाला ने तांबा, पीतल और कांस्य सतहों पर उपयोग के लिए एक एंटी-टार्निशिंग लेकर भी विकसित किया है जो ऑनलाइन मार्केटिंग स्टोर्स जैसे AMAZON के तहत व्यावसायिक नाम BRASS CARE में उपलब्ध है।

प्रयोगशाला ने भारत सरकार के "स्किल इंडिया" मिशन में भी योगदान दिया है और विभिन्न प्रकार के प्रतिभागियों जैसे कि स्कूल और कॉलेज के छात्रों, उद्यमियों और उद्योग सहयोगियों को प्रशिक्षण प्रदान करता है। CSIR-इंटीग्रेटेड स्किल डेवलपमेंट प्रोग्राम एक ऐसा कार्यक्रम है जो स्कूल छोड़ने वाले छात्रों से लेकर किसानों, ITI डिप्लोमा धारकों और स्नातकों तक विभिन्न स्तरों पर विभिन्न लोगों की आवश्यकताओं को पूरा करता है। ध्यान केंद्रित करने वाले क्षेत्रों में धातु, धातुकर्म, विनिर्माण, अपशिष्ट उपयोग, सॉफ्ट स्किल्स और उद्यमिता विकास शामिल हैं।

संस्थान ने सहयोगी भविष्यवादी आर एंड डी और शैक्षणिक उद्देश्यों को पूरा करने के लिए दुनिया भर के शैक्षणिक संस्थानों के साथ सहयोग भी स्थापित किया है। संस्थान ने धातुकर्म, पृथ्वी विज्ञान और औद्योगिक विकास के विस्तार में बेहतर सुविधाओं को प्रदान करने के लिए दीर्घकालिक शैक्षणिक आदान-प्रदान, संयुक्त अनुसंधान और एक-दूसरे की सुविधाओं तक पहुंच को सक्षम करने के लिए कई सहयोगी समझौता ज्ञापनों (MoUs) पर हस्ताक्षर किए हैं। IIT-कानपुर, IIT-पटना, ओपी जिंदल विश्वविद्यालय, IIT मद्रास, IIT रुड़की, IIT केजीपी, IIT बॉम्बे, कोलकाता विश्वविद्यालय-कोलकाता, शिव नादर विश्वविद्यालय, दादरी (यूपी), सत्यभामा विश्वविद्यालय, और यूनिवर्सिटी ऑफ स्टावेंजर-नॉर्वे, यूनिवर्सिटी ऑफ मिकोलेक, कोरिया मेरीटाइम यूनिवर्सिटी (KMU), यूनिवर्सिटी ऑफ सेंटियागो-डी-कम्पोस्टेला (संसाधन उपयोग और पुनर्चक्रण प्रौद्योगिकी के अनुसंधान और विकास के सहकारी कार्यक्रम को अपनाने की इच्छुक), QUB, बेलफास्ट; स्टुटगार्ट विश्वविद्यालय कुछ ऐसे शैक्षणिक संस्थान हैं।

हमारा दृष्टि कथन:

"खनिज और धातुकर्म अनुसंधान और विकास में एक वैश्विक नेतृत्व और अंतरराष्ट्रीय स्तर पर मानकीकृत प्रयोगशाला बनना तथा खनिजों, धातुओं और सामग्रियों में एक आत्मनिर्भर प्रौद्योगिकी केंद्र स्थापित करना।"



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 it 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 duped 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 it 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 on 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 was 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 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 technologies exist 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 metals, critical metals extraction from E-waste. A large number of technologies have been transferred to various industries. The global demand for lithium is going to increase drastically in near future due to increase 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 do not have primary resources and depend totally on imports. Nitiayog has formed a committee to look at the possibilities to extract rare earth from secondary resources such as fly ash and red mud. We have been assigned the responsibility to develop a comprehensive technology at pilot scale to extract maximum value from red mud including rare earth and use the residue. In this program three research institute and three industries are participating.

Recently we started the activities on green steel and studying the hydrogen based DRI. Currently reaction kinetics studies are under progress. Another activity in this area started is Carbon sequestration and capture using MOF and a project was initiated under CSIR CCU mission. The suitability of MOF has been tested at pilot scale at RKDF University, Bhopal which has given the 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 technology which has 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 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 in 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 another such program that caters to diverse cross section of people at various levels beginning with school dropouts to Farmers to ITI diploma holders to graduates. The focus is to develop skills in the area of metals, metallurgy, manufacturing, waste utilization, soft skills and entrepreneurship development.

The institution has also built up collaborations with the 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 KGP, IIT Bombay, University of Calcutta- Kolkata, Shiv Nadar University, Dadri, (U.P.), 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.

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.”

Organization Structure



President-CSIR
Mr. Narendra Modi
(Hon'ble Prime Minister)



VP-CSIR
Mr. Jitendra Singh
(Hon'ble S&T Minister)



DG-CSIR
Dr. N. Kalaiselvi
(Secretary DSIR)

Management Council



Director CSIR-NML
Dr. Sandip Ghosh Chowdhury

Research Council

R&D Division/Centers



MTE
Dr. S. Sivaprasad
Chief Scientist & Head



MNP
Dr. Shobhana Dey
Chief Scientist & Head



AAC
Dr. (Mrs.) S Chakravarty
Chief Scientist & Head



MER
Dr. Sanjay Kumar
Chief Scientist & Head



AMP
Dr. Shashi Kant Tiwari
Chief Scientist & Head



NML-MC
Dr. T.V. Vijaya Kumar
Chief Scientist & Head

Support Divisions/Units



RPBD
Dr. Sital Kumar Pal
Chief Scientist & Head



ENG
Mr. Uday Bhaskara Rao Modavalasa
Principal Scientist & Head



KRIT
Mr. Byomkesh Das
Chief Scientist & Head

Functionaries



Administration
Mr. Subhajit Banerjee
Administrative Officer



Administration
Mr. Aditya Mainak
Administrative Officer



HRG
Dr. S. Sivaprasad
Chief Scientist & Head



F&A
Mr. Pankaj Kumar
F&A Officer



F&A
Mr. Dayakant Kumar
F&A Officer



S&P
Mr. Anil Kr. Choudhury
S&P Officer

AMP: Advanced Materials & Processes; MTE: Materials Engineering; AAC: Applied & Analytical Chemistry; MER: Metal Extraction & Recycling; MNP: Mineral Processing; NML-MC: NML-Madras Center; S&P: Stores & Purchase; HRG: Human Resource Group; F&A: Finance & Accounts; RPBD: Research Planning & Business Development; KRIT: Knowledge Resources & Information Technology; ENG: Engineering

प्रभात खबर
जमशेदपुर, बुधवार
26.04.2023
04

विद्यार्थियों को पढ़ाई कर रिसर्च से जुड़ने की जरूरत : डॉ देवाशीष

- सीएसआइआर-एनएमएल में एक सप्ताह की प्रयोगशाला की हुई शुरुआत

वरीय संवाददाता, जमशेदपुर



सीएसआइआर-एनएमएल में वन वीक वन लैब की शुरुआत करते अतिथि.

सोमवार को रांची में सीएसआइआर-राष्ट्रीय धातुकर्म प्रयोगशाला (सीएसआइआर-एनएमएल) में वन वीक वन लैब प्रोग्राम की शुरुआत की गयी. इसके बाद मंगलवार से जमशेदपुर में आयोजित इस कार्यशाला की अगली कड़ी की शुरुआत हुई. इसमें मुख्य अतिथि के रूप में टाटा स्टील के टेक्नोलॉजी एंड न्यू मटेरियल्स बिजनेस के चीफी डॉ देवाशीष भट्टाचार्जी, विशिष्ट अतिथि सीएसआइआर-एनएमएल के डायरेक्टर डॉ अवनीश कुमार श्रीवास्तव उपस्थित थे. डॉ श्रीवास्तव ने कहा कि एक सप्ताह, एक प्रयोगशाला कार्यक्रम और प्रदर्शनी का उद्देश्य छात्रों, उद्योगों, एमएसएमइ और आम जनता सहित समाज के स्टेक होल्डर से जुड़ना है. मौके पर डॉ देवाशीष भट्टाचार्जी ने एनएमएल द्वारा देश हित में किये जाने वाले कार्यों की सराहना की गयी. उन्होंने कहा कि नयी पीढ़ी को साइंस एंड टेक्नोलॉजी से जुड़कर इनोवेटिव आइडिया को धरातल पर लाने की आवश्यकता है. इसके लिए सीएसआइआर एनएमएल द्वारा विद्यार्थियों के बीच प्रोजेक्ट जिज्ञासा द्वारा किये जाने वाले प्रयासों की सराहना की. कार्यक्रम के दौरान 80 टेक्निकल पोस्टर लगाये गये हैं. इस मौके पर शहर के विभिन्न स्कूलों के विद्यार्थी मौजूद थे.

THE AVENUE MAIL, Jamshedpur Wednesday, September 13, 2023

Corporate Training Programme at CSIR-NML

Mail News Service



Jamshedpur, Sept 12: A five-day 'Exposure Training Program on Metallic Pipes,' ETMP'23, commenced today at CSIR-National Metallurgical Laboratory (NML). The program, which will run until September 15, 2023, has drawn participants from ten different centers of the Central Institute of Plastics Engineering & Technology (CIPET) across the country. This training initiative aims to provide these officials with an in-depth understanding of metallurgical research, particularly concerning metallic pipes.The program offers a comprehensive insight into various aspects of metallic pipes, including the fundamentals of physical metallurgy, mechanical and corrosion behavior, and welding metallurgy. Participants will also receive valuable insights into relevant industry standards, which will aid them in assessing the quality of metallic pipes on-site. The inaugural function of ETMP'23 was inaugurated by Dr Sandip Ghosh Chowdhury, Chief Scientist and Head of the Materials Engineering Division at CSIR-NML. During his welcome address, Dr. Chowdhury highlighted the significance of the program in the context of new product development, quality assessment, and plant site improvements. The event proceeded with an introductory session to familiarize the participants with the program's objectives and expectations. Dr. Snehasish Tripathy, Senior Scientist at the Materials Engineering Division and Technical Coordinator of the program, delivered a formal vote of thanks, concluding the inaugural function on a positive note.

The training program will encompass a wide range of activities over its duration, including the exploration of basic theories, detailed case studies, and practical demonstrations. It is anticipated that this training will equip CIPET officials with valuable knowledge and skills to contribute effectively to their respective roles in the field of metallurgy and quality assessment. ETMP'23 at CSIR-NML represents a collaborative effort between academia and industry, fostering a culture of continuous learning and development in the field of metallurgical research and its practical applications in the context of metallic pipes. (Wpb)

दैनिक जमशेदपुर, 12 सितंबर, 2023

सीएसआइआर-एनएमएल के 74वें स्थापना दिवस पर बोले यूसिल के सीएमडी

समुद्र में यूरेनियम खोज को एनएमएल करे प्रयास



2022

1950

प्रभात खबर
जमशेदपुर 25-04-2023

वन वीक-वन लैब कार्यक्रम • सीएसआईआर दिल्ली और एनएमएल जमशेदपुर का सात दिवसीय कार्यक्रम शुरू

शोध ही किसी देश को सुपर पॉवर बनाता है भारत रिसर्च पर निवेश बढ़ा रहा: राज्यपाल

शोध की बदौलत झारखंड में पीने योग्य पानी 6 से 36% हुआ



आजादी के बाद से देश में रिसर्च को बढ़ावा देने के लिए कई संस्थान बनाये गये. इसका परिणाम है कि आज देश में 1500 से अधिक स्टार्टअप हैं. यह संख्या 2014 में 500 से कम थी. यह बात राज्यपाल सह कुलाधिपति सीवी आनंद बोस ने कही. वह शनिवार को जमशेदपुर के कोल्हान विश्वविद्यालय के 11वें दीक्षांत समारोह को संबोधित कर रहे थे. उन्होंने कहा कि आजादी के बाद से देश में रिसर्च को बढ़ावा देने के लिए कई संस्थान बनाये गये. इसका परिणाम है कि आज देश में 1500 से अधिक स्टार्टअप हैं. यह संख्या 2014 में 500 से कम थी. यह बात राज्यपाल सह कुलाधिपति सीवी आनंद बोस ने कही. वह शनिवार को जमशेदपुर के कोल्हान विश्वविद्यालय के 11वें दीक्षांत समारोह को संबोधित कर रहे थे. उन्होंने कहा कि आजादी के बाद से देश में रिसर्च को बढ़ावा देने के लिए कई संस्थान बनाये गये. इसका परिणाम है कि आज देश में 1500 से अधिक स्टार्टअप हैं. यह संख्या 2014 में 500 से कम थी. यह बात राज्यपाल सह कुलाधिपति सीवी आनंद बोस ने कही. वह शनिवार को जमशेदपुर के कोल्हान विश्वविद्यालय के 11वें दीक्षांत समारोह को संबोधित कर रहे थे. उन्होंने कहा कि आजादी के बाद से देश में रिसर्च को बढ़ावा देने के लिए कई संस्थान बनाये गये. इसका परिणाम है कि आज देश में 1500 से अधिक स्टार्टअप हैं. यह संख्या 2014 में 500 से कम थी. यह बात राज्यपाल सह कुलाधिपति सीवी आनंद बोस ने कही. वह शनिवार को जमशेदपुर के कोल्हान विश्वविद्यालय के 11वें दीक्षांत समारोह को संबोधित कर रहे थे.

आजादिकि भारत के लिए रिचर्च आर्थ पर कार्यशाला

एनएमएल में आज से तीनदिवसीय कार्यक्रम

प्रभात खबर
सीएसआइआर-एनएमएल, 'वन वीक-वन लैब' के तहत कई कार्यक्रमों का आयोजन, बोले वक्ता

आज के स्टार्टअप कल बनेंगे बड़े उद्योग



टेक्नोलॉजी से पीछल उद्योग का ही सकता है विकास

दैनिक भास्कर
जमशेदपुर, मंगलवार, 16 मई, 2023

एनएमएल में स्वच्छता पखवाड़ा समापन समारोह



जमशेदपुर | सीएसआईआर -एनएमएल जमशेदपुर में 1 से 15 मई तक स्वच्छता पखवाड़ा का आयोजन किया गया। 15 दिन तक एनएमएल में स्वच्छता अभियान चलाया गया। इसमें निदेशक डॉ अवनीश कुमार श्रीवास्तव, समन्वयक डॉ. शर्मिष्ठा सागर, सदस्यों में अजय तिर्की, आरआर श्रीवास्तव और पंकज कुमार शामिल हैं। सोमवार को समापन सत्र का आयोजन किया गया। इस दौरान आयोजित प्रतियोगिता के विजेताओं को पुरस्कृत किया गया। कार्यक्रम के मुख्य अतिथि टाटा स्टील यूटिलिटीज एंड इंफ्रास्ट्रक्चर सर्विसेज लिमिटेड के प्रबंध निदेशक ऋतु राज सिन्हा शामिल हुए। पखवाड़ा के दौरान कर्मचारियों को स्वच्छता-शपथ दिलाया गया, पौधरोपण कर परिसर को स्वच्छ किया गया। प्रतियोगिता में विजेता शिवांशु चेहरा, नभ श्रीवास्तव, इंद्राक्षी कुंडू, समृद्धि प्रज्ञा, सरन्या बेहरा, एम कार्तिकेय, रोशनी पुराण, सर्वनी बेहरा, पूर्णिमा पुराण, सौम्या कुंडू, रूपाली महतो और सरित शेखर पाल को पुरस्कृत किया गया। हिंदी भाषा में प्रतियोगिता के विजेता सुधा कुमारी झा, अमित प्रकाश और सोमनाथ दास और अंग्रेजी भाषा में चंदन कुमार चौधरी, नीतीश कुमार भकत, एलिफ कुंभार को पुरस्कृत किया गया। मौके पर प्रेमकुमार, बिराज, निखिल, गौरव, वाई उषा, विनोद मौजूद थे।

THE AVENUE MAIL, Jamshedpur Friday, August 18, 2023

Students from five states visit CSIR-NML

Jamshedpur, Aug 17: A group of 112 students from different schools in Jharkhand, Bihar, Orissa, Chhattisgarh, and West Bengal accompanied by 15 teachers visited the CSIR-NML in Jamshedpur on Thursday.

This program was organized untler "6th Scientific Excursion 2023" under "Knowledge & Awareness Mapping Platform" (KAMP)-"National Assessment for Scientific Temperament and Aptitude" (NASTA) and conducted under the CSIR-Jigyasa Virtual lab integration program.

The main objective of the program was to enhance scientific temperament and to create awareness and knowledge of scientific aptitude among school students.

Dr Sandip Ghosh Chowdhury, Chief Scientist & Head, MTE Division, CSIR-NML in welcome addressbriefly talked about CSIR and elaborated on various research activities taken up by the laboratory.

Students also participated in the "Hands-on Experiment" activity organized under CSIR-NML Jigyasa Program. Mousumi and Deepak from CSIR-NML demonstrated the "Hands-on Experiment" on coin battery and mutual inductance.



Further, Suman Tewary, Senior Scientist, AMP Division delivered a lecture on "Introduction to Artificial Intelligence and Machine Learning". In his lecture, he talked about different types of Artificial Intelligence and Machine learning and its application in daily life.

DrArpitaGhosh,Principal Scientist, AMP Division talked about "Artificial Intelligence Solutions for Steel Industry". She also talked about applications and the importance of Artificial Intelligence in the Iron and Steel industry. A day-long program also includedLabvisit atthe Urban Ore Recycling Centre, AAC and Creep Section. (W-mb)

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Senior Principal Scientist Technology
Management Directorate (TMD), CSIR



Dr. Sandip Ghosh Chowdhury
Director
CSIR-National Metallurgical Laboratory



निदेशक की कलम से

सीएसआईआर- राष्ट्रीय धातुकर्म प्रयोगशाला, सीएसआईआर प्रयोगशालाओं का एक अंग है, जो धातु, खनिज और सामग्रियों के क्षेत्र में अनुसंधान और विकास की उत्कृष्टता, प्रासंगिकता एवं स्थिरता के क्षेत्रों पर ध्यान केंद्रित करता है। हमारे पूर्व निदेशकों और मार्गदर्शकों की दूरदृष्टि के कारण, प्रयोगशाला ने अनुसंधान उत्कृष्टता और प्रासंगिकता की निरंतर गति को बनाए रखा है। यह प्रवृत्ति गत वर्ष भी जारी रही, जिसने सी.एस.आई.आर.- एन.एम.एल. के उद्देश्यों को महत्वपूर्ण योगदान प्रदान किया। प्रयोगशाला अनुबंध और अनुदान सहायता अनुसंधान, प्रौद्योगिकी विकास और हस्तांतरण, परामर्श और विज्ञान एवं प्रौद्योगिकी सेवाओं जैसे विभिन्न मार्गों के माध्यम से अनुसंधान और विकास का अनुसरण करती है। प्रयोगशाला बौद्धिक संपदा सृजन (आईपी) और सहयोगात्मक अनुसंधान करने के लिए निरंतर प्रयासरत रहती है।

वर्ष के दौरान आउटपुट और परिणाम संतोषजनक रहे। यह देखना बहुत उत्साहजनक था कि हमारा लगभग 85% बाहरी नकदी प्रवाह (आईसीएफ़) केवल औद्योगिक स्त्रोतों से उत्पन्न हुआ था। औद्योगिक समाधान प्रदान करना हमारी उत्कृष्टता को दर्शाता है। इसके अलावा, बौद्धिक सम्पदा के सृजन के सम्बन्ध में, रेपोर्टिंग अवधि में हमारे शोधकर्ताओं द्वारा 05 पेटेंट और 01 कॉपीराइट दायर किए गए थे। रेपोर्टिंग वर्ष में हमारी पाँच प्रौद्योगिकियाँ देश भर में प्रतिष्ठित ग्राहकों को हस्तांतरित की गई, जिसके अंतर्गत टाइटेनियम-एल्यूमीनियम कार्बाइट (Ti3AlC2) मैक्स फेज के विकास के लिए ज्ञान/प्रौद्योगिकी का हस्तांतरण मेसर्स ग्लोबल नैनोटेक, गोरेगाँव को; जिंकोमीटर के निर्माण के लिए ज्ञान/प्रौद्योगिकी का हस्तांतरण मेसर्स रेफोस्टील, जमशेदपुर को; अपशिष्ट पीसीबी से तांबा, एल्यूमीनियम और सोने को धातुओं/लवणों के रूप में निकालने के लिए तकनीकी ज्ञान का हस्तांतरण मेसर्स नोवासेंसा, नई दिल्ली को; उपयोग किए गए लिथियम-आयन बैटरियों (LIBs) को रीसायकल करके Li, Co, Mn, Cu, Ni जैसी धातुओं/लवणों के मूल्यवर्धित उत्पादों के निर्माण के लिए तकनीकी ज्ञान का हस्तांतरण मेसर्स नोवासेंसा, नई दिल्ली को; पीतल पिघलाने वाली भट्टी के लिए ज्ञान का लाइसेंस देने का समझौता, मेसर्स एक्वाटिक इंडस्ट्रीज प्राइवेट लिमिटेड, भुवनेश्वर से किया गया। इस सफलता का श्रेय हमारे वैज्ञानिकों की कर्मठता, समर्पण और औद्योगिक विशेषज्ञता को जाता है, जो अनुसंधान और अनुसंधान समर्थन विभागों में कार्यरत हैं। पांच में से दो तकनीकों का स्थानांतरण ई-कचरा पुनर्चक्रण के क्षेत्र में मूल्यवान धातुओं के निष्कर्षण के लिए किया गया है। हम एक ई-कचरा क्लस्टर की स्थापना में भी प्रगति कर रहे हैं, जो एक अनुदान- सहायता प्राप्त नेटवर्क परियोजना है। जिंकोमीटर के निर्माण के लिए हमारी तकनीकों में से एक का रिपोर्टिंग अवधि के दौरान मेसर्स रेफॉस्टील इंस्ट्रूमेंट्स द्वारा व्यावसायीकरण किया गया था। जिंकोमीटर को उनके तारापुर तार मिल में स्थापित किया गया था और उपकरण ग्राहक की संतोषजनक अपेक्षाओं के अनुरूप कार्य कर रहा है। स्थानांतरित की गई तकनीकों में से एक सामाजिक उद्देश्य के लिए है। ओडिशा क्षेत्र में कारीगरों के लाभ के लिए ब्रास पिघलाने वाले फर्नेस को हमारे भुवनेश्वर स्थित सहयोगी प्रयोगशाला सीएसआईआर-आईएमएमटी और ग्राहक की सहायता से स्थापित किया जाएगा। हमारे जर्नल प्रकाशनों के उद्धरण 72017 (2022) से बढ़कर 79862 (2023) हो गए हैं। पिछले वित्तीय वर्ष के दौरान, 133 पेपर एससीआई जर्नल्स में प्रकाशित हुए और 25 पेपर नॉन-एससीआई जर्नल्स में प्रकाशित हुए। पिछले साल की तुलना में प्रति पेपर का औसत उद्धरण 24.35 था, जबकि पिछले साल यह 22.25 था। संस्थागत एच-इंडेक्स भी 124 पर बढ़ गया। हमने 21 भारतीय उद्योगों और पीएसयू के साथ समझौता ज्ञापन (MoU)/समझौतों के माध्यम से विभिन्न ग्राहकों के साथ सहयोग स्थापित किया।

रिपोर्टिंग अवधि में हमारी कुछ प्रमुख परियोजनाएँ हैं: अमेड इन्कोनेल 625 और इन्कोनेल 718 मिश्र धातुओं के ऑक्सीडेशन और गरम संक्षारण व्यवहार अध्ययन; एमएसएमई योजना के तहत रीसाइक्लिंग क्लस्टर्स के निर्माण के साथ अनौपचारिक क्षेत्र क्षमता निर्माण उन्नयन और इलेक्ट्रॉनिक अपशिष्ट से संसाधनों की पुनर्प्राप्ति के लिए सक्षम तकनीक, जिससे संसाधन दक्षता और चक्रीय अर्थव्यवस्था को बढ़ावा मिलता है, जिसे इलेक्ट्रॉनिक और सूचना प्रौद्योगिकी मंत्रालय (MeitY) द्वारा वित्त पोषित किया गया है; एआरसीआई, हैदराबाद द्वारा वित्त पोषित ओडीएस-ऑस्टेनिटिक स्टील और ओडीएस-लोहे और निकल एलुमिनाइड्स के क्रीप-फैटिग इंटरैक्शन व्यवहार; एआरसीआई, हैदराबाद द्वारा वित्त पोषित A-USC पावर प्लांट के लिए उन्नत NDE आधारित निदान और पूर्वानुमान प्रोटोकॉल का विकास; ईस्टर्न कोलफील्ड्स लिमिटेड द्वारा प्रायोजित ईस्टर्न कोलफील्ड्स की कोयला विशेषता; सीएमपीडीआई रांची द्वारा प्रायोजित मॉडलिंग और सिमुलेशन विश्लेषण के माध्यम से कोकिंग कोयला वाशरी के प्रदर्शन में सुधार के अध्ययन; स्टील मंत्रालय द्वारा प्रायोजित इलेक्ट्रिक आर्क फर्नेस में मध्यम कार्बन फेरोमैंगनीज के ऊर्जा-कुशल उत्पादन के लिए पायलट स्तर पर प्रौद्योगिकी विकास; नेशनल एल्युमिनियम कंपनी लिमिटेड (NALCO) द्वारा प्रायोजित धातु मूल्यों के निष्कर्षण और अवशेष उपयोग के लिए रेड मड के संपूर्ण उपयोग के लिए प्रौद्योगिकी विकास; रणनीतिक क्षेत्र, स्पेस और नौसेना के लिए हम निम्नलिखित स्तर पर काम कर रहे हैं: गैस टर्बाइन रिसर्च इस्टैब्लिशमेंट द्वारा प्रायोजित कंप्रेसर एरोफॉयल मटेरियल GTM-SU-718 के उच्च चक्र थकान चरित्रांकन; अनुसंधान डिज़ाइन और मानक संगठन द्वारा प्रायोजित क्षेत्र से हटाए गए CBC घटकों का मूल्यांकन और आकलन; रक्षा मंत्रालय के एयरोनॉटिक्स आर एंड डी बोर्ड (एआरडीबी) द्वारा वित्त पोषित अर्ध-लगातार मोड में वैक्यूम डिस्टिलेशन के माध्यम से वाणिज्यिक मैग्नीशियम धातु को परिष्कृत करने के लिए प्रक्रिया विकास; भारतीय वायु सेना द्वारा प्रायोजित मिग-29 के स्टारबोर्ड अपर एयर इनटेक में फ्लैप नंबर 05 (आरएच) के इनर रॉकर आर्म की धातुकर्मीय विफलता जांच; एलपीएससी, इसरो द्वारा प्रायोजित अंतरिक्ष यान के ऑन- बोर्ड प्रोपेलेंट गेजिंग के लिए अल्ट्रासोनिक फ्लो मीटर के लिए इलेक्ट्रॉनिक पैकेज; कुछ प्रमुख जारी परियोजनाएँ सीएसआईआर द्वारा वित्त पोषित हैं: उपयोग की गई लिथियम-आयन बैटरियों से महत्वपूर्ण धातुओं का निष्कर्षण; एमाइन अवशोषण प्रक्रिया द्वारा CO2 कैप्चर (CC) के साथ संशोधित खनिज कार्बोनेशन (MC) और बाज़ार उत्पादों और अपशिष्ट गर्मी (WH) की प्राप्ति द्वारा अलगाव- एक समग्र प्रौद्योगिकी विकास दृष्टिकोण; अपशिष्ट मैग्नेट (NdFeB) से रेयर अर्थ की प्राप्ति- अपशिष्ट स्क्रैप से धातु/ ऑक्साइड/ लवण उत्पाद; और बड़े औद्योगिक संरचना के महत्वपूर्ण तापमान क्षेत्र की भविष्यवाणी के लिए एआई-आधारित स्मार्ट अलार्म सिस्टम का विकास।

समाज के सभी स्तरों पर जुड़ाव और समाज में वैज्ञानिक जागरूकता उत्पन्न करना संगठन के लिए हमेशा से प्राथमिकता रही है। इस संबंध में, प्रयोगशाला ने विभिन्न कार्यक्रमों में भाग लिया, जैसे: स्कूल-एनएमएल इंटरैक्शन प्रोग्राम (एसएनआईपी) और जिज्ञासा। भारत सरकार के मिशन "स्किल इंडिया" के तहत, सीएसआईआर-एकीकृत कौशल पहल कार्यक्रम ने विभिन्न क्षेत्रों में लोगों को प्रशिक्षित करने का प्रयास किया है। रिपोर्टिंग अवधि के दौरान, धातु, धातुशास्त्र, विनिर्माण, अपशिष्ट उपयोग, सॉफ्ट स्किल्स, और उद्यमिता में 300 से अधिक लोगों को प्रशिक्षित किया गया। डीएसटी परियोजना "महिला प्रौद्योगिकी पार्क (डब्ल्यूटीपी)" के तहत, हम कौशल प्रशिक्षण के माध्यम से महिलाओं को सशक्त बनाने के लिए राष्ट्रीय उन्नत विनिर्माण प्रौद्योगिकी संस्थान (एनआईएएमटी) रैंचिटो के साथ मिलकर काम कर रहे हैं। हमने पश्चिम बंगाल के चांदी क्लस्टर के लिए सामान्य सुविधा केंद्र पर विस्तृत परियोजना रिपोर्ट (डीपीआर) विकसित करने पर परियोजना शुरू की है। प्रस्तावित विस्तृत परियोजना रिपोर्ट (डीपीआर) तैयार कर ली गई है। झारखंड राज्य के पश्चिम सिंहभूम जिले के सरायकेला खरसावां प्रखंड के गम्हरिया गांव में "विज्ञान प्रौद्योगिकी और नवाचार केंद्र" परियोजना का उद्देश्य तकनीकी हस्तक्षेप से गम्हरिया गांव में अनुसूचित जनजाति समुदाय की आजीविका में सुधार करना है। एक्स.आई.टी.ई. और सीएसआईआर-एनएमएल द्वारा लक्षित समुदाय को विभिन्न कौशल-आधारित और उद्यमिता विकास-आधारित प्रशिक्षण प्रदान किए जाएंगे।

सितंबर 2023 से 3 वर्ष की अवधि के लिए एक नई अनुसंधान परिषद का गठन किया गया है। मैं नई अनुसंधान परिषद के सभी सदस्यों का हार्दिक स्वागत करता हूं। मैं पिछली अनुसंधान परिषद के सदस्यों के प्रति आभार व्यक्त करता हूँ। सीएसआईआर-एनएमएल उनके सुझावों एवं सलाहों का सकारात्मक रूप से पालन करेगा। मैं अपने मूल्यवान ग्राहकों, अनुसंधान परिषद के सदस्यों और कई अन्य मित्रों और सलाहकारों को उनके निरंतर समर्थन और मार्गदर्शन के लिए हार्दिक धन्यवाद व्यक्त करना चाहता हूं। मैं इस बात पर जोर देना चाहता हूं कि सीएसआईआर-एनएमएल का हिस्सा होने और प्रतिभाशाली एवं समर्पित व्यक्तियों की टीम के साथ काम करने पर मुझे अत्यधिक गर्व की अनुभूति हो रही है।



(डॉ॰ संदीप घोष चौधुरी)



Director's Foreword

CSIR-National Metallurgical Laboratory, a constituent of CSIR laboratories, focuses on excellence, relevance, and sustainability aspects of Research and Development, in the areas of metals, minerals and materials. Thanks to the foresight of our earlier directors and mentors, the laboratory has maintained a consistent momentum of research excellence and relevance. This trend continued in the past year, contributing significantly to the intents of CSIR-NML. The laboratory pursues R&D through various avenues such as contract & grant-in-aid research, technology development & transfer, consultancy and S&T services. The laboratory makes every effort for creating intellectual property (IP) and undertaking collaborative research.

The outputs and outcomes during the year were satisfying. It was very encouraging to see that around 85% of our External Cash Flow (ECF) was generated from the industrial sources only. This reflected upon our excellence in delivering industrial solutions. Further, with respect to the generation of intellectual property, 5 Patents and 01 Copyright were filed by our researchers in the reporting period. In the reporting year, five of our technologies were transferred to esteemed clients, countrywide viz. *Transfer of Know-How/Technology for the development of Ti3AlC2 MAXphase to M/s. Global Nanotech, Goregaon; Transfer of Know-How/Technology for the manufacturing of Zincometer to M/s. Refosteel, Jamshedpur; Transfer of technological KNOW-HOW for the extraction of Cu, Al and Au as Metals/ salts from waste PCBs to M/s. Novasensa, New Delhi; Transfer of technological KNOW-HOW to recycle spent Lithium-Ion Batteries (LIBs) to produce value added products of Li, Co, Mn, Cu, Ni, as metals/ salts to M/s. Novasensa, New Delhi; Agreement for Licensing of Knowhow for Brass Melting Furnace to M/s. Aquatic Industries Private Limited, Bhubaneshwar.* This success is attributed to the diligence, dedication, and industry expertise of our scientists in both the R&D Division and R&D support divisions. Out of the five technologies transferred two were transferred in the area of e-waste recycling for extraction of valuable metal. We are also progressing in establishment of an E-Waste cluster, which is a grant-in-aid network project. One of our technologies for the manufacturing of Zincometer was commercialized by M/s. RefoSteel Instruments during the reporting period. The Zincometer was installed at their Tarapur Wire Mill and the device is working at par the satisfaction of the client. One of the technologies transferred is for the social cause, the Brass Melting furnaces for the benefit of artisans in the Odisha region will be installed with the help of our sister laboratory at Bhubaneshwar CSIR-IMMT and the client. The citations for our journal publications has increased from 72017 (2022) to 79862 (2023). During last fiscal year, 133 papers were published in SCI journals and 60 were published in Non-SCI journals. The average citation per paper was 24.35 against 22.25 in the last year. The institutional H-index also increased to 124. We established collaborations with various clients through getting into Memorandum of Understanding (MoU)/Agreements with 21 Indian Industries and PSUs.

Few of our flagship projects in the reporting period are: *Oxidation and hot corrosion behaviour studies of Amed Inconel 625 & Inconel 718 alloys; Informal sector capacity building up-gradation with formation of recycling clusters under MSME scheme and enabling technology for recovery*

of resources from electronic waste thereby promoting resource efficiency and circular economy funded by Ministry of Electronic and Information Technology (MeitY); Creep-fatigue interaction behavior of ODS-austenitic steels and ODS-iron and nickel aluminides funded by ARCI, Hyderabad; Development of Advanced NDE based Diagnosis and Prognosis Protocols for A-USC Power Plants funded by ARCI, Hyderabad; Coal Characterization of Eastern Coalfileds sponsored by Eastern Colfields Limited; Study on Performance Improvement of Coking coal Washery under Coal India Ltd through Modelling and Simulation Analysis sponsored by CMPDI Ranchi; Technology development at pilot scale for energy-efficient production of medium carbon ferromanganese in electric arc furnace sponsored by Ministry of Steel; Technology Development For Holistic Utilization Of Red Mud For Extraction Of Metallic Values & Residue Utilisation sponsored by National Aluminium Co. Ltd. NALCO; For the strategic sector, Space and Navy we are working upon: High Cycle Fatigue Characterization of Compressor Aerofoil Material GTM-SU-718 sponsored by Gas Turbine Research Establishment; Evaluation and assessment of field withdrawn CBC components sponsored by Research Designs & Standards Organization; Process Development for Refining Commercial Magnesium Metal through Vacuum Distillation in Semi-Continuous Mode at 5-6 kg Scale funded by ARDB, Aeronautics R&D Board, Ministry Of Defence; Metallurgical failure investigation of Inner Rocker Arm of Flap No. 05 (RH) at starboard upper air intake of MiG-29 sponsored by Indian Air Force; Electronic Packages for Ultrasonic Flow Meter for On-Board Propellant Gauging of Spacecraft sponsored by LPSC,ISRO; Some of the ongoing major CSIR funded projects are: Extraction of critical metals form used Li ion Batteries; CO2 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; Rare Earth Recovery from Waste Magnet (NdFeB)- Waste Scrap to Metal/oxide/salt Product; and Development of an AI based smart alarm system for predicting critical temperature zone of large industrial structure;

Connecting society at all levels and generating scientific awareness in society has always remained a priority for the organization. In this connection, the laboratory participated in a number of programs like: School-NML Interaction Program(SNIP) and Jigyasa. Under the GOI's mission "Skill India", the CSIR-Integrated Skill Initiative program has endeavored to train people in different areas. In the reporting period, more than 300 people were trained in metals, metallurgy, manufacturing, waste utilization, soft skills, and entrepreneurship. Under the DST project "Women Technology Park (WTP)", we are closely working with the National Institute of Advanced Manufacturing Technology(NIAMT), Ranchi to empower women through skill training. We have undertaken project on developing Detailed project report (DPR) on common facility center for silver cluster of West Bengal, the intended Detailed Project Report (DPR) has been prepared. The project "Science Technology and Innovation Hub" in village Gamharia, Saraikela Kharsawan block, West Singhbhum District, Jharkhand State aims to improve the livelihood of the ST community in the Gamharia village by technological intervention. Different skill-based and entrepreneurship development-based trainings will be provided to the targeted community by XITE and CSIR-NML.

From September 2023 onwards, a new Research council has been constituted for a term of 3 years. I sincerely welcome all members of the new Research council. I like to put on record the appreciation for the last Research Council members. CSIR-NML will positively follow their suggestions/advice. I wish to express sincere thanks to our valued clients, members of the Research Council, and many other friends and mentors for their ongoing support and guidance. I want to emphasize how proud and privileged I am, to be a part of CSIR-NML and to work with a team of talented and dedicated individuals.



(Dr. Sandip Ghosh Chowdhury)

Leading Women of India...

Women Holding Prominent Portfolios in Government

Indian Women who have been assigned responsibilities in India government system and are achieving all milestones

"There is no chance of welfare in the world unless the condition of women is improved"

Nirmala Sitharaman holds two important portfolios the finance ministry and the corporate affairs ministry in GOI. She became the first full time woman finance minister of the country in 2016. Earlier, Indira Gandhi had held finance as an additional portfolio for a short duration when she was the prime minister of India. She has presented the union budget 6 times in her carrer. Before her career in politics, Sitharaman held roles at the U. K.-based Agricultural Engineers Association and BBC World Service. She has a Bachelor of Arts degree in economics at the Seethalakshmi Ramaswami College, Tiruchirapalli Master of Arts degree in economics and M Phil from Jawaharlal Nehru University, Delhi. She has also served as a member of the National Commission for Women. She has been listed as World's Most Powerful Women by Forbes (2023).



NIRMALA SITHARAMAN
FIRST WOMAN MINISTER OF
FINANCE, GOI



P T USHA
FIRST WOMAN PRESIDENT OF
THE INDIAN OLYMPIC ASSOCIATION

"Happiness is nothing but satisfaction satisfaction through work, thoughts and accomplishing our mission."

Pilavullakandi Thekkeparambil Usha is one of India's greatest athletes, often called the country's "golden girl" and "queen of track and field". A graceful athlete with long strides, she dominated Asian track and field events for most of the 1980s, winning 23 medals in all, 14 of which were gold In December 2022, Usha was elected the first women president of the Indian Olympic Association unopposed. In December 2022, she was appointed to the panel of Rajya Sabha vice chairman to control the proceedings of the upper house during the absence of both Chairman and Deputy Chairman.

Performance Targets Achieved in 2023 - 2024

	Objectives	Planned	Achieved
1.	Total External Cash Flow (ECF)^	25.0 Crores	22.49 Crores
2.	Industrial ECF (a part of ECF)	12.0 Crores	15.07 Crores
3.	Customer Satisfaction Index	4.9 (Max 5)	4.8
4.	SCI Publications	125	133
5.	Patents Filed	20	5
6.	Copyrights	5	1
7.	Technologies Developed	5	Nil
8.	Technologies Transferred*	5	5

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

***Technologies Transferred:**

1. Transfer of Know-How/Technology for the development of Ti3AlC2 MAXphase to M/s. Global Nanotech, Goregaon
2. Transfer of Know-How/Technology for the manufacturing of Zincometer to M/s. Refosteel, Jamshedpur
3. Transfer of technological KNOW-HOW for the extraction of Cu, Al and Au as Metals/ salts from waste PCBs to M/s. Novasensa, New Delhi
4. Transfer of technological KNOW-HOW to recycle spent Lithium-Ion Batteries (LIBs) to produce value added products of Li, Co, Mn, Cu, Ni, as metals/ salts to M/s. Novasensa, New Delhi
5. Agreement for Licensing of Knowhow for Brass Melting Furnace to M/s. Aquatic Industries Private Limited, Bhubaneshwar

Major Technological & Scientific targets Planned and Achieved in 2023-2024

Planned for 2023-2024	Achieved in 2023-2024
Applied & Analytical Chemistry	
• A sponsored project from Coal India Limited on "Coking coal assessment through Artificial Intelligence".	• The project proposal has been submitted to the CMPDI. We have also submitted the revised version of the proposal along with the response to the reviewer's comments. It is under process; they will call for a presentation soon.
• Self-healing coating for corrosion protection of structural steel.	• Negotiation ongoing for technology transfer.
• Benzoic acid reference material for calorimetry /or bomb calorimeter analysis.	• Benzoic acid reference material has been developed.
• Salvaging Lithium mixed metal oxide and converting into value added product from spent Li-ion Battery.	• The project has been sanctioned by TATA Steel Ltd and the project fund has been received. The project is ongoing right now. One patent has been filed and one paper has been published in high impact SCI journal.
• Development of alternate reagent for the elimination of mercury effect for reliable analysis of Hg in coal and coal fly ash samples.	• Work is in progress
• Development of 6063 grade Al disc standard (500Nos.)	• Material has been developed. CRM preparation is in progress.
• Development of two different grade Pb base disc CRMs (500Nos. of each grade).	• Material has been verified and CRM production is in progress.

Major Technological & Scientific targets Planned and Achieved in 2023-2024

Planned for 2023-2024	Achieved in 2023-2024
Applied & Analytical Chemistry	
• Development of four different grade Chromite ore CRMs (200Nos. of each grade).	• Material has been prepared and processed for ILC (Round robin analysis) for assigning the certified value and associated uncertainty.
Materials Evaluation	
• Scaling up of armour steel to achieve TRL-7	• Work is in progress
• Powder production of superalloys for additive manufacturing	• Establishing contacts with stakeholders
• Design and upscaling of medium-Mn steel meeting NMRL specifications	• Achieved
• Development of as-cast super martensitic steel having excellent YS and cryo impact properties (for VSSC ISRO)	• Achieved
• Design, installation and commissioning of customized high temperature furnace for annealing under controlled atmosphere along with quenching facility so as to enable various treatments such as decarburization, nitriding, PRX and SRX. Optimization of decarburization and PRX annealing parameters with complete decarburization of cold rolled strip was achieved using above customized facility.	• Design, fabrication, and commissioning done
Metals Extraction & Recycling	
• Green Steel Making in Induction Furnace/Electric Arc Furnace using Hydrogen based DRI	• Work is in progress
• To set up pilot scale battery dismantling setup.	• Pilot scale facility for battery dismantling has been set up. The facility was inaugurated by Dr. V. K. Sarswat, Member, Niti Aayog.
• To develop lab scale process for the recycling of discarded solar panels.	• A project on recycling of solar panels has been started under CSIR waste to wealth mission. Process development is underway.
• To initiate studies on use of MOF's in post combustion CO2 capture	• Work is in progress
Mineral Processing	
1. Pilot scale trials with oily bubble flotation. • Study of Oily Bubble effect on seam 5 coal	• Oil-coated bubble flotation can eliminate the addition of a collector to the aqueous phase. • Around 13% absolute ash rejection was achieved with a significant yield. • The tested process at CSIR-NML has been implemented in West Bokaro Coal Washery.
2. Novel Collector Reagent performance evaluation during flotation of coal • Pilot scale trials with novel reagent and conventional reagent.	Results of conventional reagents were compared with synthesized reagents based with respect to yield at the targeted ash level.

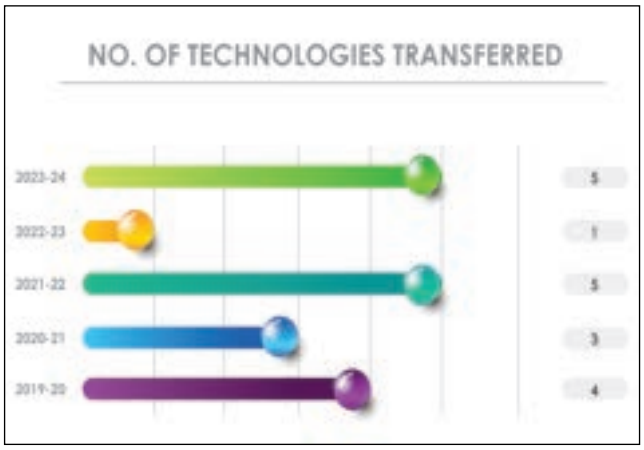
Major Technological & Scientific targets Planned and Achieved in 2023-2024

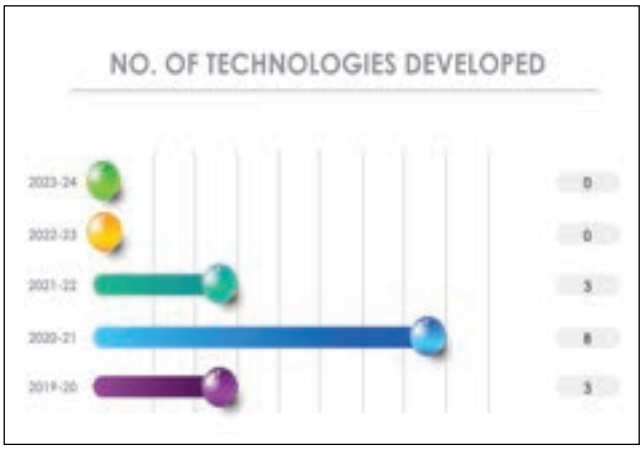
Planned for 2023-2024	Achieved in 2023-2024
Mineral Processing	
• Performance evaluation in terms of ash rejection and yield achieved	
3. Beneficiation of coking coal by hybrid mode: dry and wet processing to reduce the ash forming impurities. (Ministry of Steel, Two years) • Dry de-shaling of high ash coking coal to improve the quality of the feed material before wet processing • Dry beneficiation at coarser size using Air fluidized vibrating deck separator (AVFD) to generate pre-concentrate before subjecting to wet methods. • Wet processing of coking coal sample using Dense medium cyclone and Column flotation technique to achieve the targeted ash of 14-17% with maximum yield.	• Received coal sample from West Bokaro • Proximate analysis and physical characterization of the sample are completed. • Project work is in progress
5. Development of a process for the production of chromic oxide from chromite beneficiation plant tailing (CSIR funded). • Detailed Characterization of chromite Tailing sample will be carried out. • Bench Scale beneficiation studies in advance gravity concentrator will be done.	• Received chromite tailing sample • Completed sample preparation for test work. Work is in progress.
6. Feasibility study on reduction roasting of high-iron bauxite ore • Roasting followed by Magnetic separation was planned carried out. • It was noted that alumina content enhanced from 26% to around 44% with a yield of 43%. However, iron content in product is high due to isomorphs substitution of Fe atom in alumina. • Study on Performance Improvement of Coking coal Washery through Modelling and Simulation Analysis • Effective Utilization of Middlings and Fines of Coking Coal Washery for Recovery of Carbon Values	• Roasted sample was subjected to magnetic separation to separate the magnetic and non-magnetic fractions present in the roasted product. • Final product was chemically analyzed for assessment of the enrichment process. • Al2O3 content is enhanced from around 26% to 46% and Fe2O3 from around 44 % to 59%. • In order to predict the optimum operating parameters, a simulation-based approach was applied during the entire project. Samples were collected from different streams of the washery while conducting the project work and were analyzed for size distribution, percent solid, and ash% content. With the help of simulation, the product yield was benchmarked • Objective was to develop a process flowsheet to produce product with 19% ash for enhancing the carbon recovery from middlings of coking coal washeries. Washability studies were carried out for different top sizes of the crushed samples of as-received middling samples to selected feed size for beneficiation study. Flowsheet comprising Spiralling of the -1+0.15mm and column flotation of -0.15mm size

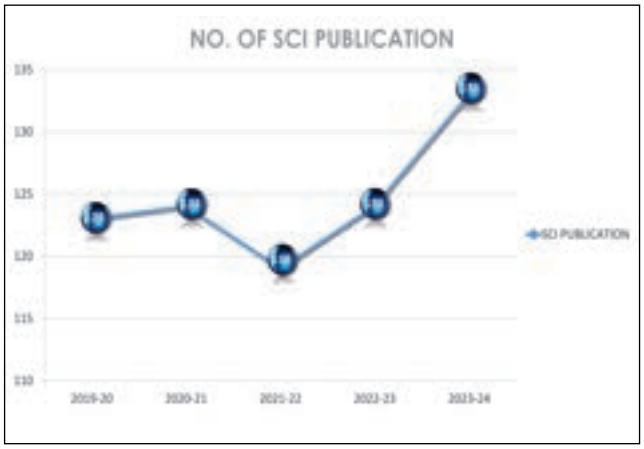
Major Technological & Scientific targets Planned and Achieved in 2023-2024

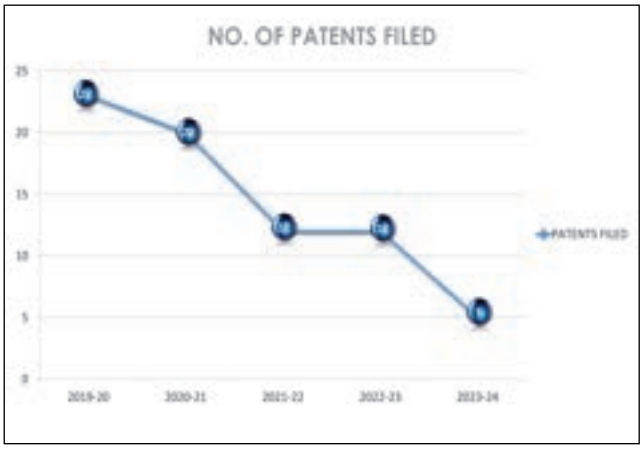
Planned for 2023-2024	Achieved in 2023-2024
Advanced Materials	
• Bench scale evaluation, LCT and mineralogical characterization studies of Meghnagar rock phosphate ore	fractions together produces a concentrate with 18.5% ash with 22.2% yield. • Mineralogical characterization of the representative ore. Confirmed flotation test result by Lock Cycle flotation test and developed the most economical flow-sheet for the commercial plant.
• 10.To develop the process flowsheet for the beneficiation of silica sand.	• Grinding circuit was optimized to control the fine generation. Around 9% of fine material of below 0.106 mm generated during grinding. Grounded product was subjected to magnetic separation to reduce the iron content to 0.08% from 0.34%. Scrubbing followed by Spiralling to reduce the heavy mineral content. Two flowsheets were proposed, providing a roadmap for silica sand beneficiation.
Advanced Materials	
• Commercialization the MXene (Ti3C2) technology.	• Technology Transferred to M/s. Global Nanotech, Goregaon on the development of Ti3AlC2 MAX phase for commercialization.
• LTCC based eddy current sensor susceptible beyond 600 oC for real time creep damage monitoring in power plant components.	• Achieved, creep damage evaluation in real time was conducted at the Lab. Embedding fabricated sensor on the sample.
• AI based smart alarm system for predicting critical zone of large industrial structure using embedded FBG sensors.	• AI based smart system for critical zone prediction using FBG sensor has been implemented at the blowpipe of Blast furnace at TSL.
• Integrity assessment of Iron Beams of Konarka Sun Temple.	• Work in progress.
• Predictive model for weld quality assessment based on thermal imaging.	• Work in progress
• CEMILAC Certification and Patent for Electroplating of Binary Zn-Mn Alloy Coatings from Deep Eutectic Solvents-based Electrolytes (December 2023 onward)	• CEMILAC certification and its end-use by ADA are under progress. Probably, it will be transferred to them by the end of this financial year.
• Development of ferrochrome slag coating for continuous steel caster rolls.	• The project has recently kicked off and work is in progress.
• Development of antimony chalcogenide-based photoabsorber coatings for photovoltaic applications.	• Synthesized Sb2Se3 photoabsorber materials for photovoltaic applications (Experiment in progress)
• Development of Zn-Al-Mg based hot dip coating for cold rolled steel sheet (RDCSI)	• Work in progress.

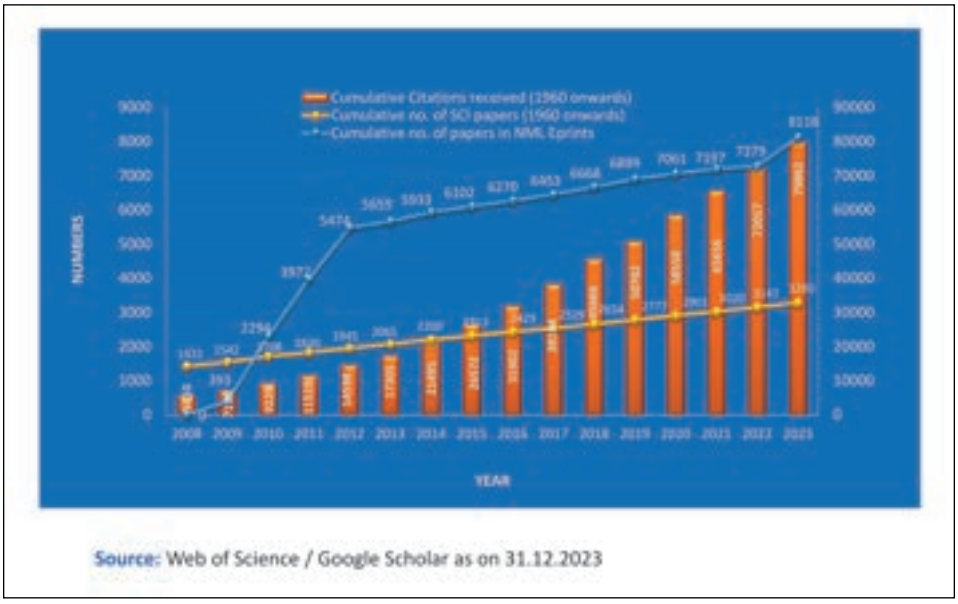
R&D Outputs


NO. OF TECHNOLOGIES TRANSFERRED
2023-24
2022-23
2021-22
2020-21
2019-20
5
1
5
3
4


NO. OF TECHNOLOGIES DEVELOPED
2023-24
2022-23
2021-22
2020-21
2019-20
0
0
3
8
3


NO. OF SCI PUBLICATION
135
130
125
120
115
110
2019-20
2020-21
2021-22
2022-23
2023-24
SCI PUBLICATION


NO. OF PATENTS FILED
25
20
15
10
5
0
2019-20
2020-21
2021-22
2022-23
2023-24
PATENTS FILED


Cumulative Citations received (1960 onwards)
Cumulative no. of SCI papers (1960 onwards)
Cumulative no. of papers in NML Eprints
NUMBERS
YEAR
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
90000
80000
70000
60000
50000
40000
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10000
0
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023
1633
1540
2256
3972
5474
5655
5933
6102
6270
6453
6668
6889
7061
7317
7379
8118
393
Source: Web of Science / Google Scholar as on 31.12.2023

Performance Targets planned for 2024-2025

	Objectives	Planned
1.	External Cash Flow (ECF)	30 Crores
2.	Industrial ECF (a part of ECF)	16.0 Crores
3.	Customer Satisfaction Index	4.8 (Max. 5)
4.	SCI Publications	140
5.	Patents	10
6.	Copyrights	5
7.	Technologies to be Developed	5
8.	Technologies to be Transferred	5

Major Technological & Scientific targets Planned for 2024-2025

Applied & Analytical Chemistry

- Coking coal assessment through Artificial Intelligence
- Direct regeneration of spent LIBs cathode material and reuse in energy storage device
- Coal characterization and analysis
- Ceramic primer for rusted steel.
- Development of different grades of coal CRMs of Indian coals.
- Development of eight grades of Indigenous iron ore CRMs from 40% Fe to 67% Fe for XRF analysis.
- Development of different grades of Bauxite and Dolomite CRMs.
- Development of 6063 grade Al disc standard (500Nos.)
- Development of two different grade Pb base disc CRMs (500Nos. of each grade).
- Development of four different grade Chromite ore CRMs (200Nos. of each grade).

Development of alternate reagent for the elimination of mercury effect for reliable analysis of Hg in coal and coal fly ash samples.

Materials Evaluation

- Powder production for additive manufacturing: Steels and Amorphous alloys
- Scaling up of armour steel to achieve (TRL-7)

Metals Extraction & Recycling

- Pidgeon process for the production of magnesium metal.
- Critical metals from the primary and secondary resources under Mapping & Tapping of Critical Minerals mission of CSIR
- Development of self-healing geopolymer under CSIR first scheme
- Development of technology for Extraction of zinc metal and salts from zinc dross.

Mineral Processing

- Development of process for beneficiation of lean grade iron ore having less than 45% Fe content
- Recovery of lithium concentrate & other critical minerals from Lithium ore of Jharkhand
- Bench Scale Beneficiation and Pelletization Studies of Iron Ore Samples from ISMQ, Egypt.
- Extraction of vanadium as high pure V2O5 and TiO2 from Vanadium titaniferrous magnetite ore
- Beneficiation and palletisation on tailing from Kiriburu mines, Meghatuburu mines and composite sample of both tailings

Advanced Materials

- Commercialization of Billet Mould Break-out detection Technology.
- Implementation of LTCC based eddy current sensor for real time creep damage monitoring in one of the power plant components.
- Implementation of AI based technology for thermal mapping of downcomer of pellet plant in a steel plant.
- Performance evaluation of Ultrasonic Flowmeter in the space environment.
- Establishment of Ultrasonic imaging technique to assess the quality of connecting rods of Tata Cummins.
- Design, fabrication and transfer of Binder Gauge device.
- Set up development for 3.5 cm X 3.5 cm and 5 cm X 5 cm AEM alkaline electrolyser cell for green hydrogen
- Development of biodegradable Zn-alloys for implant applications
- Development of biodegradable Mg-alloys for implant applications
- Development of multilayer Zn coated high strength Mg-based biodegradable alloys
- Design and development of Iron amorphous alloy powders for thermal spray coatings.
- Fe-Nitride powders for hard magnets through Ammonia gas nitriding route.
- Application of GMI based sensor “MagRays” in structural integrity assessment of components in cement industry
- Development of working prototype of Planar flow Castor (5kg) for producing thin metallic strips.
- Development of ferrochrome slag coating for continuous steel caster rolls
- Development of antimony chalcogenide-based photoabsorber coatings for photovoltaic applications
- Development of Zn-Al-Mg based hot dip coating for cold rolled steel sheet (RDCSI)
- Development of Fe-based amorphous alloy and its coating by HVOF for hydro turbine components
- An energy-efficient phase specific process for ZnFe-alloy electroplated high strength steel for automotive application
- Electrodeposited corrosion resistant carbide coatings on SS 316L for Sink Roll applications in Continuous Galvanizing Lines
- Advanced Colorized Hot Dip Galvanising Zn-X (X- Mn, Ti, Co) Alloy Coating with Excellent Powdering and Corrosion Resistant
- CEMILAC certification for Binary Zn-Mn Alloy Coatings to Replace Toxic Cd Coated High Strength Steel Aerospace Components

Technologies Commercialised

Zincometer Technology Transferred to RefoSteel Instruments- A sensing device Zincometer for Zinc coating weight measurement in GI line, installed at Tarapur Wire Mill. Device is working at par the satisfaction of the clients.

CSIR-NML has transferred the technology for estimating the coating weight of steel wires in GI line to M/s Refosteel Instruments, Gamharia. This technology will be useful to measure the Zinc coating weight in real time in the GI line; both in pad wiping (40-150 GSM) as well as nitrogen wiping lines (above 150 GSM). M/S Refosteel Instruments is now authorized to commercialise this sensing device; Zincometer. The project for development of the technology on development of a Multi-strand sensing device with closed loop feedback control for Real-time Zinc Coating weight measurement in GI line was undertaken by CSIR-NML. This technology has been developed under CSIR funded projects. Zinc coating is the most effective and widely used process to prevent corrosion and increase the longevity and performance of steel wire. Zinc coating is generally applied to steel wire by hot dip galvanizing (HDG) process. Zinc coating on steel wire gets done by two wiping technologies; Nitrogen (N2) wiping for thick coating lines (100-500 GSM) and pad wiping (30-90 GSM). The N2 wiping system is equipped with sensor-based closed loop zinc control system for controlling individual wire coating weight. In the pad wiping line, as the wires exit the galvanizer, each wire passes longitudinally between a set of two rectangular pads. Individual screw clamping mechanisms are provided to compress each set of pads together to tightly wipe the wire. There is no such real time automatic control system is existing in the pad wiping line. Present practice is to cut a small piece after each shift and measure the coating weight by dissolving zinc in a solution. This does not assure uniformity of the coating weight along the few km length of the wire. It results over-coating and also under-coating of GI wires. Hence requirement of real time coating weight measurement in the thin coating line to assure uniform coating weight along the length remained as an unmet requirement. CSIR-NML has developed the technology for coating weight measurement of GI line in thin coating line. The sensing device has been upgraded to 10 channel system under the CSIR Fast Track Commercialisation (FTC) project. 5-channel system has been installed and commissioned at Tarapur Wire Mill of Tata Steel in October, 2023. The technology has been transferred to a Ghamaria based MSME company M/s Refosteel Instruments on 4th December, 2023. Figure 1 shows the 5-channel system along with sensors installed at Tarapur Wire Mill.

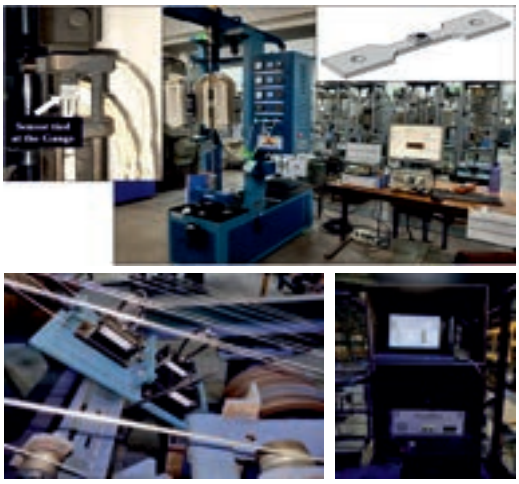


Figure 1: Sensor placed in 3 lines at Tarapur Wire Mill (a) and Zincometer placed at TWM (b).

The feedback received from the user industry on the performance of the system is below:



From : Shishir Desai <Shishir.Desai@tatasteel.com> Mon, Feb 19, 2024 03:19 PM
Subject : RE: Transfer of Technology Zincometer
To : Sarmishtha Palit <sarmi@nmlindia.org>
Cc : refosteel@gmail.com, refosteel@yahoo.com, Tarun Kumar Das <tkdas@nmlindia.org>, vvmaha@tatasteel.com, Dr. S.K.Pal <skp@nmlindia.org>, Dr AK Srivastava <director@nmlindia.org>, Rajesh Mohite <Rajesh.Mohite@tatasteel.com>

Feedback from Client

Understand you are writing about the 3 channel system installed at TWP-2, Tarapur.
The system is working satisfactorily
Regards

Shishir Desai

Electronic packages for ultrasonic flow meter for on-board propellant gauging of spacecraft

Spacecraft propellant gauging is one of the important activities that allow estimating the amount of propellant available onboard in a spacecraft. The propellant availability dictates the life of the spacecraft; also the data related to the propellant availability determines the mission sequence and decisions. CSIR-NML along with LPSC, ISRO, Bangalore are in this project to fabricate four systems using flight qualified electronics for on-board propellant gauging of space craft based on CSIR-NML technology fluid flow rate detection through a narrow tube. Calibrator unit is developed, tested and delivered to LPSC, ISRO. Several trials were made to measure the flowrate in the laboratory setup. Trials were made in continuous as well as pulsed flow mode. Acceptable results were obtained. Procurement of space-qualified components as per the supplied BOM has been completed by LPSC, ISRO. Final calibrator unit performance was demonstrated to the LPSC Director Dr V. Narayanan on

5th January, 2024 to discuss the future course of action. Picture of demonstration is given in Figure 2.



Figure 2: Demonstration of UFM to the Director, LPSC, Bangalore

Development of the process for recovery of plating grade Nickel and Copper sulphates from Monel Scrap: Laboratory to Commercial Production

Monel scrap is a vital part of the reusable metal industry. Since Monel scrap is much more expensive than typical stainless steel scrap metal, it is important to recycle the scrap as much as possible. It is found in various parts and machinery including keel bolts, valves, turnings, marine piping systems, aircraft and anchor cables. Monel scrap is primarily composed of nickel (65-70%), copper (20-29%), and also contains manganese and iron, as well as trace amounts of other elements. Therefore, there are variety of Monel scraps of different compositions are available for recycling. Both copper and nickel are high value mental and economic recovery of these metals will generate huge revenue. A private industry, was interested in recovery of both copper and nickel from Monel scrap as their sulphate suitable for plating industries. Accordingly, CSIR-NML developed a hydrometallurgical process for recovery of plating grade copper and nickel sulphate from Monel scrap supplied by the party. The produced products under optimised conditions were of desired quality and were found suitable for plating application as tested by the user industries. A complete flow-sheet with material balance on kilogram scale was developed with preliminary techno-economics feasibility. The process was demonstrated to the party and a pilot plant of 10 kg per day scale was set-up at party's premises and continuously ran for several weeks. Based on the data generated from the pilot plant, a commercial plant of 500 MT capacity was designed with details of equipment's MOC, size etc. Erection commissioning of the plant is in progress. The plant is partially running for commercial production of plating grade copper and nickel sulphates.

Certified Reference Material (CRM) Services Provided

CSIR - NML is pioneer in developing certified reference material that are contributing in establishing the metrological traceability, calibration of instruments and validating the analytical measurement methods. We are serving the nation with 35 nos. of CRMs having Accreditation as per ISO 17034:2016 as RMP producer by NABL, Quality Control of India, since 2022. It produced CRMs, of different categories

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

Several additional CRMs for Steel Spectrographic Standards, Aluminum base, Lead base in Disc form and Iron Ore, Chromite Ore, Coals for different grades in powder form are under preparation mode. All above CRMs have been developed as import substitution, under Atamanirbhar Bharat mandate given by Gov. of India. All the developed CRMs are available in its compositional value in CRM brochure with CSIR-NML official website (www.nmlindia.org).

In the FY 2023-24, CRM Unit, AAC Division has re-certified some CRMs and prepared the following new CRMs

#	CRM No.	Name of CRM	Date of Issue	Status
1	217	0.4% Carbon Steel (Turning Form)	10.11.2023	New
2	152	Coal (Powder Form)	24.01.2024	New

The laboratory has received renewal of RMP accreditation as per ISO/IEC 17034 by NABL, Quality Control of India for 13.01.2024 to 12.01.2026 for all available 35 Nos. of metallurgical CRMs. All the developed CRMs with their compositional value are available in the CRM brochure and CSIR-NML official website (www.nmlindia.org). Many more CRMs for Steel Spectrographic Standards, Aluminum base & Lead base spectro standard in disc form, Iron Ore, Chromite Ore, and Coals (for different grades) in powder form are under preparation process. All the above CRMs contributed to the Import substitution and developed under the ***Atmanirbhar Bharat*** initiative of Govt. of India.



Impact Making Technology

Integrity of the Iron Beams at Konarka Temple.

This project is under the Science and Heritage Research Initiative (SHRI) scheme of DST. IIT, Bhubaneswar is the collaborator of this project. The project has three broad objectives: a) Broadly review the technology available during that period making beams; b) In-situ non-destructive characterization of Konarka iron beams and validation with a few microstructural tests of selected samples; c) Characterize the nature of the corrosion occurring in iron beams at the Konarka using portable electrochemical corrosion testing equipment. In this connection, a team comprising scientists from CSIR-NML and Professors of IIT-BBS have already visited thrice to Konarka Sun temple. Among 38 Iron beams, one iron beam was selected as the Test Beam with the approval of the Assistant Superintendent of ASI. Both ultrasonic and electrochemical tests were carried out on the test beam to generate useful data and to collect information under the guidance of Dr. O N Mohanty. In the second and third visits further experiments using ultrasonic and phased array ultrasonic (PAUT) were carried out on 3 sides of the test beam. Figure 1 represents the iron beam of Konarka sun temple and the measurement setup. The collected data consisted of ultrasonic signals as measured on the test iron beam (by CSIR- NML), electrochemical corrosion analysis on few selected places on the beams (by IIT- BBS) and collection of iron beam samples for optical microscopy to study in laboratory (IIT-BBS).



Figure 1: The test iron beam of Konarka sun temple and the measurement setup

Synthesis, Characterization and Application of Amine Functionalized Metal Organic Framework materials (MOFs) in post combustion CO_2 capture and Photo catalytic CO_2 conversion to valuable products

Carbon dioxide mitigation using functionalized Metal Organic Framework (MOFs) is a promising strategy due to convenient operation, low regeneration cost, good structural and thermal stability, outstanding cyclic efficiency, economic viability and environmental friendly. In this project, MOFs are hydrothermally synthesized in the laboratory and functionalized by amines impregnation to enhance CO_2 adsorption capacity than that of as synthesized MOFs and to achieve faster rate kinetics. Wet-impregnation technique is adopted to functionalize MOFs with secondary diamine in different amine concentrations to enhance CO_2 adsorption capacity in wide range of temperature and multiple adsorption cycles. Bench scale static and dynamic CO_2 adsorption-desorption experiments were carried out and break-through curve represents dynamic adsorption performance. Both primary (R-NH) and secondary groups (R-NH2) on same site enhances the ability of CO_2 adsorption in secondary diamine due to more active amine sites than primary amines. The materials were also presented good structural and thermal stability. The CO_2 adsorption capacity decreases with increase in temperature and adsorption cycles. The CO_2 molecules are found to be energetically active with higher kinetic energy and the specific molecular orientation for nucleophilic attack might not be possible at elevated temperature. The MOFs are characterized using N_2-adsorption/desorption (BET analysis), XRD, TGA, FT-IR analysis. The Freundlich, Langmuir, Sips and Toth isotherm models are used to correlate experimental static CO_2 uptake. The isosteric heat of adsorption is calculated to understand degree of heterogeneity and surface energy distribution of adsorbents. Second module of this project is about end use of CO_2. The MOFs are used as photo catalyst in a photo-chemical reactor setup at specific condition to get CO_2 conversion into valuable industrial products such as methanol and formic acid. This bench scale experimental data of this project will be useful for future application in selective CO_2 adsorption-desorption from industrial flue gas with modified adsorbents under CCUS application.



Figure 2: Temperature controlled adsorption-desorption column for CO2 capture



Figure 3: Photo chemical reactor for CO_2 conversion

Processing of Tin slag and technological extraction of critical elements

Tin slag is a potential resource of Niobium (Nb), Tantalum (Ta), and other critical metals. It contains 8-10% Ta_2O_5, 14-18% Nb_2O_5. This work is supported by the Ministry of Steel to

recover Nb and Ta as high pure (>95%) salts; and concurrently as ferro-niobium (63%Nb). The project is governed by objectives of beneficiate tin slag, and use the concentrate/as received sample to extract Nb and Ta, by a non-HF process. The feed material has been subjected to mineral liberation analysis and flotation circuits. The concentrate and as-received samples have been subjected to hydrometallurgical processes. The PLS generated is tested for separation of the desired metals like Nb, Ta, Ti, etc. In conjuncture with this, Ministry of Mines supported a project to develop a novel hydrometallurgical technological process for extraction and separation of scandium from Tin slag. Figure 4 is as received Tin slag sample.



Figure 4: Tin slag

Transfer of technological Know-How to recycle spent lithium ion batteries (LIBS) to produce value added products of Li, Co, Mn, Cu, Ni as metals/salts, saleable plastics and graphite

CSIR-NML signed a MoA with the New Delhi based recycling company for the transfer of technological Know-how to recycle spent lithium ion batteries (LIBs) to produce value added products of Li, Co, Mn, Cu, Ni as metals/salts, saleable plastics and graphite. The recycling plant of the company will be soon operational for the production of saleable products of Cu, Ni, Co, Mn and Li from LIBs based on CSIR-NML technology. CSIR-NML has already transferred similar technologies to various recycling plants for commercial exploitation under the aegis of Urban Ore Recycling Centre. Based on the developed and proven know-how at CSIR-NML, technological Know-How in the closed-loop design for the recovery of Li, Co, Mn, Cu, Ni, plastics and graphite from Black cathodic material of spent Lithium-ion batteries (LIBs) has been developed. The LIBs were classified, dismantled and processed for shredding/pulverization followed by physical separation to separate black cathodic material, plastics and mix metal fractions from spent LIBs. Characterization and chemical analysis of black cathodic material discarded LIBs was done using AAS/ICP. Subsequently, developed hydrometallurgical process (leaching, solvent extraction, selective precipitation, electro wining, etc.) flow-sheet to recover Li, Co, Mn, Cu, Ni as metals/salts, plastics and graphite from spent LIBs has been fine-tuned using the waste LIBs and rechargeable batteries supplied by the company. The developed technology will be commercialized after demonstration at scale-up/pilot level. The marketable products obtained from the complete Recycling of PCBs is shown in Figure 5.



Figure 5: Saleable Products obtained from the Complete Recycling of PCBs

Transfer of technological Know-How for the extraction of Cu, Al and Au as metals/salts from waste PCBs

CSIR-NML signed a MoA with New Delhi based Recycling company for the transfer of technological Know-how for the extraction of Cu, Al and Au as metals/salts from waste PCBs. The recycling plant of the company, will be soon operational for the production of saleable products of Cu, Al and Au from PCBs based on CSIR-NML technology. CSIR-NML has already transferred similar technologies to various recycling plants for commercial exploitation under the aegis of Urban Ore Recycling Centre. Based on the developed and proven know-how at CSIR-NML, technological Know-how for the extraction of Cu, Al and Au from waste PCBs has been developed. A hybrid metallurgical process consists of mechanical pre-treatment, physical beneficiation, hydrometallurgical advance separation and/ or electro was used for this technological KNOW-HOW to extract Cu, Al and Au as value added product (metal/ salts). The developed flow-sheet has been fine-tuned using the waste PCBs supplied by the supplier. The developed technology will be commercialized after demonstration at scale-up/pilot level.

Impact on Society

Phenome India-CSIR Health Cohort Knowledge-base

COVID-19 pandemic emphasized the need for longitudinal prospective cohort studies within Indian sub-continent. The cohort studies are essential to establish link between risk factors and health outcomes. Presently, risk prediction algorithms are mostly based on epidemiological data from Caucasian population. There have been evidences that these predictions are inaccurate for the Indian population due to ethnic diversity, varied dietary and lifestyle patterns, and altered risk profiles. Therefore, it is important that India-specific risk prediction algorithms are to be developed for communicable (COVID-19) and non-communicable diseases (Cardiovascular disease and Diabetes). This multi-centric program will involve longitudinal collection and bio-banking of biological samples from about 5,000 CSIR employees, pensioners and their family members with concurrent collection of multi-parametric data and will include clinical questionnaire, lifestyle and dietary habits, anthropometric parameters, imaging/scanning, biochemical data, and molecular data including genomics, plasma proteomics, and metabolomics. These data will be archived in a central data server and analyzed to develop robust individual and pathway-based observations which then using artificial intelligence-based tools will help to identify risk factors and develop risk matrix for various communicable (COVID-19) and non-communicable (CVD, Diabetes) that will be applicable to the Indian population. When combined with prospective collection of biological samples and analysis of the phenome using big-data approach, it can yield a wealth of information in establishing causation and development of diagnostic and prognostic biomarkers especially for chronic non-communicable metabolic diseases, which is an emerging health crisis in India.

CSIR-NML is actively participating in Phenome India-CSIR Health Cohort Knowledgebase project. A team under the leadership of Dr. Arun Bandyopadhyay, (Director, CSIR-Indian Institute of Chemical Biology (CSIR-IICB) Kolkata) visited CSIR-NML for conducting an awareness programme on 13th September 2023 (Figure 1) for 'Phenome India – CSIR Health Cohort Project'.



Figure 1: Awareness Program on Phenome India-CSIR Health Cohort Knowledgebase.

Cohort portal https://csircohort.org/ is developed to enable the registration, data uploading and storage of all the participants of the Cohort study. The first sample collection of CSIR-NML employees, pensioners and their spouses was held from 12th to 18th March 2024. Amongst the registered 490 participants, around 330 have booked their slots and appeared for the various tests and scans. On the last day of the PI-CHeCK program, a valedictory function was organized at NML residential colony, Agrico, Jamshedpur.

Energy Efficient Coke-based Brass and Bell Metal Melting Furnace of Capacity 50 kg for Brassware Artisans

Brass, aluminium or other non-ferrous artefacts of various types are prepared by the artisans of brass clusters located in various parts of the country. The raw materials for the production of brass artefacts are brass scrap or copper and zinc. These raw materials are obtained from locally or from the raw materials suppliers. For melting metals/ scrap various furnace options are available. The hitherto known furnaces operated for melting brass/aluminium for manufacturing artefacts are coal/coke fired furnace, gas base furnace, oil fired furnace, induction furnace etc. The preference of furnace depends on the locality, availability, cost and ease of operation. Among the various types of melting furnaces, coal/coke based melting furnace or 'Bhatti' is used by most of the artisans in different parts of the country. The melting furnace or 'Bhatti' is utilized for the melting of brass, aluminium, scrap of brass, scrap of aluminium etc. The melting furnace is prepared by the unit owners as per their traditional processes is shown in Figure-16. The problem with above type and design of brass melting furnace is the evolution of toxic gases which leads to health hazard due to presence of excessive suspended particulates matters and zinc fumes including other gases in flue. The design philosophy of the development of brass and bell metal melting furnace is- minimum alteration of existing traditional brass melting furnace, ease of operation and maintenance, provision for modification/upgradation for higher capacity, construction by using locally available materials, minimisation of additional investment.



Figure 2: The melting furnace is prepared by the unit owners as per their traditional processes.

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

The project aims to improve the livelihood of the ST community in the Gamharia village by technological intervention. Different skill-based and entrepreneurship development-based training will be provided to the targeted community by XITE and NML. Different technological interventions, like, waste to wealth, water management, etc., will be done, and hands-on training will be given to the local populations to enhance their quality of life. Training will be given so that they can adopt some of these technologies for doing business. Facility creation in terms of the establishment of a rural tool room centre is another aim of the project. The activities of the projects are as follows.

1. To design, develop and coordinate a six month Technology based Entrepreneurship Development Programme (TeDP) at XITE
2. To establish minimum five technology based business ventures every year
3. To create a Rural Toolroom Centre (RTC) for offering training to rural people, for DIY (do-it-yourself) work and for making tools and equipment available on rent
4. To implement an efficient water management system
5. To enhance and build on local skills and know-how through science and technology interventions and develop access and linkages to national and global markets for enhancing their income level.

CSIR Jigyasa 2.0

During its Platinum Jubilee year, CSIR launched the CSIR-Jigyasa Virtual Laboratory Project, an effort motivated by the Prime Minister's vision of a new India and Scientific Social Responsibility (SSR) for CSIR. The goal of the "CSIR-Jigyasa 2.0 Programme: Virtual Lab Integration" initiative is to motivate children to learn science easily, joyfully, and with excitement. As part of this project, CSIR-NML plans to set up different kinds of scientist-teacher engagement programs and develop cutting-edge educational resources and materials through Virtual Laboratory (VL) using cutting-edge digital technology with an emphasis on materials, metallurgy, minerals, and metals. Students in grades VIII through XII are the intended beneficiaries of this project, which primarily focuses on government-funded rural schools. In FY23-24, CSIR-NML organized various programs for the students and teachers and connected 30 nos. of schools located around Jamshedpur. Under the Jigyasa program, we have conducted 11 nos. of one day CSIR-NML visit for 1530 students and 88 teachers. We have also conducted 2 nos. of visit of scientists to different schools, 1



nos. of teacher's workshop (online in association with KAMP) for 115 teachers, 5 nos. of Popular lecture series for 541 students and 25 teachers, 2 nos. of Vigyan Jyoti program for 88 girls' students and 7 teachers, 1 no. of STEM club catering 45 students and 5 teachers and 3 nos. of students micro projects for 65 students. Under this project we have also mentored 1 ATL schools for 29 students. CSIR-NML has participated in World Largest Climate Clock assembly and demonstration along with Energy Swaraj Foundation where 61 students and 8 teachers from 5 schools participated. CSIR-NML also conducted 2 outreach programs for the students, one at IISF at Digha and other one at JNV Chaibasa where 99 students and 1 teacher participated. CSIR-NML has also developed 5 nos. of "DO IT YOURSELF (DIY)" kit, like, RGB colour mixing, solar fan and light, wireless electricity, gravitational energy conversion and electrical to sound energy converter, demonstrating the basic concepts of science. Apart from this, CSIR-NML has developed 11 nos. of virtual content covering, comics, simulation, quiz, animation and videos. The topics covered were tensile strength of materials, corrosion rate, E-waste management, measure of central tendency, accuracy and precession, continuous casting, extraction of metals, advanced materials, etc. Through this Jigyasa activity, CSIR-NML has connected 2458 students, out of which 50.24% are girl students.

Skill Development Program

The "CSIR-Integrated Skill Initiative" programme was started by the Council of Scientific and Industrial Research (CSIR), in partnership with the Indian government 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, 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, waste utilization, soft skills, and entrepreneurship development. In FY 2023 – 2024, CSIR-NML trained 701 participants through corporate training programs, societal training programs, and other programs including BTTD 2023. CSIR-NML Conducted 2 corporate training programs namely, Remaining Life Assessment & Failure of Engineering Components (Rfec'23), Exposure Training on Metallic Pipe (ETMP"2023). CSIR-NML has conducted 25 Societal training programs (STP) for college students and others. The societal training includes Internship training in metallurgical engineering, Innovative Product prototype making, Hands-on experiments on water splitting for green hydrogen generation, Computer 3D Printing & product development (C3DPD), and other internship training. CSIR NML has also organized an Exposure to research facility for undergraduate students. Apart from this, CSIR NML has organized winter training for M.Tech, undergraduate and diploma students. CSIR-NML is also focusing on the orientation of the training as per NSDC guidelines.

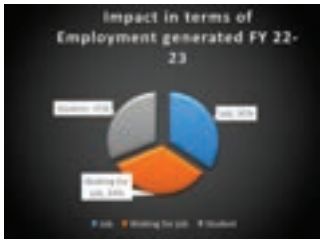
Impact analysis of skill developments carried out in FY22-23:

In FY 22-23, 689 participants were registered under skill development. CSIR-NML tried to serve every segment of the society. The training statistics and employment data are as follows as responses received till Feb 2024. Out of 311 respondents from FY 22-23, 110 participants received jobs whereas 107 participants are waiting for job. Among the job recipients, 15% are female.

Women Technology Park (WTP) for capacity building and entrepreneurship development (CSIR-NML and NIAMT)

The objectives of this project are: a) To offer a six-month certificate entrepreneurship development Train the Trainers (ToT) programme on Innovative product development to create a pool of competent women trainers; b)To offer training to women in the areas of carpentry and waste management; c) To carry out need assessment study for women-centric product innovation for developing







innovative machines and tools for improving working condition of women through S &T d)To establish incubation centre for women entrepreneurship development focusing rural India e)To create common facilitation centres for women entrepreneurs. Under the project, CSIR-NML organized job job-oriented training (JOT) program. The details of the training are given below:

Computer, 3D Printing and Product Development (C3DPD)

Computer, 3D Printing and Product Development was conducted for two months from May 2023 to July 2023. The training was provided to 82 participants in five areas, namely Paper Making from upcycling of paper wastes, Arts & Craft, Basic Computer, Fly Ash and 3D Printing. CSIR-NML provided training in the area of Computer, 3D Printing and Product Development (C3DPD) to women from remote areas like Nuagram, Ghatsila, Singhpokhria, Danguaposi, and Baharagora villages. The participants of the training program were mostly from rural areas. In addition to the training, participants were provided training on Entrepreneurship Development, Product Marketing and Skill Development.





Handmade Paper Making at Old Age Home Furida

Under the job-oriented training program, CSIR-NML organized handmade paper-making training for older women who are coming from rural areas in July and September 2023. In this training, participants were given training on making useful products from waste paper. Several different products like handmade paper, paper

plates, key ring holders, and bookmarks are made from waste paper. The training program aimed to help women from different backgrounds to use their spare time to make themselves financially empowered and for upliftment of their living conditions socially.



Animation and Video Making, 3D Printing and Computer Basics

Under the Job-oriented training program, CSIR-NML conducted "Animation and Video Making, Computer and 3D Printing" training in November 2023. The duration of this training program was two months. This training program was conducted for women from rural areas. The minimum Qualification for this training was 10Th Qualified. The training was provided with no fees. The training program aimed to impart video and animation design skills, 3D printing and basic computer skills such as MS Office and Tinkercad. A total of 27 participants completed the training program. The feedback from the participants was positive and they hoped more such training programs could be conducted soon by CSIR-NML for the benefit of society.

Office Management and Entrepreneurship Skill

Under the EDP program CSIR-NML in collaboration with NIAMT, Ranchi is conducting "Office Management and Entrepreneurship Skill" training for a period of six months from November 2023 till April 2024 that intends to facilitate the participants with detailed knowledge of the concept of Management, Entrepreneurship and Professional Skills industry, the occupation of Human Resource Management, the role of Office Operations Executive and their functioning. This training is designed based on the Qualification Pack (QP) under the National Skill Qualification Framework (NSQF), and it comprises the following National Occupational Standards (NOS)/ topics as well as additional topics. A total of twenty-six (26) participants were provided the training program.



Number of Employment Generated Training Wise for DST-WTP is listed below:

Sl No.	Name of Training Program	Name of Beneficiary	Place of Job
1.	Carpentry and Woodcraft with 3D Design Software	Durga Rani Mondal	NGO
2.		Namita Kumari	CSIR-CIMFER
3.	Waste Management: Handmade Paper Making	Kalpana Sarkar	Tata steel Foundation
		Pushpa Masih	JNAC, Jamshedpur
4.	Computer 3D Printing and Product Development (C3DPD)	Laxmi Soren	NGO
5.		Akriti Thakur	VEDANTA, Jharsuguda
		Nandini Paul	VEDANTA, Jharsuguda

Leading Women of India...

Women Heading PSUs

Indian Women who are committed and contributed in achieving the results are rising to the lead positions of their own organizations

Our core strength lies in developing, as well as adopting, innovations and environment friendly process technologies that are both indigenous as well as hailing from across the globe.

Sukla Mistry is the first women director of refineries in the country's largest oil refining marketing company, Indian Oil Corporation (She headed Indian Oil's Digboi Refinery (which is the oldest operating refinery in Asia, where she played a key role in maximization of value added products like Rhino Wax brand and commissioning of IOC's Golai Marketing Terminal Mistry has an experience of over 35 years in the areas of refining and petrochemicals She was earlier heading IOC's Barauni Refinery in Bihar where she played an important role in rolling out BS 6 grade fuels She has worked at IOC's refineries at Barauni Digboi Haldia and Panipat as well as at the Refineries Headquarters Some of the awards that she has been conferred with, include Best Woman Executive Award 2009 Petrotech Ojaswini Award 2016 SCOPE Award for Outstanding Woman Manager 2016 17 and ET Prime Women Manufacturing and Operational Leadership Award 2021



SUKLA MISTRY
FIRST WOMAN DIRECTOR OF
INDIAN OIL CORPORATION LIMITED (IOCL)



VARTIKA SHUKLA
FIRST WOMAN CMD OF
ENGINEERS INDIA LIMITED (EIL)

Our focus on renewable energy sources, cleaner technologies and sustainable practices is at the forefront of our operations.

Vartika Shukla is the Chairman Managing Director of Engineers India Limited (EIL). She has done Chemical Engineering from IIT, Kanpur and Executive General Management Program from IIM (Lucknow). She is a Member of the Oil Industry Development Board (OIDB), She has served EIL for over 3 decades and led many prestigious projects leading to key Refineries Petrochemical complexes, Fertilizer plants both in India and overseas and securing Energy security of the nation Her initiatives at EIL include widening the prospects in the areas of coal gasification, biofuels, renewable Energy, and Green Hydrogen space. She has contributed to the development of National Policies especially in the area of Auto Fuel vision policy, National Bio Fuel Policy and future road map for the refining and petrochemical sector. She is the first woman executive in the Indian Oil Gas industry to be bestowed with PETROFED Woman Executive Award. She aims EIL India for a Net Zero carbon emission by the year 2035 by 2070.

Flagship Projects

A. Metallurgical Failure Investigation of Engineering Components

Preamble

Failures in engineering components are common during service exploitation. Root cause could be defective materials, inappropriate operation, faulty design, natural aging and deviation from usual prevailing operational environment. Failure of components results in shutdown of plants, financial loss due to high downtime and in some cases casualty. Post failure initiative involves removing, repairing and re-fitting of components, which are sometime very unwieldly. Therefore, to prevent / mitigate future catastrophes for avoiding economic forfeiture, metallurgical failure analysis is of great importance for healthy, hazards free, smooth and desired service life of the components.

Different engineering components have diverse modes of failure depending on nature of operation, material and environment. CSIR-NML has a legacy over the years to develop expertise on the above subject and extends the hand for cooperation to different industries, from defence to structural, refineries to chemical and automobile to fabrication sectors. A consolidated data of collaboration in this respect has been provided below for 2023-'24:

Oil refiners & petro-chemical (# IOCL # Mann Industry); Power (# NTPC # Jindal Power); Transport (# Indian Railway # Delhi Metro Railway Corporation); Structural (# Aditya Birla #Indian Defence # Air Force). The highlights of major activities are provided in subsequent section.

Root Cause Analysis of Failures in 18" OD API 5LX-70 HFERW Linepipes.

The project aimed at finding out the origin, nature and reason of pre-mature failure of 18 OD, HFERW API 5LX-70 pipes during hydro test. Failure in 18" OD, API 5LX-70 HFERW pipes, manufactured by a vendor in western India, was reported during the hydro-test prior to service exposure. In order to assess the root cause of the failure, two pipe segments were identified and were sent to CSIR-NML. One of the pipe segments (Pipe no.: 96-10) had a visible crack in the identified, whereas no flaw was detected in the other pipe (Pipe no.: 84-5) during visual inspection. Post visual inspection and dimensional measurements, non-destructive evaluation using ultrasonic testing was carried out and pinhole type flaws were detected the in the marked region of Pipe no.: 84-5 (Figure 1-2). The identified regions were sectioned and microscopically examined using Scanning Electron Microscope (SEM) and Energy Dispersive X-ray Spectroscopy (EDS). The pinholes were found to be associated with the presence of series of inclusions along the thickness. The large strings of interconnected inclusions were mostly found to be complex oxides/sulphides/ oxysulphides of Al, Ca, Na, Mg, Si etc., which could be attributed to the entrapment of mold flux or desulphurization product during continuous casting of the slabs (Figure 3). The nearby regions of the pinholes were also found to be associated with a high density of inclusions, as found in SEM-EDS studies. Since the fracture surfaces of Pipe no.: 96-10 were completely corroded and devoid of any informative signature, samples perpendicular to the fracture surface were assessed using SEM-EDS, which also depicted branching of the propagating crack towards inclusions (Figure 3). These inclusions majorly consisted of complex oxides/oxysulphides of Al, Ca, Na, Mg, Si etc. The findings confirmed, that the string of large sized inclusions was distributed in extremely heterogeneous fashion. They were responsible for local weakening of material. The reduction in material strength locally, resulted in pre-mature failure of component from that particular zone during hydro testing.

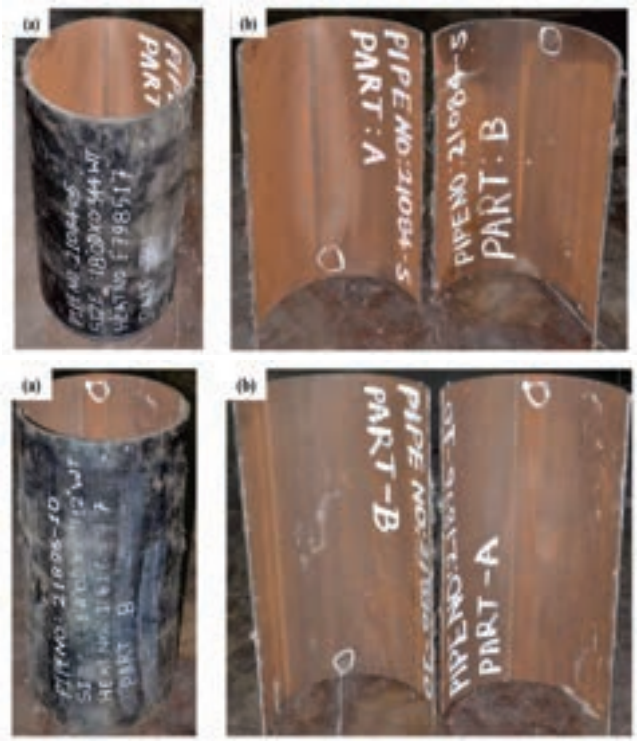


Figure 1: Photograph of 84-5 pipe in (a) closed form and (b) open form depicting the inner surface.

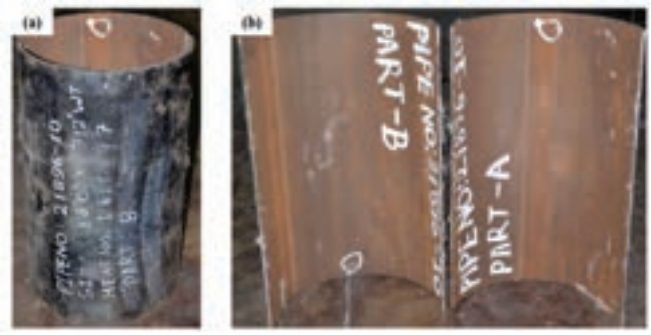


Figure 2: Photograph of 96-10 pipe in (a) closed form and (b) open form depicting the inner surface.

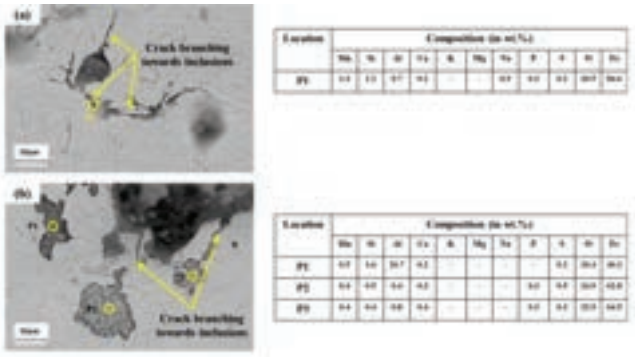


Figure 3: SEM analysis of surface perpendicular to the fracture surface depicting crack branching towards inclusions present at immediate vicinity of the fracture surface.

Metallurgical Failure Investigation of Line Pipe Steel API 5LX70M PSL2

The project was related to the metallurgical failure investigation of Line Pipe Steel of API 5LX70M PSL2 grade. A failure in one of the line-pipe had occurred during hydro-testing at the user's end. The cause of failure could not be ascertained at the field station. The detailed failure investigation involved exploration of nature-origin-reason of the failure of pipe material. A metallurgical investigation was conducted to analyze the failure of an API 5LX70M PSL2 grade line pipe steel, prompted by a 24 mm crack emerging during hydro testing (Figure 4). The study involved examining two segments of the pipe: the damaged section with the crack and an undamaged portion away from the crack site. It was noteworthy, that the crack appeared at a significant distance (~6□□) from the weld line, minimizing the influence of primary welding on the crack's formation. Ultrasonic scans revealed discontinuities near the crack region. Chemical composition, hardness, average Yield Strength (YS) and average ultimate tensile strength (UTS) confirmed compliance with specifications for both damaged and undamaged part (Figure 5). Micrographs showed a consistent ferrite-bainite microstructure typical of API X70 grade steel (Figure 6). Fractographs displayed smooth cleavage facets indicating brittle fracture, accompanied by



Figure 4: Photographs of the damaged region of the as-received pipe part (a) outer-side view of the damaged location(b) magnified view of the crack on the outer surface (c) inner-side view of the same location and (d) magnified view of the crack on the inner surface.

localized dimples. A large non-metallic particle containing Ti, Si, and O was found on the fracture surface, suggesting foreign particle entrapment near the crack (Figure 7). The microstructure beneath the fracture/crack surfaces revealed a layered weld-pool/weld region (of approx. 26 mm length comparable to the crack length) with the presence of typical welding type microstructure comprising of fine grain and coarse grain heat affected zones (Figure 8). The criteria suggested localized intense heating due to welding. The presence of weld overlay-type microstructure around the crack area indicated exposure to multi-pass welding. A continuous steady gradient in microstructure just below the cracked region was the manifestation of multi-pass overlay welding. Temperature rise and subsequent

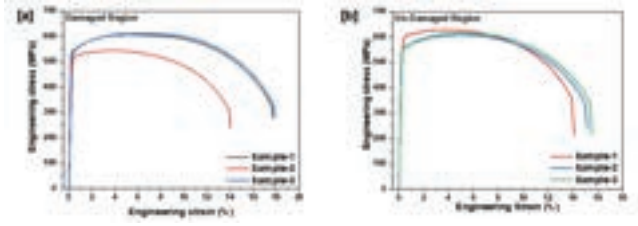


Figure 5: Engineering stress-strain curves of the samples from (a) damaged region (b) un-damaged region.

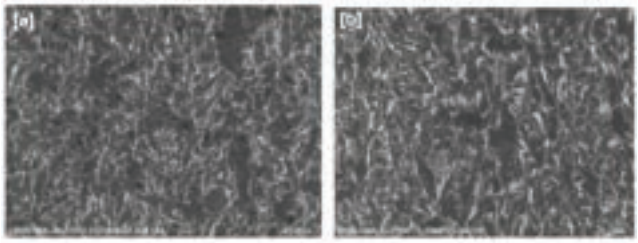


Figure 6: SEM micrographs of the component (a) damaged and (b) un-damaged location.

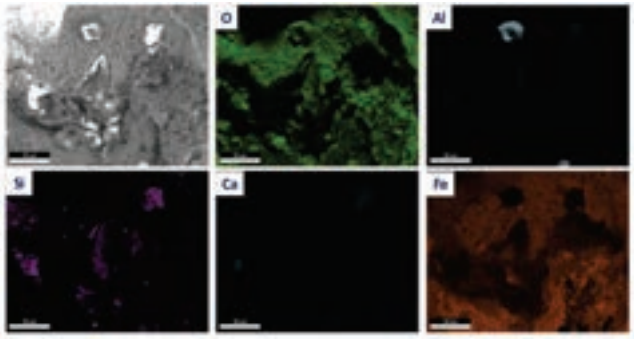


Figure 7: EDS elemental mapping of the non-metallic particles on the fracture surface.

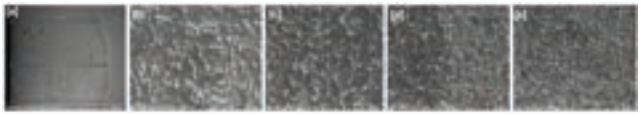


Figure 8: SEM micrographs below fracture surface (a) at a glance different region of the welded microstructure, (b) coarse grain HAZ, (c) fine grain HAZ, (d) HAZ-base metal interface and (e) base metal.

cooling during welding resulted in structural characteristics, that appeared on both sides of cracking. Moreover, presence of complex oxide heterogeneities over fracture surface endorsed the application of some kind of fusion welding over the component. The reason of such kind of welding cannot be figured out as it was related to fabrication-installation-commissioning-subsequent testing.

Root cause analysis of failure of the re-heater tube and economizer tube

Boilers produce super-heated high-pressure steam, which are subsequently utilized to run turbine blades for electricity generation. The boiler consists of various zones in which different grades of tubes carry steam/water at varying pressures and temperatures. Premature failure of such re-heater and economizer tubes from a boiler has been reported in recent past. The reason for failure could not be ascertained at the field station; hence, the investigation was assigned to CSIR-NML for finding out the root cause of such premature degeneration of the components during service. For re-heater tube chemical composition conformed to the specified standard of steel grade - SA213T91 (Figure 9a & 10a-b). Mechanical properties (Tensile and Hardness) of the non-fire side material was in agreement with the specified standard (SA213T91) (Figure 10a-b). Mechanical properties deteriorated drastically for the fire side material. Microstructure of the re-heater tube away from the failure was consistent (tempered martensite). However, presence of few creep voids was observed over the inner wall indicating local rise in temperature (Figure 11). Microstructure of the region just below the failure location contained Cr-rich coarse precipitates indicating a significant rise in the temperature during service. Formation of thick scale layer was found both over the inner and outer wall surface near the fracture zone (Figure 12). Interface between the oxide scale and metal surface possessed deep voids. Thick scale formation and subsequent development of discontinuities at interfaces (voids) impeded the heat transfer from flue gas to water / steam inside through re-heater tube wall, leading to local overheating of the tube



Figure 9: Identification of the 'fire side' and 'non-fire side' in the (a) re-heater tube, (b) economizer tube, along with demarcation of the failure zone in the (c) re-heater tube and (d) economizer tube.

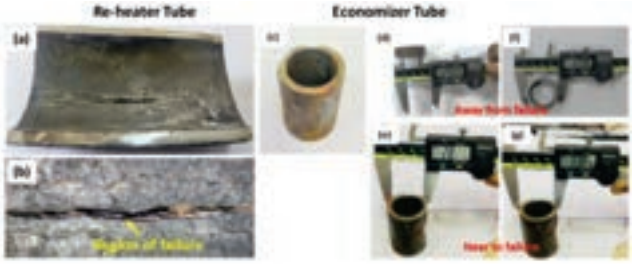


Figure 10: Macroscopic view of the inner wall side in the failure location of the re-heater tube, (b) magnified picture of Figuere. 9(a), (c) View of the economizer tube showing formation of normal/general corrosion product both in the outside and inside of the tube; measurement of the inner diameter in the location (d) away from failure, (e) near to failure; measurement of the outer diameter in the location (f) away from failure, (g) near to failure.

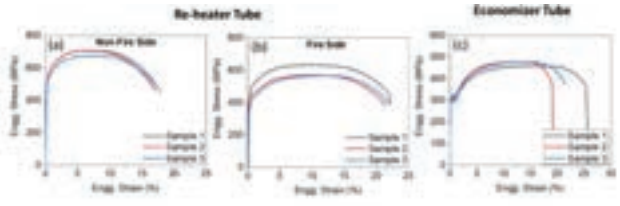


Figure 11: Tensile properties estimation of the re-heater tube (a) non-fire side (b) fire side; (c) economizer tube.

material (Figure 13). For economizer tube (Figure 9b & 10c-g), chemical composition conformed to the specified standard of steel grade- SA210 GR-A1. Mechanical properties (Tensile and Hardness) were found to comply with the SA210 GR-A1 grade steel (Figure 11c). Microstructure of the economizer tubes were ferrite-pearlite (Figure 14a). No evidence of microstructure and mechanical property degradation during service was found (Figure 14b-c). The re-heater tube failed because of localized over heating leading to severe creep and oxidation. Formation of creep voids along the grain boundaries made the grain boundary weak and the material failed eventually under the operating pressure of flowing water/steam at elevated temperature. The economizer tube failed because of steam/water cutting/polishing from the adjacent tubes, hence it was considered to be a case of a secondary failure.

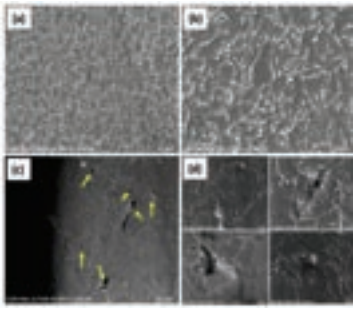


Figure 12: SEM micrographs from the location 'non-fire side-away from fracture' in the re-heater tube (a, b) distribution of precipitates in the matrix (c) formation of creep voids near to the inner wall which is in contact with the steam (d) magnified view of the creep voids formed in different areas.

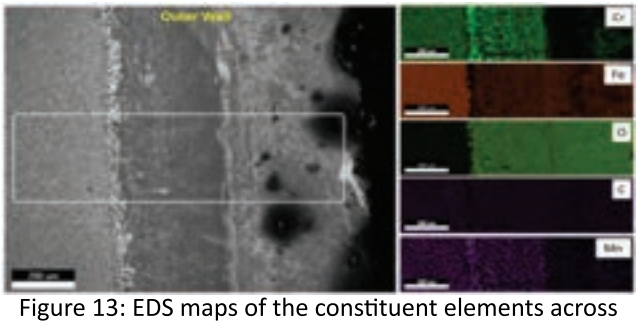


Figure 13: EDS maps of the constituent elements across the matrix and scale phase in the outer wall of tube in the location, 'fire side'- near failure.

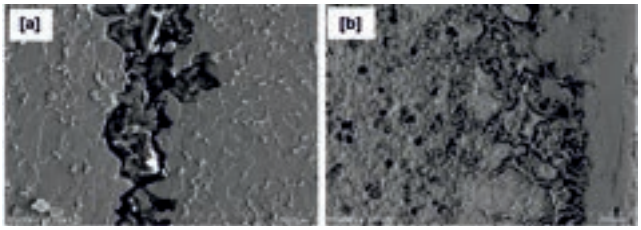


Figure 14: SEM investigation just below the fracture surface showing high density of creep voids over(a) inner wall and (b) outer wall.



Figure 15: Economizer tube (a) optical microstructure and 'Fire side- near fracture' location (b) outer wall of the tube & (c) inner wall of the tube.

Metallurgical Failure Investigation of the Blasted Oxygen Cylinder

There was an incident where an oxygen cylinder blasted into fragments at site. The cylinder was issued from the store, reached the site and the job was yet to begin when the blast happened. Preliminary examination revealed no traces of fire / ignition / external heat. The investigation was assigned to CSIR-NML to explore the reason of failure and possible remedial measure. A broken segment of oxygen cylinder (Figure 16), which experienced sudden blast during test, was investigated through visual examination, chemical analysis, microstructural examination, mechanical property evaluation and fractography (Figure 16). Discrepancy / deviation considering bulk chemical composition, X-ray diffraction study of bulk alloy, macro-hardness, tensile properties and Charpy impact toughness were absent for cylinder material. All these data were compared with standard specification of the alloy (provided by end user) and no deviation was found. The fracture surface contained elongated craters of considerable size. A detailed SEM



Figure 16: Image of as-received part of the damaged oxygen cylinder (a) outer surface, (b) partial inner surface and (c) fragmented part

analysis of sub-surface parallel to fracture plain revealed the presence of significant amount of elongated (Fe,Mn)S inclusions at / around the craters (Figure 17). Presence of substantial quantity of inclusions in the form of long stringers raised an issue about the cleanliness of the alloy. Moreover, these heterogeneities acted as stress raiser. During test under the application of stress, crack was triggered from the regions containing inclusions / stringers at early stage and component failed pre-maturely. Final failure occurred through micro-void coalescence exhibiting the characteristic of ductile dimple fracture. The failure was accompanied by substantial wall thinning close the failure location.



Figure 17: Investigation outcome of damaged oxygen cylinder (a) engineering stress-strain diagram of cylinder material, (b) microstructure in SEM and (c) fractography

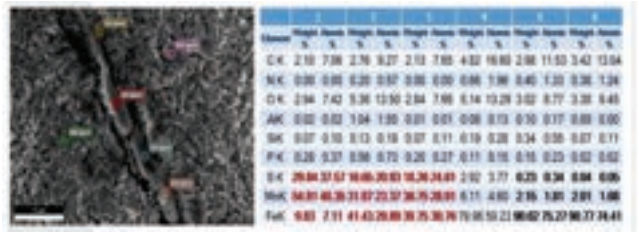


Figure 18: Scanning electron micrographs and corresponding EDS chemical analysis of non-metallic phase just below the fracture surface.

Metallurgical Failure Analysis of KSA Clamp of MIG-29 Aircraft

An in-service failure was reported for KSA clamp band used in MIG-29 aircraft. In preliminary report it indicated, that during landing traces of oil was found on stbd cowling and VDT. During further checking, KSA clamp band of STBD was found broken. A crack was also observed at spot welded location of other KSA clamp band. With this background, an investigation was planned to find out the factor and nature of pre-mature failure of the mentioned component. Metallurgical failure analysis of KSA clamp bands were carried out by visual observation, chemical analysis, optical microscopy, scanning electron microscopy, and hardness evaluation. One broken KSA clamp band and one cracked clamp band were investigated (Figure 19a-b). It has been observed, that crack was initiated from edge near spot-welded region (Figure 19a). Bulk composition of the alloy corresponded to grade ASTM 202/AISI 202 stainless steel. Microstructure of the broken specimen consisted of alternate lamellae of bright and shaded band (Figure 20a-b).

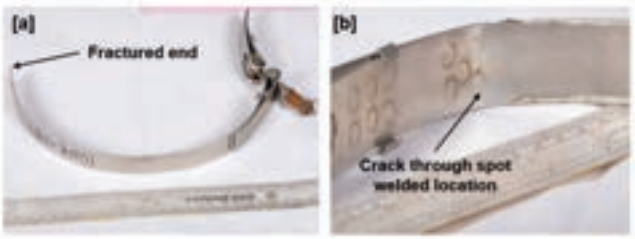


Figure 19: As received components (a) fractured clamp band and (b) cracking through spot welding for non-fractured clamp band

Microstructure of cracked specimen contained polygonal □-phase with fine scale dispersion of alloy carbides (Figure 20c). The bulk hardness of both component was higher than that of the standard and might be attributed to the strain hardening, which took place during secondary processing of the component. The primary cause of failure was fatigue. Fatigue crack was initiated from the clustered oxides, predominantly found in the weld zone and adjacent area (Figure 21b). They perhaps formed during welding and appeared as irregular shaped islands / long stringers (Figure 21c and e). During service exploitation, fatigue crack was nucleated from that region and propagated over fracture plan (Figure 21b). Beach marks / striations over fracture surface endorsed fatigue crack propagation during service. The final failure of the component occurred through fast fracture (Figure 21d). Primary cause of component failure was fatigue. Fatigue crack was nucleated from the heterogeneities consisting of complex combination of oxide and oxy-sulphide, located close to the weld zone. The occurrence of inclusions might be the outcome of inappropriate spot welding procedure. Theses oxides acted as stress raiser and during service, triggered fatigue cracking. The crack grew in length over certain time span. When the length reached a critical value, the rest of the component failed due to fast fracture exhibiting the characteristic of mixed mode i.e., small amount of dimples with cleavage facets.

Metallurgical Investigation of Fractured Rails Involved in Derailment of an Express Train

There was an incident of derailment of express train in recent past. The derailment caused severe damage to the railway track over considerable length. At few locations the track was found broken. The preliminary investigation has been carried out and it was presumed, that the breakage might be caused by the high speed impact of parts like undercarriage / wheels / axles / bogies of the derailed locomotive and coaches. However, the same could not be confirmed at site. It has been subsequently decided to explore the reason of derailment, the breakage of railway tracks and sequence of incidents during accident. With this background, an investigation has been planned to address the aforementioned issues to prevent such catastrophe in future. From the accident site couple of segments of

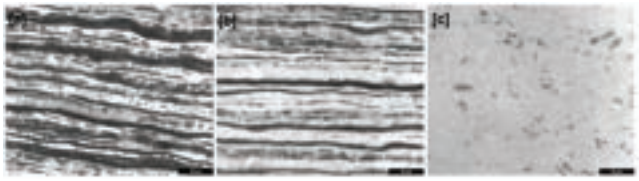


Figure 20: Optical micrographs of KSA clamps (a) near fracture, (b) away from fracture and (c) away from cracked surface of non-fractured specimen

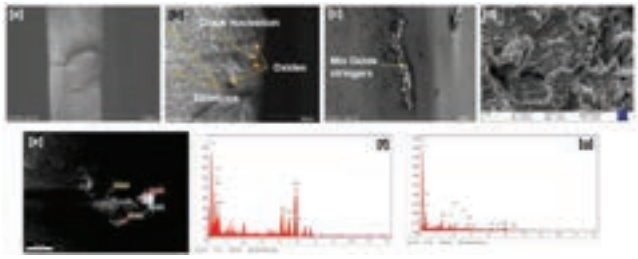


Figure 21: Damged KSA clamp revealing (a) overall fracture surface, (b) fatigue crack nucleation from oxides along with signature of striation, (c) stringer of mixed oxide with micro-cracking close to edge, (d) fast fracture showing cleavage characteristic, (e) entrapped oxides near weld zone of un-broken clamp, and (f)-(g) EDS point analysis of selected location of Figure 21 e.

damaged / broken railway track of various dimensions have been received. Initially the investigation focused on selective pieces. The fracture surfaces of all specimens were covered with oxide scales, which could not be removed completely. Ultrasonic inspection revealed the presence of heterogeneities at the subsurface of head portion of railway track. The bulk composition of three rail samples satisfied specification. In depth examination of fracture surface revealed, that primary failure mechanism of the railway track material was caused by fatigue cracking during service. The cracks were initiated from the junction of head and web or from the sub-surface of head region. Clustered inclusions at that region triggered fatigue cracking during service. Final failure of the component occurred through fast fracture of mixed mode where localized dimples were present over the faceted fracture surface. Other various tests are going on along with examination of left over rail segments using different techniques. Once the analysis becomes over, a conclusive remark could be made on the reason-nature-sequence of the incident.

B. Advanced Ultra Super Critical (AUSC) Materials

Development of Advanced NDE based Diagnosis and Prognosis Protocols for A-USC Power Plants:

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

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

This module addressed on the development of non-destructive techniques for the advanced manufacturing processes like laser and hybrid laser weld quality assessment of Ni-based super alloy. Hybrid laser-arc welding of nickel-base alloys can increase productivity and decrease costs during construction and repair of critical components in nuclear power plants. The keyhole formed under high laser intensity gives the hybrid welding technique the greater penetration depths compared to arc welding. To assess the quality of welds phased array ultrasonic and ultrasonic imaging were used to measure the level of porosity in terms of their size and locations of the pores inside the weld through proper signal analysis. Another important objective of this project is multi-parameters NDE measurements of futuristic materials like ODS material. The goal is to develop an appropriate NDT technique for damage evaluation of such kind of components. Under this objective, ODS ferritic steel (Fe Al Cr Ti + Oxide dispersoids) developed at ARCI is characterized using Magnetic Hysterisis Loop (MHL), Ultrasonic(UT), Non-Linear Ultrasonic (NLU) and Eddy Current (EC) based NDE techniques. An Extruded ODS ferritic bent rod with irregular corrugated surface of length 560mm and average dia of 19mm was received from ARCI. As many as 05 specimens were prepared as per ASTM standard that were undergone creep-fatigue interaction tests at two different conditions in interruption mode and subsequently, NDE measurements were performed to generate data-base from the as-prepared till material rupture. The data generated from these measurements could be employed for remaining life assessment of components fabricated of ODS material and operating at high temperature and stress. The other important aspect of this module is to develop sensor susceptible to high temperature >600 oC for real time integrity assessment of power plant components. Assessing and monitoring of such degradation during operation at harsh industrial environment is hindered by non-availability of high temperature (HT) sensors. In this module sensor based on Low Temperature Co-Fired Ceramic (LTCC) technology has



Figure 22: Real-time Creep damage monitoring at 650 oC/ 305 MPa using fabricated LTCC-EC sensor

been fabricated and used for real-time creep damage evaluation at 650 oC/305 MPa till the sample rupture (Figure 22). This will help to overcome the current limitation for real-time integrity assessment of components operating at temperature beyond certain limit and assessment of the extent of damage.

C. Coal Characterization and Analysis

CSIR-NML is actively involved in the coal characterization and analysis such as band by band analysis, seam overall analysis of coal samples received from various subsidiaries (CMPDIL, ECL, BCCL, CCL, SECL, NCL, MCL, WCL etc.) of Coal India Limited. CSIR-NML is recognized as a Referee Laboratory for Coal Analysis. Through Applied and Analytical Chemistry Division it carries out quality assessment of both coking and non-coking coals through chemical characterization using its state-of-the-art coal characterization laboratory (Figure 23). Recently, we ventured into the Geological Survey of India sponsored project for coal quality assessment of newly explored coal block in India.



Figure 23: Coal characterization and analysis facility.

D. Rare Earths Extraction

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

With the joint funding of CSIR, NALCO, HINDALCO and VEDANTA to the tune of Rs. 5.12 crores, CSIR-NML is working on the development of a holistic process to extract Al, Fe, Ti and REEs from red mud samples of India. This work is monitored by NITI AAYOG RARE EARTH COMMITTEE chaired by Dr. V.K. Saraswat. At this stage, a Demonstration of 100 kg feed scale of red mud has been given to the delegates of Niti Aayog, NALCO, HINDALCO, VEDANTA and R&D partner labs on 12th December 2023 and the complete development was showcased to Dr. Saraswat on his maiden visit to CSIR-NML on 1st Feb 2024.



Figure 24: (a) shows the flowsheet of holistic utilisation of red mud process and (b) - (d) shows the demonstration of process to industrial patners and Dr. Saraswat (NITI-Aayog)

Extraction of critical metals form used Li Ion Batteries

CSIR-NML developed CSIR's first holistic and patented process that can tackle a complete separation among Li, Ni, Co and Mn, from spent/ waste lithium-ion batteries of mixed chemistry of LCO, LCA, LMO, NMC, LFP, LNA is established using hydrometallurgical processes. CSIR-NML has also commissioned CSIR's First 1TPD battery dismantling setup, along with a 100L Metal extraction and 10L Solvent Extraction facility. The pilot plant is a first-of-kind Hire-Operate-Transfer (HOT) platform for MSMEs and Entrepreneurs in India. Dr. V.K.Saraswat, Member, Niti Aayog, in his maiden visit to CSIR-NML, inaugurated the CSIR's First Battery Dismantling and Metal Extraction setup installed in the Critical Metal Processing Pilot Scale Facility on 1st Feb 2024 is shown in Figure 25.

E. E-Waste Cluster

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

The Project commenced from the 3rd of July 2023, which is an extension of the awareness programs carried out by MeitY through various agencies and the R&D works carried out by various national laboratories. The project will enable the informal sector to get formalized by getting the various recycling technologies developed at national laboratories. The major objectives of the project are: (1) Creation of 50 master trainers for handling 15000 informal operators engaged in the area of e-waste, identification of value chain and to convert them to micro entrepreneurs. (2) Dissemination of technology for recycling PCBs & recycling of e-waste, plastics through setting up of recycling common facility in form of clusters of micro-entrepreneurs in different states of the country. (3) Creation of content (manuals) in various scripts, power point presentations and video recordings and shall be translated to different Indian languages. Major aim of the proposal is to enable the informal sector to obtain adequate training and state of the art recycling technologies and thereby formalize. The formalized clusters will be facilitated with MSME cluster formation scheme (CFC) to create infrastructure respective State Government and MSE-CDP program of MSME. Informal sector will be upgraded to formal entity with adequate capacity building and handholding with



Figure 25: Marketable products obtained from the complete Recycling of PCBs

indigenously developed PCB recycling technologies and plastics processing technology of CSIR-NML, C-MET and CIPET-LARPM for enhancing recovery of resources from electronic waste thereby promoting resource efficiency and circular economy. The marketable products obtained from the complete Recycling of PCBs is shown in Figure-25.

Advanced Materials and Processes

Advanced Materials and Processes (AMP) Division is involved in the development of advanced materials, techniques and processes for the improvement of functional properties of the materials, component's performance and mitigation of environmental problems of materials used in energy, space, oil & gas, iron & steel, infrastructure and biomedical sectors. This division consists of three research groups namely, Functional Materials, involved in the development of energy, bio and magnetic materials, Surface Engineering involved in developing various biocompatible and environment friendly coatings for improving corrosion/wear resistances of materials and Non-Destructive Evaluation involved in development of devices, sensors & non-destructive evaluation of components. Currently researchers and scholars along with technical staff are working in the division to evolve and translate end to end solution to the stake holders dealing with advanced materials and processes under different technological sectors. Some of the important projects carried out by the division are detailed.

Functional Materials

Development of Metal-organic frameworks based Composites as Electrocatalysts for energy generation and storage applications

Green and sustainable energy production and storage is a necessity step to reduce global warming and pollution and is now a major area of technological development. Together with electrical power, the generation of oxygen, hydrogen as a fuel and their storage will be a major component in the search for sustainable future energy needs. However, electrolysis of water using green electricity (generated from solar or wind) is very inefficient. An alternative to this is the direct 'splitting' of water into hydrogen and oxygen using an electrocatalyst, normally composed of conductive metal and organic linker or metal oxides. Metal Organic Frameworks (MOFs) possess several advantages like large surface areas, high density of active sites, flexible crystal structures and infinite possibility of structural modification by changing organic ligand, metal ions or linkers support framework materials and their composites as electrode materials. In addition to this, bi-metallic or tri-metallic MOFs provide emerging state-of-the-art materials for water splitting performance due to their reported high specific catalytic activity, different physical, chemical, optical and electronic attributes including ionic and electronic conductivity, wide compositional tolerance combined with stability and durability. Major challenges in this area are the use of sustainable elements in the construction of these catalysts, prolonging the lifetime of the electrocatalytic materials involved and scalability. Under this In-house project, earth-abundant, low cost transition metal-based Co, Ni and a bimetallic CoNi MOFs have been designed, characterized well through SCXRD, PXRD, TGA, FT-IR, UV, SEM-EDX, HRTEM, XPS and utilized for oxygen evolution reaction (OER) via water splitting as well as supercapacitor applications in alkaline medium (Figure 1). The synergism and bi-metallic coupling of CoNi-based material just prerequisites a low over potential of 392 mV to deliver a current density of 100 mA cm-2 with a favourable Tafel slope of 78 mV dec-1 in 1 M KOH electrolyte. Substantially, bi-metallic CoNi-based material achieved excellent specific capacitance 314 Fg-1 at a current density of 1 Ag-1 in 6 M KOH with good capacitance retention. The bi-metallic MOF exhibits more proficient than single metal-based MOFs for both Oxygen Evolution Reaction (OER) and specific capacitance values. Interestingly, this work demonstrates the multi-functionality of a framework material utilized as electrocatalysts as well as electrode material for energy generation and storage respectively.

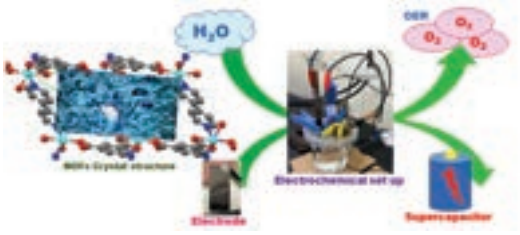


Figure 1: Pictorial representation of MOFs crystal structure, working electrode for OER and supercapacitor applications.

Structural engineering into 3D macroscopic architecture with hierarchical porosity for real application of energy storage devices

Through this project, several MXenes and carbon based electrode materials for the green energy storage system i.e., supercapacitor with efficient energy storage performances, have been developed. For example, recently, a biomass-derived nitrogen-doped highly porous graphitic carbon via a mechanochemically assisted microwave plasma-induced synthesis process has been developed to address the challenge of low volumetric capacitance and energy density caused by the sluggish reaction kinetics and a limited potential window (<1.2 V) in aqueous electrolytes. The

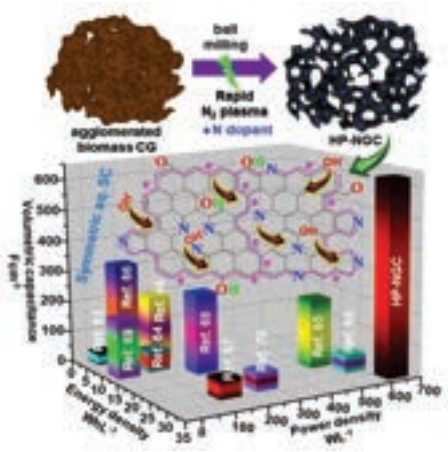


Figure 2: Mechanochemically assisted microwave induced plasma synthesis of N doped graphitic porous carbon exhibiting ultra-high volumetric capacitance and energy density when used as an aqueous symmetric supercapacitor.

developed aqueous symmetric supercapacitor succeeds to deliver comparatively high volumetric capacitance and energy density in a potential window of 1.2 V, as pictorially depicted in Figure 2. The work is published in ACS Applied Electronic Materials (impact factor = 5.07). Another work published in prestigious Journal of Materials Chemistry C (impact factor of 8.06) discussed the development of coffee-waste derived N, P co-doped multi-layered graphitic carbon and ultrafine NiPO nanosphere-based composite electrode and its all-solid-state asymmetric supercapacitor with prolonged cycle life. The effectiveness of the developed supercapacitors have been practically demonstrated by running a LED board containing multiple red LEDs for several minutes in different time intervals, as shown in Figure 3. In this regard, it is important to mention that the work is featured in the community spotlight blog published by the journal of materials chemistry c of royal society of chemistry (RSC).

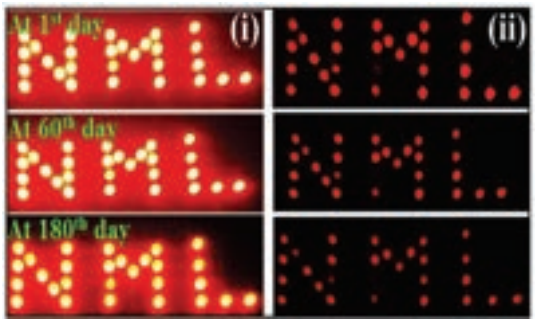


Figure 3: Illumination(i) at start and (ii) after 3 mins. of the LED board containing 28 red LEDs at different time intervals by connecting the prepared coffee-waste derived carbon composite based supercapacitor device.

This research group is also developing a Ti3C2-TiO2 and octahedron-shaped, nanosized Zinc titanate-based ternary nanocomposite with an optimized composition which showed excellent overall photocatalytic performance (as published in Inorganic Chemistry Communications, 2024, 160, 111880), and also explored the manufacturing, performances and future perspectives of various 3D-printed MXenes-based electro-design the fields of energy storage applications by publishing a review article. Similarly, 03 book chapters on various MXene and carbon based energy storage topics are in press. Overall the activity covered different dimensions of energy storage research and material development through this project which also helps to find many future leads for further work. The current focus is on full fabrication of cylindrical supercapacitors for practical applications.

Processing of Glassy Metal Powders through Gas Atomization for Additive Manufacturing Applications

The alloys with high glass forming ability have superior strength and wear properties, but unable to forming any product due to its low ductility. Recently, additive manufacturing (A/M) has been popularized for making any critical shaped products by powders of spherical shape and good flowability. The CSIR-NML has a long experience in developing alloys with high glass forming ability (GFA) by rapid solidification techniques. Such alloys with specific composition, known as bulk metallic glasses, have good mechanical and functional properties compared to their crystalline counterpart. However, the required cooling rate for development of glassy alloys is ~ 103 to 106 K/s, resulting in form of thin ribbon or rods of smaller diameter or very small components (~ mm in size) and restricting them as the form of bigger size product. In this research, our target is to develop Fe based glassy alloy powders to be utilized for making A/M products. In-house developed FeCrMoBSiCP alloy powders showed good sphericity (Figure 4) and amorphous in nature, possessing high flowability. As a

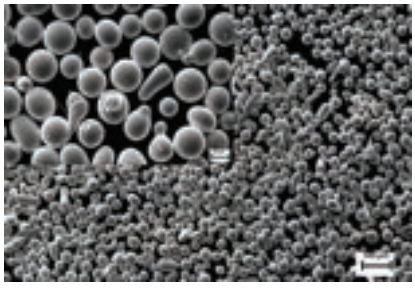


Figure 4: SEM-SE images (high magnification at inset) of gas-atomized FeCrMoBSiCP alloy powders

consequence, the powders have been additively manufactured as sample products of 20mm x 20mm x 8mm by DED technique. This research is an initiation on the development of glassy metal alloy powders for making A/M product component with high mechanical and functional properties. There is a future scope to develop similar quality other alloy powders for making critical high performance machine components by A/M.

Processing and Property Optimization of Iron based Soft Magnetic Nanocrystalline Alloys

Iron based nanocrystalline alloys (FINEMET type) are the modern soft-magnets with lower core-loss (<0.1 w/kg for 1T/50 Hz), high magnetic permeability (105-6) and optimal cost of production. The ultra-soft-magnetism of nanocrystalline core properties can be achieved through strict compositional control, high quality strip preparation using planar flow caster setup and multi-step core annealing cycle. In this present work, CSIR-NML undertook complete process optimization and streamlining of industrial 150 kg batch nanocrystalline production unit located at Bhiwadi, Rajasthan. Despite large capital investments, regular trials the nanocrystalline current transformer (CT) cores does not qualify the industrial standards and required magnetic properties. In accordance, the NML team did complete diagnosis of existing raw materials, process parameters and annealing cycle and found large deviations in each step. Along with the Industrial partner, the de-bottlenecking exercise were made into three verticals namely; i) melting and alloy chemistry, ii) planar flow strip casting of ribbons with thickness less than 35 microns and iii) design suitable annealing cycle for best magnetic properties. In this pursuit, initial efforts were to select suitable grade of ferro alloys (less residuals and Al content), change of furnace lining material compatible to high silicon, high boron alloys, charging sequence and vertical ingot casting. With multiple industrial trials and efforts, we have achieved a nominal composition of 83Fe-8.6Si-1.8B-5.6Nb-1.3Cu desirable for strip casting and annealing process. The use of air-induction furnace and strict control of inclusion/slag re-entry problem allow us to design a new synthetic refining flux suitable for the alloy melt. NML has developed a novel CaO-SiO2-B2O3 synthetic flux with excellent fluidity, kinematic viscosity maintaining basicity of 1.1 resulting in improvement in the ingot and strip casting operation (Figure 5). The good quality ribbons with average ribbon thickness ranging 30-35 micron were achieved for first time after NML intervention by modifying the melt-puddle hydrodynamics by optimizing; nozzle-slit width, nozzle-wheel gap, melt super heat and melt-hydrostatic over pressure. During the improvements, the samples of each trial has been studied for their chemical, magnetic, thermal and CT core quality tests. A total of 26 plant trials of 150 kg each were conducted to date. After NML intervention, cores from every trial is passing the CT core plant standards. The imported nanocrystalline cores from China and US has been considered for benchmarking and optimization. At present work is in progress to further improve the ribbon surface quality, dimensional tolerance and new annealing schedule.



Figure 5: Photographic comparison depicting improvement in alloy ingot quality after fluxing treatment.

Development and integration of semi-automatic melt ejection and ancillary units for 5 Kg Planar flow casting (PFC) system

The Planar flow casting (PFC) is a near-net shape casting technique that enables production of micron thick strips in a single-step manufacturing process. The PFC casting process offers a casting speed ranging 10-100 km/hr of strips and a cooling rate of order 103-7 K/s. The large undercooling allows for the preparation of microcrystalline or amorphous strips based on alloy composition. The PFC is an industrial process for producing both modern soft magnets (amorphous/nanocrystalline) and hard magnets (NdFeB/Sm-Co). CSIR-NML is a pioneer in the Chill block melt spinning (CBMS) development in India and all the existing melt-spinning units nationwide are based on the NML technology. For industrial setup, chill block casting technique is not suitable and planar flow casting with the rectangular slit nozzle and internally water cooled rotating mould is essential to produce wide strips of large quantity. In this direction, NML has developed an in-house design and development of 5-10 Kg/batch planar flow caster with internally water-cooled rotating wheel. Particularly, detailed thermal, fluid flow modelling has been carried out to design internal ducts for uniform mould surface cooling without warping. The fabrication of rotating mould based on CSIR-NML design input and key raw materials was carried out jointly with IDTR, Adityapur. The fabricated Cu-5Ti based water cooled rotating mould measures 200 mm wide, 350 mm dia and can rotate at of 2500 rpm capable of producing



Figure 6: Photographic image of developed planar flow casting setup.

35-50 mm wide strips of few hundred meters. Subsequently, the next focus is to develop suitable melt-handling, melt ejection, mould dressing and strip separator (Air knife) systems for producing continuous wide strips. The detailed mechanical design consists of a supporting frame capable of semi-automatic X-Y-Z motion with a melt-housing assembly. The housing assembly includes induction coil for melting and ceramic crucible fitted with bottom rectangular slit nozzle. Further, detailed sub-component assembly including choice of ceramics for crucible/nozzles and integration of wheel dressing and air knife units has been finalized. The work aims to fabricate and integrate all components and demonstrate strip casting of 35-50 mm wide continuous Al-Si or Fe-amorphous alloys. The complete working setup has been fabricated and assembled to carryout trials of non-ferrous and ferrous alloy strips (Figure 6). First set of trials were conducted on pure Zinc and Al-12.5Si eutectic alloy using a graphite slit nozzle. A continuous 25 mm wide 200-meter metallic strip were produced. In the second lot, Fe-based eutectic alloy trials using quartz crucible and RF induction coil was carried out. A continuous strip formation with varying thickness were achieved by controlling wheel peripheral velocity. To the best of our knowledge, this is the first indigenous development of Planar flow casting equipment setup. A patent application has been filed on the design, assembly and product obtained from the developed setup.

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

We have developed simple and scalable spray-drying based synthetic strategy for ceria incorporated rGO-Nickel Cobalt oxide (rGO-CeNiCo2O4) and corresponding alloy (rGO-CeNiCo) hollow spheres as efficient bi-functional and Hydrogen Evolution Reaction (HER) electro-catalyst, respectively. Both the catalyst showed reasonably low over potential and low Tafel slope of 51 mV/dec for HER. Synthetic procedure has been up-scaled to 50g scale using our existing facility. Developed ceria incorporated rGO-Nickel Cobalt oxide (rGO-CeNiCo2O4) based hollow spheres (Figure 7) as efficient bi-functional electro-catalyst which showed: η10 of 210mV, η1000 of 320mV and Tafel slope of 35 mV/dec for OER, and η10 of 115mV, η1000 of 345mV and Tafel slope of 51 mV/dec for HER. Also Developed ceria incorporated rGO-Nickel Cobalt alloy (rGO-CeNiCo) based hollow spheres as efficient HER catalyst with η10 of 86mV and η1000 of 345mV, and Tafel slope of 45 mV/dec. Fabricated two electrode electrolyser rGO-CeNiCo2O4 ‖ rGO-CeNiCo2O4 achieved current density of 10 and 1000 mA cm-2 at a comparatively low potential of 1.49 and 2.03V, respectively, at 23°C. In a 2cm x 2 cm AEM based electrolyser (Figure 8), having MEA construction of rGO-CeNiCo2O4 ‖ Anion Exchange Membrane (AEM) (Sustainion) ‖ rGO-CeNiCo2O4 achieved a current density of 607 mA cm–2 at 2.0 V and 1000mA cm–2 at 2.18 V at 23 ˚C and provide stable performance for 100 h at 2V. The obtained results are far ahead to that of proposed results. Our future target is to utilize both the catalyst for Anion exchange based electrolyzer (rGO-CeNiCo ‖ AEM ‖ rGO-CeNiCo2O4) to achieve a current density of 1000 mA cm–2 at 2.0V

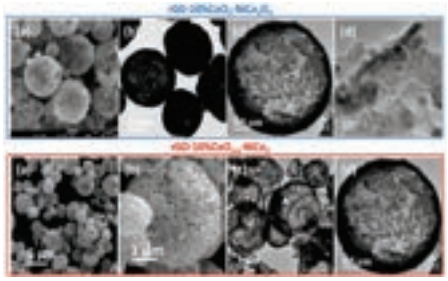


Figure 7: SEM (a) and TEM (b-d) images of rGO-10%CeO2-NiCo2O4 (top) and rGO-10%CeO2-x-NiCo2 alloy (bottom)

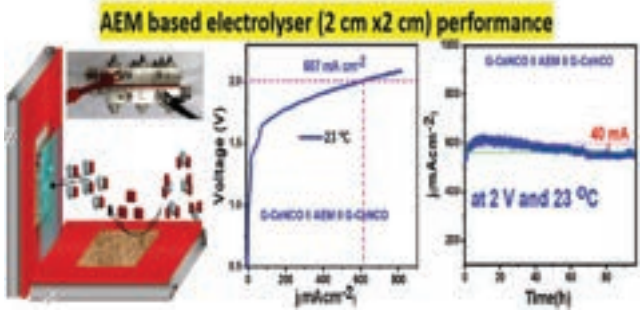


Figure 8: (a) Pictorial representation of the fabricated AEM electrolyser, b) Cell voltage versus current density plot, c) Chronoamperometry graph of AEM electrolyser (rGO-CeNiCo2O4 ‖ AEM ‖ rGO-CeNiCo2O4).

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

Under this project, spray drying based synthetic strategy for porous hollow sphere as well as thin sheet using aqueous metal ammonium carbonate complex solution as precursor have been developed. The developed strategy is generalized for different inorganic single or multi metal oxides, sulphides and selenides. The developed procedure is simple, cost-effective and scalable. It don't need any organic / inorganic structure directing agent or any costly metal precursor. We have used simple aqueous soluble metal salts like nitrate, acetate. The developed synthetic procedure is scaled-up to 100g. Using the developed method we have synthesized spherical shaped TiO2, MoS2/ NiP loaded TiO2 sheets as presented in Figure 9, which showed efficient photocatalytic activity for different organic transformation and water splitting. TiO2 sheet incorporated PVDF-co-HFP based membrane showed excellent dye removal efficiency from waste water via membrane distillation. We have also synthesized 2D thin nano-sheets of different colour metal oxide, which finds applicability as cool pigment. We have also synthesized bare and rGO incorporated porous hollow sphere of different metal oxides and sulphides, which showed excellent energy storage (LIB, capacitor) and conversion (water splitting) efficiency.

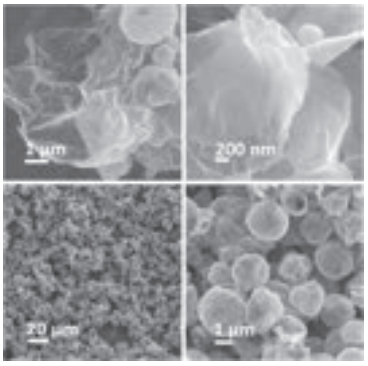


Figure 9: SEM images of synthesized 2D sheets (a-b) and hollow spheres (c-d).

Hybrid Heusler-Glassy Magnetic Alloy Composites for Caloric and Shape Memory Applications

CSIR-National Metallurgical Laboratory (N.M.L), Jamshedpur is working on a project titled Hybrid Heusler-Glassy Magnetic Alloy Composites for Caloric and Shape Memory Applications" sponsored by SERB-DST, New Delhi. There is a worldwide research endeavor towards achieving high entropy and Relative Cooling Power (RCP) in magnetocaloric materials while in the case of FSMAs, efforts are targeted towards achieving high recoverable strains with preferable low magnetic fields. The on-going project is aimed to develop magnetic composites comprising of Heusler and amorphous-nanostructured alloy systems for caloric and shape memory applications. Master alloys of Heusler system based on NiMnGa were prepared though vacuum arc melting in Argon atmosphere. The alloys with typical compositions of Ni53Mn18Cu6Ga23 (at %) and Ni52Mn25Ga23 (at %) designated as Alloy-1 and Alloy-2 were prepared in the form of ribbons. To understand the transformation temperature, Differential Scanning Calorimetry (DSC; Make: TA instruments) thermograms were obtained for Alloy-1 for both heating and cooling cycles at a ramp rate of 20K/min in inert atmosphere and shown in Figure 10a. From the plots, the Austentic start (AS), Austenitic finish (AF), Martensitic start (MS) and Martensitic finish (MF) were found to be 56oC, 70oC, 60oC and 45oC respectively. These transformations were closer to room temperature for prospective magnetocaloric application. Magnetostriction was measured for Alloy-2 using 2-terminal capacitance technique developed in the laboratory. The variation of Magnetostriction for Alloy-2 is shown in Figure 10b. In the as-spun state, the ribbon of Alloy-2 displayed a magnetostriction of 275ppm at an applied magnetizing field of 1.0 Tesla.

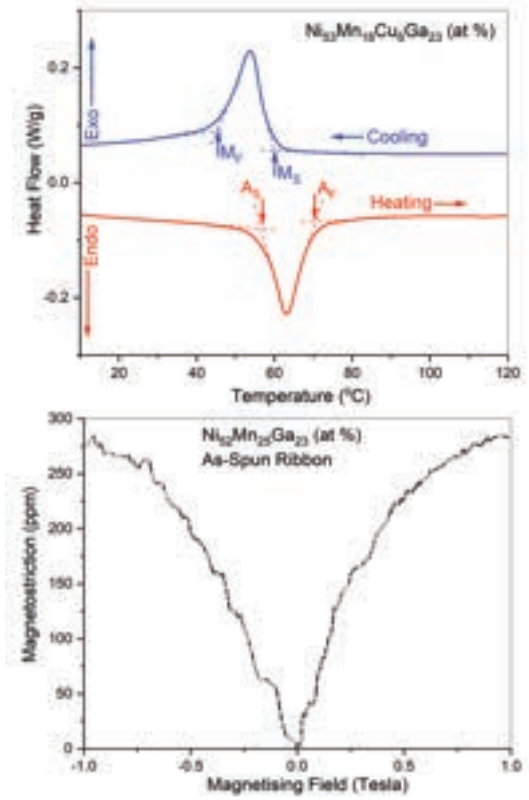


Figure 10: DSC thermograms obtained for as-spun Ni53Mn18Cu6Ga23 (at %) ribbons showing the transformation characteristic temperatures (a) and Magnetostriction plot for as-spun Ni52Mn25Ga23 (at %) ribbons obtained upto a magnetizing field of 1.0 Tesla (b).

Development of Mg/Zn based biodegradable implants for orthopedic applications

Majority of the orthopedic procedures use metallic implants for fracture fixation; these metallic implants need to be removed from the body of the patient through a revision surgery, once the patient recovers from the injury. Revision surgeries could be avoided only if biodegradable implants, which degrade within the body once the healing completes, are used. This project aims to develop Mg-based and Zn-based biodegradable implant materials for orthopedic applications. Though, Mg alloys exhibit high specific strength, low elastic modulus (closer to human bone) and low density, its degradation rate is high. This is the major constraint towards the development and commercialization of biodegradable Mg alloys. Zn alloys have been projected as a promising substitute for biodegradable Mg alloys as the degradation rate of Zn alloys are less than Mg alloys. However, Zn alloys have low strength and poor plasticity which needs to be enhanced for all practical applications. Therefore, this project had three objectives: (i) develop a process for the preparation of high strength Mg/Zn-based biodegradable alloys, (ii) develop a process for the preparation of surface modified in-vitro stable Mg-based biodegradable alloys, and (iii) fabrication of Mg-/Zn- based biodegradable orthopedic implants.

Biodegradable Zn alloys possessing high strength and ductility has been developed employing biocompatible and nutrient elements. Developed alloys have ultimate tensile strength(UTS) varying from 290 MPa to 335 MPa and elongation (ε) varying from 14 to 50 %. As cast alloy billets are hot extruded, at temperatures between 250 to 290°C depending on the alloy composition, to get plates of Zn alloys possessing required strength and ductility. Preparation, post processing and the composition details of the alloys are being patented. In-vitro biocompatibility and toxicity studies of these alloys have been conducted. Results are very encouraging and the animal experiments are planned very shortly. Prototype implants have also been fabricated from various alloys.

High strength biodegradable Mg alloys have been developed employing biocompatible and nutrient elements. Developed alloys have ultimate tensile strength(UTS) varying from 250 MPa to 400 MPa and elongation (ε) varying from 13 to 26 %. As cast alloy billets are hot extruded to achieve the mechanical properties. The input billets used for extrusion are of 127 mm diameter and the output extruded rods are of 32 mm or 22 mm diameter. Extrusion temperature is selected as per the composition of the alloy and is varied between 275°C and 400°C. The process of melting, casting and post processing and the compositional details of the alloys are being patented. The biocompatibility and toxicity studies of these alloys have also been done. Results of a few alloys are very encouraging. Prototype implants have been fabricated from various alloys. Desired corrosion rate and duration of survival in simulated body fluid (SBF) for biodegradable alloys for implant applications are ~0.25mm/year and > 90 days respectively. Multi-layer Zn coating developed on high strength Mg alloys exhibited a corrosion rate of 0.04 mm/year which is less than the desired rate. Multi-layer Zn coated Mg alloy plates survived for more than 5 months in simulated body fluid (SBF). Figure11(a, b) shows the coated Mg alloy plates exposed for140 days in SBF. Multilayer Zn coating is done on Mg alloy capsules employing the lab scale barrel electroplating system (developed at CSIR-NML). Multilayer Zn coated Mg alloy capsules are shown in Figure 12. Developed coating is biocompatible and very adherent. Patent document of the process is submitted for filing.



Figure 11a,b: Coated Mg alloy plates exposed for140 days in simulated body fluid (SBF).



Figure 12: Multilayer Zn coated Mg alloy capsules.

Surface Engineering

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

The European Union has decided that the maintenance engineers from Europe will not attend any aircraft containing cadmium (Cd) coated components from 2019. Therefore, the aircrafts have to change the Cd coated components with suitable components coated with non-toxic materials. With this, a mission mode project was evolved under "Aerospace Materials and Technologies"

theme where CSIR-NML, Jamshedpur is going to develop Zn-based alloy coatings on high strength steel used in aerospace industry which will work as a replacement of toxic Cd coatings. The objectives of the project are: Development of binary (ZnMn) and ternary Al/Zn-Mn alloy coatings from deep eutectic solvents (DES)/ionic liquids by electrodeposition approach to replace toxic cadmium (Cd) coating; and Obtaining similar to or better performance of coating than the Cd plating and improvement of the aircraft maintenance. The work plan has been formulated on the basis of the above mentioned objective, and the process for binary (Zn-Mn) alloy coating from choline chloride (ChCl) type deep eutectic solvents (DES) on high strength steel has been developed and passed all the requisite tests as per ASTM standard. At present, we are scaling-up the process as per requirements of end-user (Aeronautical Development Agency, Bangalore) and certification agency CEMILAC Bangalore. On the other hand, we are also optimizing the second coating, i.e., ternary alloy (Al-Zn-Mn) from aqueous and non-aqueous electroplating bath. The milestones for the binary (Zn-Mn) alloy coatings are as follows: Passed the electrochemical corrosion tests, i.e., open circuit potential (OCP) test in distilled water and 3 . 5 % NaCl solution for 15 days as per ASTM G 82; Passed Bend Test as per ASTM B 571 std.; Passed continuous salt spray test passed as per ASTM B 117 standard with trivalent chrome passivation, i.e., NO RED rust observed for more than 42 days for unscratched and more than 21 days for scratched samples, see Figure 13(a); Passed Hydrogen Embrittlement (HE) as per ASTM F 519, see Figure 13(b); and Hardness test passed as per ASTM E384, i.e., 308±5.87 HV. As per requirements of end-user and certification agency, the future plan of the project has been planned to complete few more tests like: wear (ASTM G133), tensile (ASTM E8/E8M) and fatigue (ASTM 406) tests, respectively. Thereafter, the as-developed process for binary (Zn-Mn) alloy coating will be implemented to real components like: fastners, and landing gear by end-user.

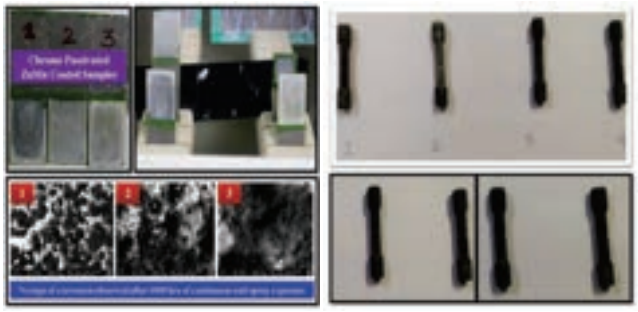


Figure 13: (a) Continuous salt spray test (ASTM B 117) for trivalent chrome passivated binary (Zn-Mn) alloy coating and corresponding SEM after 1000 hrs exposure, (b) hydrogen embrittlement, HE (ASTM F 519) before and after 200 hrs tests.

Low-Temperature (<100 °C) Glow Discharge Plasma Nitriding of Aluminum/Aluminum Alloys

Glow discharge plasma nitriding (GDPN) is a well-known industrial process used to modify the surfaces of steel, aluminum, titanium, etc., without affecting the dimensionality and making them wear, corrosion, and fatigue-resistant in various environments. Most of the advantages of the plasma nitriding techniques are beset with the requirement of heating the specimens at elevated temperatures (~250°C-500°C) to diffuse nascent nitrogen by vibrating the atoms and yield the desired case depth. However, the elevated temperatures heating is detrimental to the structural integrity of a low melting point metal (aluminum) component that affects its physical and chemical properties. Though the plasma nitriding of Al/Al-alloys offers a wide variety of mechanical, chemical, and electrical properties, its use is restricted in aviation and other high-end applications due to the degradation of structural integrity. To date, the GDPN of Al/Al-alloys without pre/post-heating has not been reported. This research work proposes developing the AlN layer over the Al/Al-alloys by GDPN without external heating. In the proposed method, a high-intensity acoustic surface wave will facilitate nitrogen diffusion during GDPN. The fusion of high-intensity acoustic surface waves (0.5-1 MHz) with biasing oscillates the surface molecules and accelerates the diffusion of the bombarding nitrogen ions into the surface.

Figure 14 shows the aluminum substrate's external heating less glow discharge plasma nitriding using the 1 MHz acoustic sensor. Figure 1c reveals the incorporation of the nitrogen atoms into the aluminum surface. However, the formation of the AlN phase has not been confirmed by XRD analysis, which indicates further parameter optimization of plasma nitriding of Al with the specified acoustic sensor.

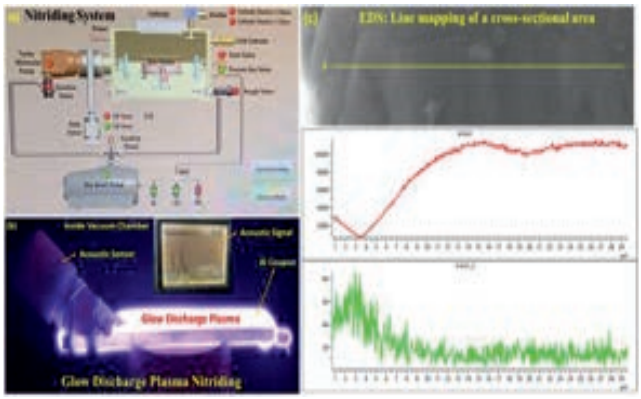


Figure 14: Glow discharge plasma nitriding process for Aluminum substrate. (a) Plasma nitriding system, (b) glow discharge plasma nitriding of the aluminum substrate, and (c) EDS line mapping of the cross-sectional area of the 4 hr nitrided aluminum sample.

Deposition and Characterization of Antimony Chalcogenide-based Light Absorbers Coatings for Photovoltaic Applications

Society is shifting towards renewable energy generations to minimize greenhouse gas emissions for better environmental conditions. Among all the renewable energy sources (wind, water, solar, etc.), photovoltaic (PV) technology is a promising way to harvest solar energy into electricity. Among all the PV technologies, thin-film solar cells (TFSCs) gained enormous attention due to their excellent properties, i.e., they require less material, can be deposited on a flexible substrate, and require low deposition temperature. The Sb2Se3 thin film coatings have exhibited promising optoelectronic properties with low-cost and eco-friendly characteristics and excellent device efficiency, showcasing their potential for PV applications. The thermal evaporation method is a well-known industrial process used to deposit high-quality thin films. This proposed work studied Sb2Se3-based absorber thin film deposition using the thermal evaporation method on glass and flexible substrates and studied structural, elemental, morphological, optical, and electrical properties. The developed Sb2Se3 absorber thin will be employed to fabricate high-efficiency Sb2Se3 thin film solar cells film on glass and flexible substrates. Synthesized Sb2Se3 absorber materials via mixing individual Sb and Se elements, followed by post-annealing/sintering of Sb2Se3pellet and depositing Sb2Se3 thin films onto a glass substrate using thermal evaporation. We have also simulated Sb2Se3-based thin film solar cells using SCAPS 1D simulation, and the simulated Sb2Se3 device exhibited power conversion efficiency (PCE) of over 20.0%.

Non-Destructive Evaluation

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

Industrial ducts and pipes carrying fluids at high temperature are refractory lined for protection. Failures of these structures is a catastrophic event causing loss of production and, more importantly, possible loss of life. Despite being refractory lined, these conduits are vulnerable to wear and thermal cracking. A crack in the refractory exposes the pipe to high temperature and thus the monitoring of the thermal condition of these structures is essential. Several examples of such structures exist in a steel plant (e.g. Blast Furnace, Down comer of Pellet Plant etc.). Appearance of a hot spot on the surface of such structure is an indicator of the onset of an unsafe condition. Monitoring hot spots of these structures can be done through thermal camera. Apart from being tedious, such an arrangement is grossly inadequate as many areas of the structure would not be accessible. Embedded temperature sensors (thermocouples, FBGs etc.) are a viable alternative but embedded sensors sense temperature at discrete points and not all locations in a large structure can be so instrumented. Hence, there is a need to develop an understanding of the thermal conditions of the entire structure through only a few temperature measurements. Under this mission mode project, development of an AI based system that can give the entire thermal picture with acceptable accuracy (90%) based on the minimum number of sensing points was aimed. CSIR-CGCRI is the collaborative Laboratory of this project. To develop the AI model, blow pipe of blast furnace and downcomer of Pellet Plant weres considered. Blast furnaces are an integral part of steel plants, used to produce pig iron from iron ore for subsequent processing into steel. Blowpipe is one of the important components of a blast furnace which transmits preheated air into the blast furnace through the tuyere. During the combustion process in the blast furnace, blowpipes deliver a hot blast of air at 1200 °C and 4 atm. pressure inside the blast furnace. There is a possibility of erosion of the refractory lining of the blowpipe which may result in catastrophe and loss in operations. Due to the erosion of the refractory, the temperature of the blowpipe surface is altered abruptly. Online monitoring of the entire blowpipe surface is essential which is not possible with thermography owing to the inaccessibility of the front portion of the blowpipe. So, there is a need for real-time temperature monitoring of the blowpipe utilizing suitable sensor arrangements considering the environmental constraints. Also, the entire blowpipe body cannot be supported by sensors. So, The Conjugate Heat Transfer (CHT) model of the blowpipe generated via the Finite Volume Method. Multiple hotspots or critical hot zones are created and solved numerically. Based on the CHT model, number of sensors to map the thermal profile of entire blow pipe was optimized to 20. Four arrays of Fibre Bragg Grating

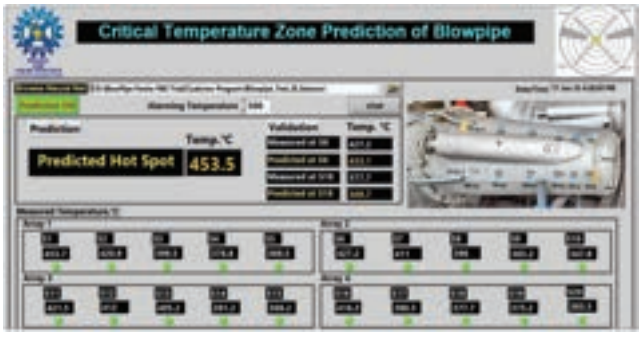


Figure 15: Blowpipe Real-time Data Logging & Hot Spot Prediction Panel

(FBG), used as the temperature sensor, each with 5 FBGs were embedded on the surface of a blowpipe. Using 20 sensor temperature data as input, an ANN based model was developed to predict the temperature of the highest temperature zone and an alarm generation protocol was incorporated at the critical temperature. Instrumented Blowpipe is installed at the HBF of Tata Steel in November 2022. Real time data is getting collected continuously. Figure 15 shows the instrumented blowpipe and the GUI panel for real time data logging and hot-spot prediction.

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 will be carried out with the support from West Bengal Electronics Industry Development Corporation Limited (WBIDCL), a nodal agency of Department of Information Technology & Electronics, Government of West Bengal and other industry partners and stakeholders. The centre will be developed by pooling complementary competencies of five CSIR laboratories having excellence in sensor development and field application in the areas of geotechnical and structural health monitoring and industrial process control instrumentation with well-defined application domains as demanded by the stakeholders and industry partners. The 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 of 5 CSIR Labs (CSIR-CGCRI, NML, SERC, CRRI, CIMFR) being CGCRI the nodal. For the establishment of the centre, procurement is under process. Discussion with MSME companies for technology transfer is in progress.

Intelligent Defect Identification and Classification Technique for Welded Assembly

The development of cost-effective, reliable, fast, and accurate non-destructive techniques is crucial for assessing the quality of welded components. An intelligent defect

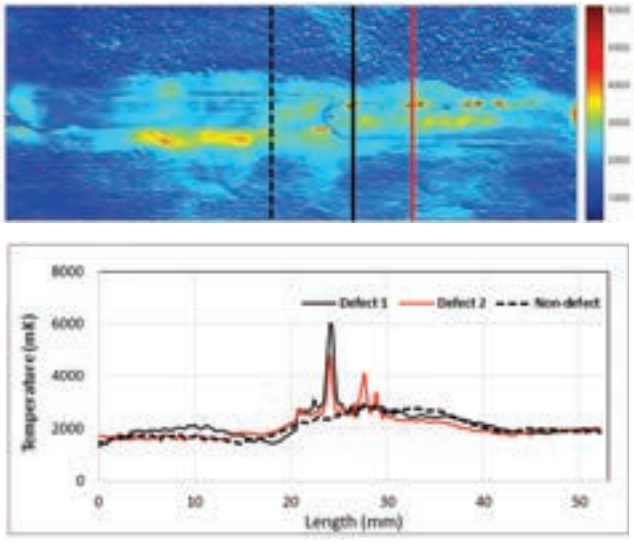


Figure 16: Thermal image of defects in welds and corresponding thermal profile

detection protocol is being created to evaluate the quality of welded assemblies by combining artificial neural networks (ANN) with infrared thermography (IRT). This involves using thermal imaging to identify different weld defects, which will then be classified using ANN. This approach will enable real-time identification of weld defects, reducing the reliance on highly skilled workers. The study includes: fabricating welds by varying weld parameters, detecting weld defects using lock-in thermography (LIT), developing an ANN-based system for defect identification, classifying defects based on their geometry, location, and nature, and providing input for optimizing welding parameters to produce sound assemblies with desired properties. Initially, the technique's sensitivity and resolution will be established by detecting known defects in reference samples and then used to identify unknown defects within the welds. The feasibility of using laser thermography (LT) to detect very small defects in welds will be explored. The main goal of this investigation is to establish a set of quality indicators for different types of weld defects, which will be valuable for locating and identifying defects during in-situ weld inspections and for optimizing welding parameters to produce efficient joints. A thermal image of welds with defects is shown in Figure 16.

Evaluation of debonding area in Con rods using Ultrasonic Imaging

A connecting rod, also called a 'con rod', is the part of a piston engine which connects the piston to the crankshaft. Bushes are fitted at the connecting rod small end. Any debonding above the acceptance criteria between the bush

and the connecting rod compels rejection of the rod. Hence evaluation of debonding quality is essential prior to use of the connecting rod. Under this project sponsored by M/S Tata Cummins, % of debonding area is being assessed using ultrasonic imaging after setting up the measurement parameters. Further scanning, an image processing tool had been developed to qualify the rods based on the % of debonding area. Rejection criteria of the Rods are basically based on the amplitude of the reflected ultrasonic signal from the bond area. A typical ultrasonic image and the processed image beyond the acceptable criteria of the connecting rod bush is shown in Figure 17.

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

Breakout is the most catastrophic phenomenon associated with a continuous casting process. This is the major contributor to the loss of productivity and equipment life. The best way to do breakout detection is to have temperature sensors installed in the wall of the continuous casting mould. In this project, Fiber bragg grating (FBG) based temperature sensor array will be embedded in 10 number of moulds supplied by Tata Steel. Instrumented moulds along with the software will be used for breakout prevention in the caster CC3. The work will be carried out in phases based on the number of moulds received from the customer. This technology has been developed and patented by CSIR-NML and Tata Steel. Under this project, complete implementation will be done at Tata Steel and the ROI can be estimated by the user industry by preventing breakout (BO) using instrumented moulds. Already 4 instrumented moulds have been installed and BO was prevented.

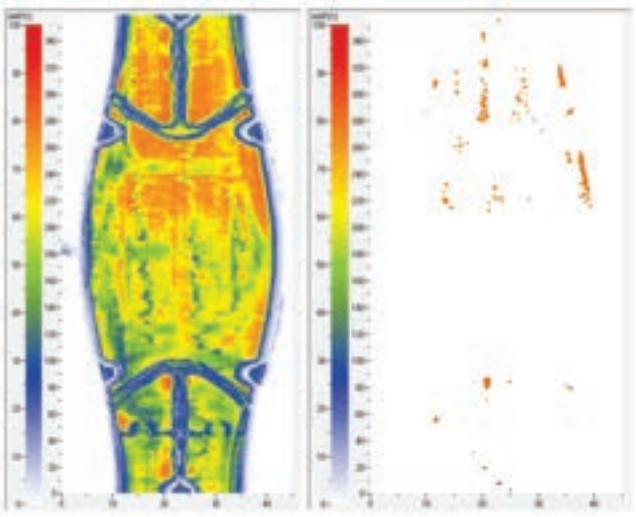


Figure 17: (a) Image of the Connecting Rod (b) Image after applying threshold criteria



Team - AMP

Analytical & Applied Chemistry

Analytical & Applied Chemistry Division (AAC) is striving to be acknowledged for excellence in basic and applied research in the areas of Analytical Chemistry, Corrosion Inhibitors & Polymeric Coatings, Coal Chemistry, Energy Materials, and Certified Reference Materials (CRMs). AAC division is fully equipped with state of the art analytical instruments for analytical support to the ongoing R&D projects of CSIR-NML and provides analytical testing service to outside agencies. AAC Division is a NABL accredited laboratory for Chemical Testing as per ISO/IEC 17025:2017 and Reference Material Producer as per ISO/IEC 17034:2017. Under the scope of Certified Reference Materials (CRMs) activity, the AAC division is engaged in developing and serving Certified Reference Materials (CRMs) for metallurgical products like Ores, Coal, Steel (powder, gaseous Pin, spectrographic and chip/turning standard), Ferro-alloys, and other metal alloys. Below are some of the major achievements/ activities of the AAC Division in the year 2023-24.

Distribution, Association and Extraction of Rare Earth Elements from Coal wastes

The redemption of Rare Earth Elements (REEs) from coal ash has multifarious advantages in utilization of waste and also as a way to minimize unnecessary mining. There is a significant escalation in the quantity of coal ash production, as well as the need of REE in modern day advanced technological products. Utilization of coal ash has been a persistent area of research and development considering its REE enrichment. An understanding of the natural occurrence of REEs with coal minerals is fundamentally important to develop suitable chemical and physical extraction process. Therefore, our aim is to identify our indigenous sources first through the exploration of various geographical regions as well as to optimize an environment friendly way of extracting the valuables from the coal samples, preferably after converting them to coal ash. The primary idea is to extract REEs from coal ash in a non-destructive manner so that the residual ash could be further utilized as additives towards multiple applications.

Exploration of REE enrichment in various coal blocks in India

To diversify supply of these valuables, exploration of indigenous resources is of central importance in every country which possesses natural abundance. India possesses about 6% of the total global reserve of REEs, nevertheless, it produces only 1% of the global supply (Indian Bureau of Mines, 2019). Insufficient knowledge of the distribution of REEs in the Indian sub-continent is one of the prime reasons behind the lower-than-expected production. However, multiple exploratory works in order to determine the distribution of REEs in some of the important geographical locations in Eastern Coalfields were carried out. Out of them, two were located in Rajmahal Coalfield and another one was located in IB valley, Odisha. The average concentration of REEs with yttrium (REY) for the coal blocks of Rajmahal coalfield (on an ash basis) was found to be about 500 ppm, which is significantly higher than the world average for coal ash (435 ppm). The distribution of individual REEs in coal ash derived from Dhulia North coal block is as shown in **Figure 1.**

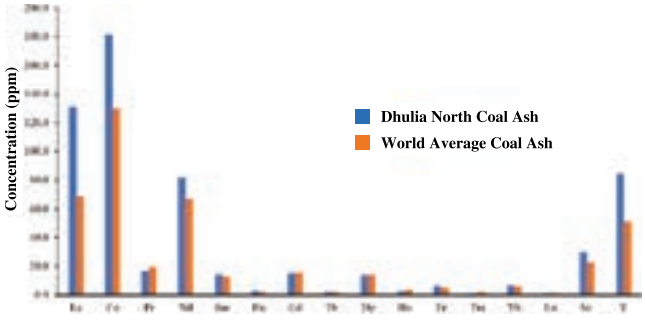


Figure 1: Comparison of REE content between World Coal Ash & Coal Ash of Dhulia North Coal Block. *Environ Geochem Health* 45, 6967–6983 (2023).

In Figure 2, a plot of REY vs C_{outl}, demonstrating the promising and non-promising regions of chosen coal block in Bhalukasba Surni is demonstrated, particularly in the depth range of 181-183 m and 396-400 m. Statistical correlation of REEs with major oxides revealed noteworthy correlation with P_2O_5 and TiO_2, possibly indicating associations with common REE-bearing phosphate minerals such as xenotime, monazite, along with apatite and anatase.

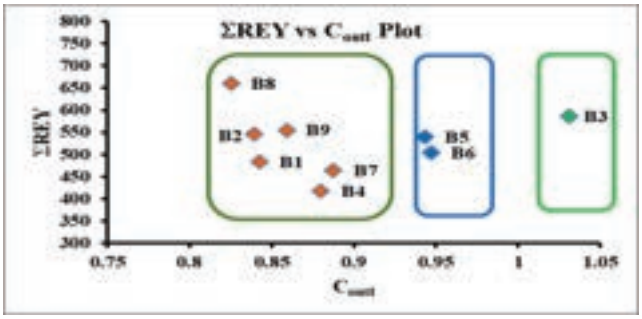


Figure 2: A graphical presentation of promising and unpromising regions for extraction of REY on the basis of $C_{outl.}$ *International Journal of Coal Science and Technology* 2023 (Accepted, under production)

Lastly, in case of Samaleshwari coal block of IB valley, the concentration of critical REEs varied in the range of 100-300 ppm, and the outlook co-efficient (C_{outl}) ranged from 0.7-1.0, demonstrating the suitability of chosen coal seams as a promising source of REEs (Figure 3). All the four boreholes which were analyzed were found to be potentially rich source of light rare earth elements (LREEs) particularly La, Ce, Nd and Y. The lower enrichment of heavy rare earth elements (HREE) is reflective of the overlap between monazite/bastnaesite and its aluminosilicate host, thus rendering it economically un-exploitable.

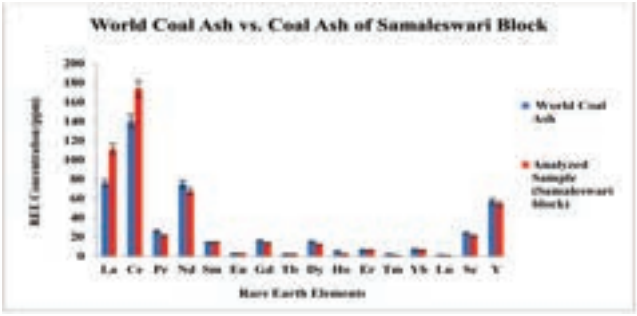


Figure 3: Comparison of REE content between World Coal Ash & Coal Ash of Samaleswari Coal Block. *Environ Earth Sci* 82, 130 (2023).

Leaching of REEs from coal ash using organic acids

Leaching using strong mineral acids such as HCl or HNO_3 at elevated temperatures is the most prevailing method till date. The extraction of REE from coal ash heavily depends on usage of strong mineral acids which are harmful for environment. Earlier we studied the REEs leaching using organic acids. However, the potency of organosulphonic acids in leaching out REEs from coal ash matrix was not explored prior to our efforts, particularly for coal ash, where the leaching potential of both methanesulphonic acid and *p*-toluenesulphonic acid was compared. MSA imparted good selectivity in leaching, wherein, it leached out 70% of REE along with minimal quantities of other coal ash elements (<10%), without altering the aluminosilicate matrix. Importantly, the leaching potency of organosulphonic acid was found to be at par with mineral acids as shown in Figure 4 and hence it could be considered as a green alternative to mineral acids.

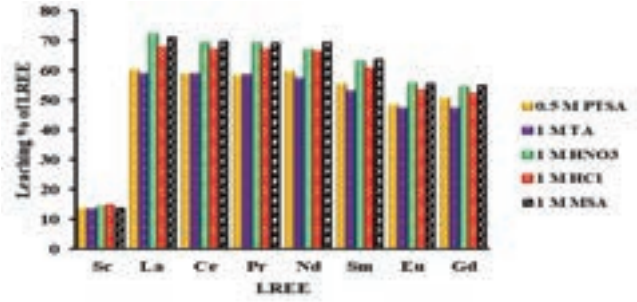


Figure 4: The leaching potency of organosulphonic acid compared to minerals acids and tartaric acid. *Minerals Engineering* 185, 2022 (107664).

Occurrence and association of REEs in heat altered coals of Indian origin

Thermal influence alters both the organic and inorganic components of coal. Insufficient knowledge on the association of rare earth elements (REEs) with the parent matrix of thermally altered high-ash coals limits the potential for such coals being utilized for isolation of valuables. In the Indian scenario, such investigations are even more crucial more so because about 2% of the coals are thermally metamorphosed and hence rendered useless. Our team conducted a systematic analysis of the content of REEs (both HREE and LREE) in addition to delineation of the crucial associations with the inorganic plexus of a high-ash coal acquired from Eastern Coalfield, India. The distribution



Figure 5 demonstrates the results obtained for all the individual steps in sequential leaching of heat altered coal for LREE ; HREE; and the major elements such as Si; Fe; Al; Ca; Mg and Ti. The steps were as follows: S1 and S2 represent water soluble and ion-exchangeable fractions, S3 represent complex/carbonate bound fractions, S4–S6 represents the reducible fractions, S7 represents the oxidizable fractions, S8 was for solubility in strong acids and lastly S9 was for the residual fusion step. LREEs got primarily leached out (47%) at the stage where acid-soluble fractions were ascertained, suggesting their presence in primarily ionic form.

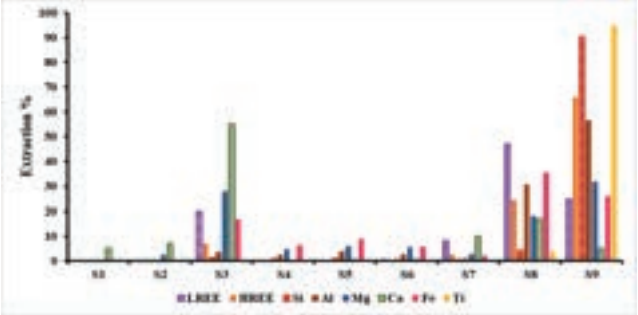


Figure 6: Extraction efficiency of REEs and major elements during the process of sequential leaching. *International Journal of Coal Science and Technology* 2023 (Accepted, under production)

and occurrence modes of REEs within a magmatically altered high-ash coal were determined *via* nine-step sequential extraction (**Figure 5**), which led to the conclusion that about 66 % of HREE and 25% of LREE were included in the residual fraction.

Self-healing coating for corrosion protection of structural steels

Paint is widely used to prevent corrosion of mild steel structures. However, when a crack is developed in the paint coating due to any reason, corrosion starts from the cut area and propagates rapidly, damaging the entire coating. To address the issue, CSIR-NML has developed and patented a coating formulation that self-heals autonomously in presence of water and prevents onset of corrosion near the cut area. A project was initiated to scale up the process and commercialize it through technology transfer. A pilot plant to produce 200 liters/batch of self-healing paint was set up and paint was produced as per the industry standards. The paint quality was evaluated as per IS 101 standard procedure and it meets all the standard requirements. The self-healing coating was applied on mild steel plates (5 inch x 6 inch) and exposed in the outdoor across 6 cities of India (Delhi, Mumbai, Chennai, Kolkata, Digha and Jamshedpur) to evaluate the performance of the coating in real world environment. Mild steel plates coated with a commercially available epoxy paint from Asian Paints were also exposed as reference samples. After six months of outdoor exposure, corrosion was observed near the scribed region of the reference sample whereas, the self-healing coated samples remained corrosion free (Figure 7). Accelerated corrosion tests were carried out through salt spray test and the coating passed 1000 hours of salt spray test without formation of red rust in the scribed region. Scanning Electron Microscopy (SEM) study revealed self-healing of the scribed region (Figure 8). Effort is going on to commercialize the technology through technology transfer.

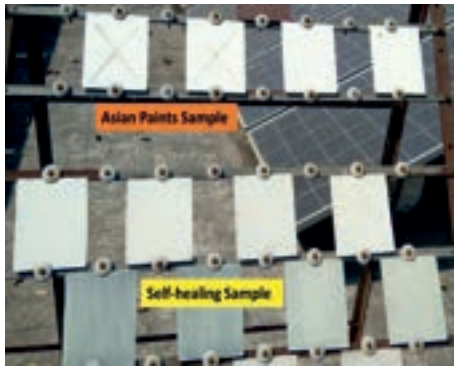


Figure 7: Photographs of the mild steel samples coated with commercially available paint and self-healing paint.

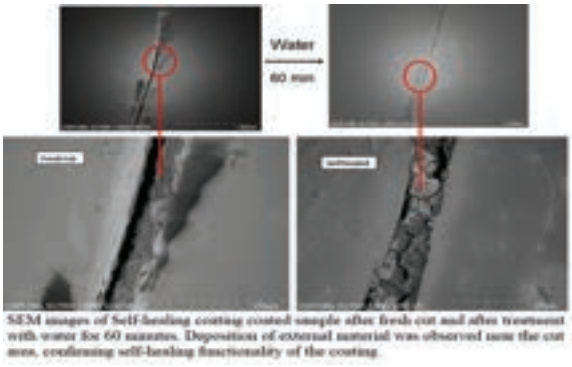


Figure 8: SEM micrographs of the self-healing coating

Chemical treatment of rebar to improve the corrosion resistance

Mild steel rebar is commonly used for the reinforcement of concrete. Although naturally coated with a corrosion resistant black oxide layer (i.e. mill scale), mild steel rebar is prone to atmospheric corrosion forming red rust during storage and transport, which negatively influence its customer acceptance. The rusting problem is particularly severe in a marine atmosphere, in the rainy season, and in hot and humid climates. In addition, corrosion of steel rebar in concrete is known to occur over a period of time due to diffusion of aggressive agents through the concrete resulting in flaking and failure of concrete structures. Therefore, there is a need to improve the corrosion resistance of steel rebar in an economical and scalable manner.

An anti-corrosive treatment process for rebar using inorganic chemicals has been developed by CSIR-NML. The chemical treatment process involves spraying of the water-based chemical on the rebar surface after the water-quenching step. The process is green, economical, and suitable for integration into the rebar production line. The treated rebar passes 72 hours of salt spray test and 6 months of outdoor exposure test without the formation of red rust (Figure 9). The chemical treatment process was evaluated by Tata Steel and JSW Steel for integration into the rebar production line for the production of corrosion resistant TMT.

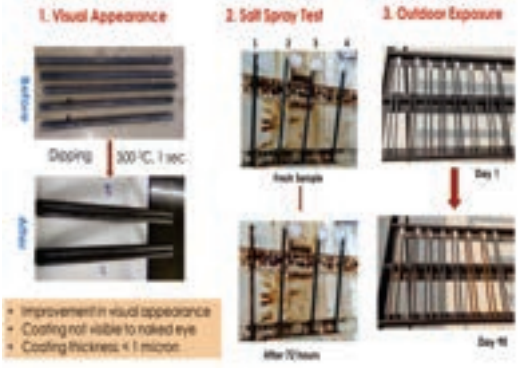


Figure 9: Chemical treatment of rebar to improve the corrosion resistance

Analytical strategies for quantification of mercury in coal samples

Analysis of mercury (Hg) content in coal samples is important in order to assess the fate of mercury in the power plant, quantification of anthropogenic emission of gaseous mercury from the stack emission and formulation of a successful strategy for lowering mercury emission to the environment. However, analysis of Hg in complex sample matrices poses some critical challenges owing to its peculiar chemistry of the tendency to form amalgam with metals, high volatility and inaccurate analytical results in the presence of interfering ions. Analysis of Hg in ICP-MS often produces misleading results due to the undesirable "memory effect" of the analyte. Several reagents, namely gold, polyurethane, and mercaptan-based reagents, are reported to minimize the memory effect to achieve the desired analytical output. However, till now there is no study has been conducted for a comparative evaluation of the performance of these reagents for the reliable analysis of Hg in coal and coal fly ash samples. The current research work focuses on the comparative evaluation of the reported reagents along with the development of eco-friendly, non-toxic, and low-cost reagents to minimize the memory effect for Hg analysis in coal samples by using ICP-MS.

Direct regeneration of spent electrode material

Regeneration of spent lithium-ion battery (LIB) electrode materials is essential for sustainable development of the LIB energy storage sector and resource management of the critical metals such as Li, Co, Ni, and Mn. Enormous use of LIBs has been seen in the last two decades in portable electronic devices. In addition, now it is predicted that LIBs will be exploited in electric vehicles and stationary energy storage systems in the coming decades. Wider exploitation of LIB energy storage technologies creates an alarming situation, especially for the resource management of critical metals and the environment. To address this issue CSIR-NML has developed a method for the direct regeneration of a spent lithium cobalt oxide (LCO) cathode material. The deficiency of Li concentration in spent cathode material is fulfilled by the solid-state regeneration process just by heating with the required amount of Li_2CO_3 at 740 °C for 6 h. In particular, the Li void in the defective LCO crystal structure has been repaired, and the morphology is restored into the pristine LCO. Overall study showed improved morphological and electrochemical properties This work demonstrated a simple and cost-effective regeneration process of spent LCO.



Figure 10: Graphical presentation of direct regeneration of spent LCO electrode material. *Energy Fuels* 2024, *38*(7), 6499–6507

Benzoic acid reference material for calorimetry analysis

Benzoic acid is used as a reference material (RM) for calorimetry analysis such as in bomb calorimeter instrument for calibration. This reference material is hugely used in our country for gross calorific value (GCV) analysis. However, till now there is no Indian manufacturer for producing such type of reference material for GCV analysis. In particular, we are importing this RM from foreign manufacturer. Therefore, indigenous benzoic acid reference material development is an urgent need to meet the demand for benzoic acid reference material production and contribute to product development for import substitution. Under a CSIR-funded project (CSIR-FTT) we have synthesized ultra-pure benzoic acid from commercially available raw material and developed benzoic acid reference material (RM) for calorimetry analysis.



Team - AAC

Materials Evaluation

Materials Engineering Division focuses on four research verticals: Corrosion engineering, Materials mechanics, Materials processing and Microstructural engineering. The goal of the division is to develop metallic materials, provide technical support to various industries in materials property evaluation, root failure cause analysis and solution to failed components, and structural integrity assessment and remnant life estimation services. The division has state of the art infrastructure: a battery of creep loading facility, one of the largest in Asia, Fatigue-fracture test facility that can span acorns various aspects such creep-fatigue/creep-fracture/multiaxial fatigue, Field Emission Gun (FEG (), Scanning Electron Microscopes with EDS, WDS and EBSD as well as FEG Transmission Electron Microscope with EDS and EELS facilities, Gleeble Thermomechanical Simulator, Forming machine for Forming Limit Diagram as well as Hole Expansion Ratio evaluation, Laboratory scale 2 high rolling Mill and various equipment for corrosion rate as well as evaluation of corrosion products. This division has recently added a gas atomizer based metal powder producing facility for additive manufacturing

Unveiling abnormal grain growth mechanism in grain-oriented silicon steels

Grain-oriented (GO) steels with a strong Goss texture ({110} <001>) are predominantly used in transformers for power generation and distribution. The rapidly expanding power sector of India demands indigenous technologies and know-how for GO steel production, in order to facilitate high-cost import substitution. However, the major challenge in the development of GO steels lies in identifying the suitable precursor microstructure and texture that can exhibit effective abnormal grain growth (AGG) of Goss grains during the secondary recrystallization (SRX) step. The crucial factors which synergistically affect the abnormal grain growth during SRX are the primary recrystallization (PRX) texture and its grain boundary character distribution (GBCD) as well as the fraction, morphology, and distribution of inhibitors. The proposed work aims to identify the responsible mechanism for abnormal grain growth of Goss grains in GO steels, for which two 3.2 wt.% Si steels with different aluminum contents (0.02 wt.% and 0.04 wt.%) have been prepared by vacuum induction melting and casting. The variation in aluminum content has been made basically to attain a consequent variation in AlN precipitate fraction, which would act as the major inhibitor (along with minor effect from MnS) for grains other than Goss oriented grains during SRX, thereby allowing AGG. Figure 1 depicts: the process steps (consisting of vacuum induction melting, casting, hot forging, hot rolling, hot band annealing, cold rolling and decarburization anneal) adopted for lab scale development of grain oriented silicon steel. The objectives of the project are: statistical assessment of the evolution of crystallographic character of grain boundaries surrounding Goss grains by EBSD and its variation with primary recrystallization texture and correlations of the evaluated GBCD with the evolution of pinning effect of inhibitors present on the corresponding boundary segments. The following activities have been completed with respect to the designed alloys: CALPHAD based phase equilibria assessment; homogenization of the cast ingots followed by hot-forging till thickness suitable for lab scale hot rolling; real time cooling profile measurements using thermocouples welded at the center of samples, during each pass (and after each pass) of designed hot-rolling schedule; microstructural and microtextural characterization of as forged and as rolled specimens (after quenching post each pass of hot-rolling) to understand the microstructural and textural evolution; design of optimized hot rolling schedules with varying finish rolling temperatures (FRT) and deformation, with aim to obtain the requisite through thickness microstructure and varying texture gradient in the hot bands; detailed textural assessment to determine the effect of austenite content on local orientation selectivity and texture development in hot bands; optimization of hot band annealing parameters for obtaining recrystallized microstructure along with varying texture gradients though the thickness of the strip; laboratory scale cold rolling of annealed hot bands to ~ 0.25mm thickness followed by microstructure and texture characterization; design of customized high temperature furnace for annealing under controlled atmosphere along



Figure 1: Processing of the CRGO steel upto decarburization and PRX.

with quenching facility so as to enable various treatments such as decarburization, nitriding, PRX and SRX and its installation and commissioning completed; optimization of decarburization and PRX annealing parameters with complete decarburization of cold rolled strip was achieved using above customized facility. Development of indigenous CRGO technology is possible with the understanding of abnormal Goss grain growth with respect to its neighboring GBCD and inhibitors.

Indigenous Development of Equivalent standards applicable for Russian Grades

With the drive towards indigenous development of marine infrastructures for Indian Navy and scarcity of Russian grade material due to geopolitical strategy, there is need to study alternate materials available in Indian market which is equivalent to the Russian grade used in Naval infrastructure (ship building). In this project, different alternate equivalent standard material properties were evaluated to finalize on the suitable replacement from Indian market as desired by the sponsor. The objective of the project was to evaluate different equivalent standard materials and suggest suitable alternative to replace the presently used Russian grade material. The assessment of the suggested equivalent material grade by sponsor for a given Russian grade and authenticate its exactness was carries out. Twelve GOST standard specification were studied and their equivalent comparable IS grade were suggested. This project indirectly facilitated the Atmanirbhar Bharat vision of developing indigenous infrastructure for our national defense sector.

Precipitation hardened compositionally complex alloys (CCAs) aided with hetero-deformation induced (HDI) strengthening

The birth of high-entropy alloys (HEAs) has fueled research on the design and property evaluation of several multi-component alloys with excellent strength-ductility synergy for structural applications. These groups of alloys were also referred to as compositionally complex alloys due to the addition of high concentrations of multiple elements instead of a single base element as observed in conventional alloys. This quest for the development of novel high-temperature alloys has focused on two different compositional designs: (i) refractory elements-based composition i.e., RHEAs (body-centered cubic matrix precipitation hardened by ordered BCC_B2 precipitates) and (ii) transition metal (TM) based alloy design i.e., face centered cubic matrix with ordered $L1_2$ precipitates (TM-HEAs). Several studies on TM-HEAs have shown excellent strength-ductility combinations at both room and elevated temperatures. The present work attempted to design two such cost-effective low-density TM-based medium entropy alloys (TM-MEAs) and assessed the mechanical properties at room and elevated temperatures. The objectives of the project were to design new low-density cost-effective compositionally complex alloys (CCA); optimization of the process parameters to obtain mechanical properties comparable to some of the existing superalloys; and to enhance the understanding of heterogeneous deformation induced (HDI) strengthening mechanism. A preliminary investigation and processing optimization was carried out on a Ni-Fe-Cr-Al-based CCA (*Precursor alloy*) and the room and high-temperature mechanical properties were investigated. Precipitation kinetics study was performed for this without Co alloy at 600°C for the condition exhibiting best combination of strength and ductility at high temperature tensile tests. **Study on Alloy A:** Alloy A was prepared with Co addition to *Precursor alloy* and modifying composition to strictly keep it a γ-γ'-based microstructure. Room and high-temperature properties evaluation of Alloy A exhibited better performance over *Precursor alloy*. Precipitation kinetics of Alloy A hinted at sluggish diffusion (up to 20 days) and expected to be in the growth regime while the *Precursor alloy* with high Fe content (up to 30 wt.% and 0 Co) showed coarsening after 5 days. Hence, specimens of Alloy A are currently under ageing treatment for 30 days (completed), 50 days and 60 days. Evaluation of strengthening mechanisms for room temperature mechanical properties was also done. **Study on Alloy B:** A master ingot of Ni-Fe-Cr was prepared using induction melting to reduce segregation and carbon content in the finally developed Alloy B. The master ingot was remelted with Ti and Al additions in a vacuum induction furnace to obtain the final as-cast material. As-cast alloy was homogenized at 1200℃ for 15 h and hot rolled for up to 65 % thickness reduction. The hot-rolled sheet was aged at 850℃ for 10 h followed by a second ageing treatment at 600℃ for 24 h. A two-step ageing treatment was planned to introduce a heterogeneous microstructure with multiple phases (matrix-γ, double aged-γ' and primary TiC) with different sizes and distribution. Microhardness values were evaluated for all the studied specimens including master alloy ingot (Ni-Fe-Cr), as-cast (Ni-Fe-Cr-Al-Ti) alloy, hot-rolled specimen condition and at both ageing treatments, respectively. Room temperature mechanical properties evaluation was completed using miniature tensile specimens and subsize specimens are currently being prepared from a new melt to obtain repeatability of the observed results. To evaluate high-temperature properties, a new melt has been prepared and currently is being processed. Energy efficiency

is one of the major focus areas for sustainable development. Researchers have always worked tirelessly in this direction as it not only helps a nation economically but also impacts environmental restoration. Growing environmental concerns have prompted the exploration of newer materials and process routes that can reduce greenhouse gas emissions. The current endeavor is an effort in this direction to reduce greenhouse gas emissions by developing low density material.

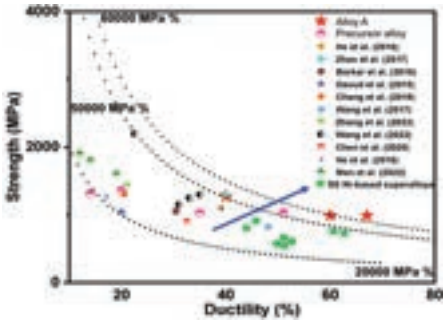


Figure 2: Comparison of room temperature mechanical properties

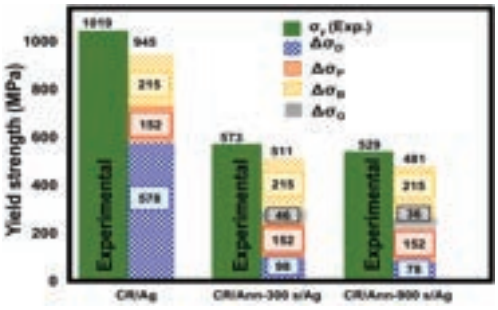


Figure 3: Evaluation of strengthening mechanisms and validation with experimental work (σ_Y- yield strength, σ_D- dislocation strengthening, σ_P- precipitation strengthening, σ_B- benchmark strength, σ_G- grain boundary strengthening)

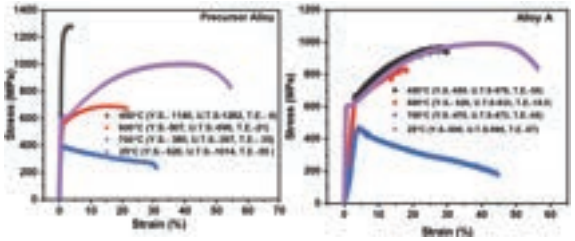


Figure 4: Comparison of room to high temperature mechanical properties in Precursor alloy and Alloy A

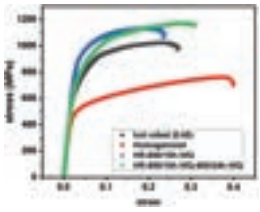


Figure 5: Room temperature mechanical properties of Alloy B with miniature tensile specimens

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

Hydrogen storage is currently the bottleneck towards shifting to a hydrogen-based economy, due to the inherent difficulty of handling hydrogen because of its low volumetric energy density. A potential solution for a suitable and safe way to store hydrogen is to employ solid-state hydrogen storage systems. However, binary metal hydrides are either very stable (LaH_2, YH_2, ZrH_2, TiH_2 etc) or very unstable (NiH, FeH etc). Elements like Mg, Al have high hydrogen absorption capacity (4-10 wt%) in the form of hydrides, however their applicability is restricted due to their poor desorption, irreversible or partially reversible kinetics and inherent material challenges like oxide formation and need for rigorous activation process. Intermediate stabilities of hydrides opened attractive new possibilities for practical systems by combining hydride-forming (Zr, Ti etc.) and transition (Ni, Fe etc.) metals, which can reversibly absorb large amounts of hydrogen. It is noted that H_2 release temperature decreases several hundred °C as compared to stable hydrides due to mixed chemical surroundings (hydrogen interacts with both hydride forming (e.g. Zr) and non-hydride-forming (e.g. Ni) elements). It is in this view, the present work focusses on developing alternate class of materials proven to have excellent reversibility at room temperature and low-pressure storage cycle, free from activation process and enhanced cycling properties. The present study aims to design and develop HEA alloy system comprising predominantly (Ti,Zr) based C14 laves phase as well as BCC refractory HEAs. The project aims at: **d**esigning of HEAs using computational thermodynamic approach (CALPHAD) with a target of hydrogen storage capacity > 2.5wt.%; exploration of appropriate processing strategy for selected HEAs (Arc & Induction melting); detailed microstructural characterization of as cast and heat treated alloys for establishing the phase fractions and respective phase compositions; and evaluation of hydrogen storage characteristics in terms of pressure composition isotherms (PCIs) and hydrogenation/de-hydrogenation kinetics. The following progress and achievements have been made under this project: a) Design of multicomponent HEAs (07 nos.) adopting CALPHAD approach in conjunction with literature-based information, targeting primarily AB_2 Laves phase type and disordered BCC phase type systems has been done. The designed alloys have been categorized as C14 Laves phase (AB_2) type alloy and (BCC + Laves) phase type alloy; b) Arc melting and casting of selected HEAs (08 Nos.): C14 Laves phase (AB_2) type alloy: Two number of designed alloys pertain to this category wherein A: Ti,Zr,Nb

and B: Fe,Nb,Ni,Cr,Mn. Such alloys basically contain hydrogenating elements (A) on one sublattice, whereas the dehdrogenating elements (B) on another sublattice, which synergistically are expected to render good kinetics of hydrogen absorption as well as desorption at or near room temperatures; (BCC + Laves phase) type alloy: Five numbers of designed alloys pertain to this category wherein BCC phase is 70-80% and Laves phase is 20-30%. The BCC phase in these alloys (although rich in one/two components) contain both hydrogenating as well as de-hydrogenating components (in lesser fraction) randomly arranged among various available sites of a single sub-lattice which can aid the hydrogenation/de-hydrogenation kinetics; c) Microstructural characterization and phase determination of the selected alloys were performed adopting Light Optical Microscopy, Scanning Electron Microscopy, X-Ray Diffraction and Energy Dispersive X-Ray Spectroscopy; d)Heat treatment of some of the cast alloys was carried out to explore/establish the variation of phase fraction with

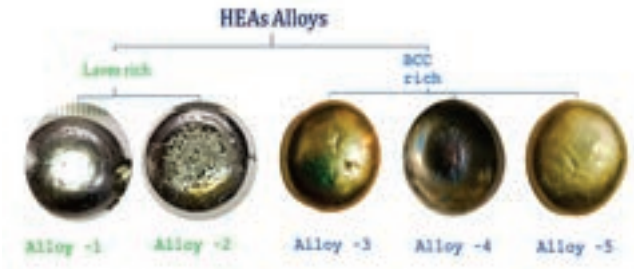


Figure 6: Arc melted buttons of designed alloys

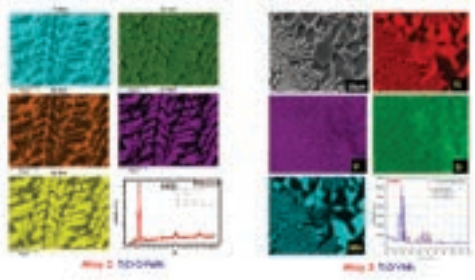


Figure 7: Elemental distribution of as-cast arc melted Alloy 2 and Alloy 3

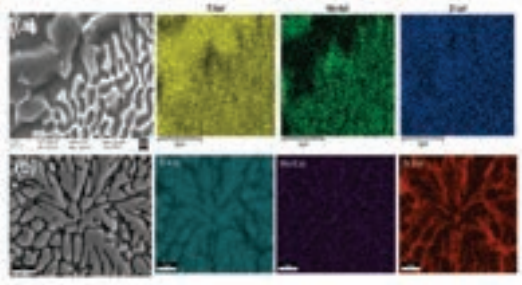


Figure 8: Influence of solidification parameters on phase fraction and distribution in Alloy 3, (a) as arc melted and cast on water cooled copper plate (BCC fraction: ~ 30%) and (b) as arc melted and suction cast (BCC fraction: ~ 78%)

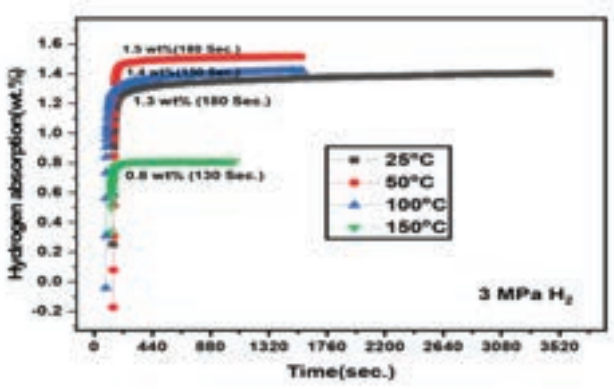


Figure 9: Hydrogenation kinetics at different temperatures for one of the developed Laves phase rich alloys

respect to temperature. Heat treatment was attempted to increase BCC fraction in (BCC + Laves phase) type alloy, however the effect is significant in morphological changes/coarsening and less on constituent fraction; e) However, in the arc melted followed by suction cast alloys diffusional transformation is suppressed which leads to increase in BCC fraction by preventing Laves phase formation along with refinement in microstructure; f)Evaluation of the hydrogen storage performance of the arc melted alloys (03 alloys) were performed. Alloy reached hydrogen equilibrium within 2-3 minutes depending on alloy composition. Designed alloys seem to possess good hydrogen absorption kinetics near room temperature; g) Based on the afore-mentioned understanding, a Laves phase-based alloy is prepared using vacuum induction melting (1 kg Capacity) facility. Detailed characterization of the hydrogen storage performance of the induction melted alloy is in progress. Hydrogen is considered the potential future energy carrier for a carbon-free economy. Storing hydrogen safely and efficiently is vital for its successful utilization that can provide the most reliable and safe practical solution for delivering clean energy for different applications, such as fuel cells. In this regard, solid-state hydrogen storage systems can play a pivotal role in storing hydrogen safely and efficiently that can be utilized whenever needed instead of fossil fuels, leading to a sustainable society and the economy.

Influence of the weld microstructure on hydrogen permeability and trapping behavior in API line pipe steels

One of the significant technological challenges in realizing hydrogen-based energy technologies is the development of cost-effective, efficient, safe storage and transportation systems for hydrogen. Hydrogen in high-pressure compressed gas is considered a commercial and economical form of hydrogen energy technology. However, the integrity

of storage and transportation of systems and components is critical, as most of all, available engineered structural materials are susceptible to hydrogen embrittlement and can lead to catastrophic failure. Stabilized austenitic stainless steels are less vulnerable to hydrogen-induced damage and embrittlement than other structural materials because of their low diffusivity and high solubility to hydrogen. However, the high cost of these steels increases the cost of developing the hydrogen energy infrastructure. Many industries have focused on analyzing the suitability of the existing oil and gas pipelines for hydrogen transport across cities with either only hydrogen fuel or mixed fuel. At the same time, research is underway to develop more hydrogen embrittlement-resistant pipeline steels and manufacturing technologies for hydrogen transportation and storage. Selecting the proper welding techniques and procedures is also essential in developing hydrogen infrastructure. The weld regions are more susceptible to hydrogen embrittlement due to their heterogeneous microstructure and high tensile residual stress, which are further dependent on the type of welding and procedures. It is well-reported and established that diffusible (reversible) hydrogen is mainly responsible for hydrogen embrittlement in iron, steel, and other structure materials. Therefore, one of the effective ways to control hydrogen embrittlement is by developing and modifying the steel microstructure with stronger traps (irreversible traps) that act as trap centers for the diffusible hydrogen in a material. In this view, the effect of different weld procedures and flux materials was studied for welding different API non-sour and sour grade X65 and X70 pipeline steels on the hydrogen permeation and trapping behavior. The sponsored industry supplied the API steels with varying welding techniques and parameters for this investigation. The hydrogen permeability in the different microstructures of these steels' weld, HAZ and base materials has been investigated through the electrochemical permeation method as per the ASTM standard G 148. This project aims to investigate the effect of the weld microstructure of different welding techniques and fluxes on the hydrogen permeability and trapping behavior in different sour and non-sour API grade steels. Hydrogen permeation and trapping behavior of API grade X70 and X65 sour and non-sour grade steels welded using SAW with different flux materials and ERW at different parameters were studied. It was observed that sour-grade steel has a lower effective hydrogen diffusion than non-sour-grade steel; accordingly, sour-grade steel has been found to have more irreversible trap centers than non-sour-grade steel. The API X-70 steel welded by SAW with flux 2 resulted in a distinct distribution of strong trap sites for hydrogen, as seen from the transient curve shown in Figure 10. The weld region exhibited the highest concentration of these sites, followed by the Heat-Affected Zone (HAZ). The base material, however, had the lowest trap sites. The effective diffusivity of hydrogen revealed an inverse trend. It was highest in the base material, lower in the HAZ, and lowest in the weld region. Welding with flux-2 was found to have more trap density and a lower effective diffusivity than flux 1 (Figure 10). The project will lead to selecting suitable steels and welding procedures essential for developing a safe and economically viable hydrogen energy infrastructure. This, in turn, will help ultimately pave the way for replacing the traditional energy sources in many applications and industries with hydrogen energy.

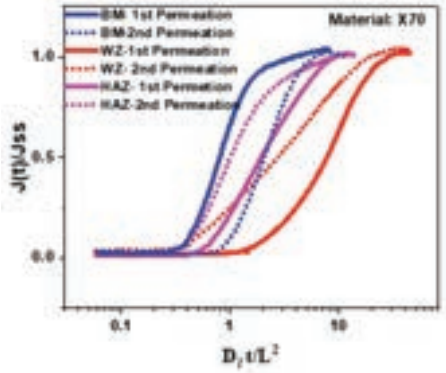


Figure 10: Hydrogen permeation transients of API X70 steel in weld, HAZ and base material welded.

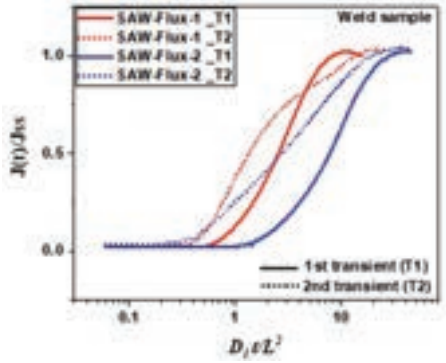


Figure 11: Hydrogen permeation transients of API X70 steel in weld region showing the effect of different fluxes.

Metallurgical Failure Investigation of API L80 grade seamless tube

The project is related to the metallurgical failure investigation of API L80 grade seamless tubings during the pull-off of the same from a gas well. Failure of the tubing was considered a serious event as it was associated with a safety hazard that could resulted in serious injury to the personnel working on the derrick floor. The scope of the work included visual examination, chemical analysis, microstructural examination (OM and SEM), mechanical property

evaluation (hardness measurement and tensile test), and fractography of the failed pieces of material. The objective of the present work was to find out the root cause behind the failure of API L80 grade seamless tubings during the pull-off of from a gas well. A detailed macroscopic and microstructural investigation revealed material flow near failed ends of the tubing, accompanied by ductile dimple fracture. It indicated that during trial/service, the applied load crossed the yield strength of the tubing material. The material could not withstand the overloading for a much longer period owing to the heterogeneity present in the material in the form of banding, which limited its ductility and hence the material failed. The identification of the root cause behind the failure would help in preventing such catastrophic accidents in oil and gas wells. In order to prevent such catastrophic failures of tubing material in the oil and gas wells, it was recommended to choose the material appropriately that can withstand the applied load during operations.

Generating Forming Limit Diagram (FLD) of Hot and Cold Rolled (HR & CR) Steel Sheets using Nakajima Test

A steel company approached CSIR-NML for developing forming limit diagram (FLD) steel sheets using Nakajima test. The sheet thicknesses are in the range of 1~2 mm. Nakajima test is carried out as per ISO 12004 -02-08 standard in universal sheet metal testing machine with varying blank width from 25 to 200 mm. The project aimed for developing forming limit diagram (FLD) of hot and cold rolled (HR & CR) Steel sheets using Nakajima test. Figure 12(a) shows the picture of Erichsen universal sheet metal testing machine available at CSIR-NML, which is used for Nakajima test. A typical test specimen geometry called dog bone shape blank (waisted blanks with parallel shaft) employed for testing is displayed in Figure 12(b). The outer dimension of the specimen is considered as 200 mm with different blank widths. The width of the dog bone shape (i.e., shaft) of around 25, 50, 75, 110, 125, 145 and 200 mm are considered for uniform allocation of forming limit diagram (FLD) from uniaxial to biaxial tensions. The test specimen's geometries are fabricated from the steel sheets provided by AMNS using electric discharge machining. Choice of appropriate grid spacing is essential for quality of the strain analysis. Regular square grids of dimension 1.0 mm are produced on the top surface of the steel sheets through electrochemical etching. These grids are employed to measure the major and minor strains during deformation with four cameras integrated with the machine. After preparation of grid on the specimen surface, it is placed in the machine to carry out the Nakajima test based on ISO 12004 standard. The drawing punch of 100

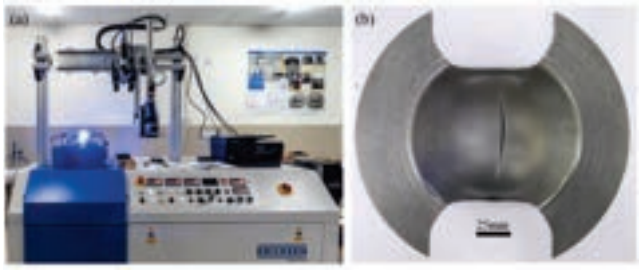


Figure 12: (a) Universal steel metal testing machine, (b) grids generated on the top surface of specimen

mm diameter with punch velocity of 60 mm/min is maintained to carried out all FLD tests. The holding force to restrict the slipping of the specimen is kept 150 kN. After the test is over, the in-process captured images are analyzed by AutoGrid® strain analyzing system to determine the strain paths and subsequently draw forming limit diagram of different grades steel sheets. Having the recommendations, the company would be able to choose the right sheet for various automobile application by understanding of the formability of sheets.

Microstructure and Mechanical Property evolution of WAAM-ed Inconel 625

Inconel 625 is a nickel-based superalloy with good high temperature tensile properties, creep and rupture strength due to the solid-solution strengthening effect of molybdenum and niobium. Components manufactured using Inconel 625 like aircraft engine exhaust systems, turbine shrouds, compressor vanes and thrust reverser systems are designed for high operating temperature at high alternating stresses and often fail by low cycle fatigue. Thus, investigation of low cycle fatigue behavior (LCF) is an important aspect to be considered when such components are designed. Wire arc additive manufacturing (WAAM) with its high deposition rate and cost effectiveness is preferred for large components with medium to low complexity over selective laser melting (SLM) process. The as-deposited microstructure of Inconel 625 consists of γ–matrix along with carbides (M_6C, MC and $M_{23}C_6$), δ-phase and Laves phase. While δ-phase and Laves phase are derogatory to mechanical properties, fine distribution of carbides can help improve mechanical properties. Variation in heat input will evidently lead to variation in thermal gradients and cooling rate which consequently will affect the precipitation behavior. WAAM processes generate much higher heat input than laser beam and electron beam processes which can cause detrimental microstructure leading to inefficient mechanical properties. It has been observed that increasing heat input in WAAM deposition of Inconel 625 leads to increasing primary and secondary dendritic arm spacing. Interestingly mechanical properties

are reported to increase with heat input but there are evidences in the literature that report diminishing mechanical property with increase in heat input. There is need for study of mechanical performance with varying heat input and correlating it with the developed microstructure. In this work, tensile response as well as LCF behavior will be studied on Inconel 625 prepared at three heat inputs (low, medium and high).

The broad objectives of the project were: a) To study the effect of three different heat inputs (low, medium and high) on the microstructure of WAAMed Inconel 625; and b) To study and correlate the LCF behaviour of three different heat input WAAMed Inconel 625 with microstructure. Deposition of two Wire Arc Additive Manufacturing Samples of rectangular block type (200 X 140 X 23) with high heat input and low heat input has been conducted. Figure 13 shows the as-deposited samples. Machining of the deposited samples using a shaping machine is completed. The LCF and tensile samples will be made from the rectangular block WAAM deposit. This proposed work will add to the pedagogical understanding of the effect of heat input on low cycle fatigue behavior of WAAMed Inconel 625. Establishing this correlation will lead to better design and optimization of process parameters when depositing components that have high sensitivity to low cycle fatigue using WAAM.

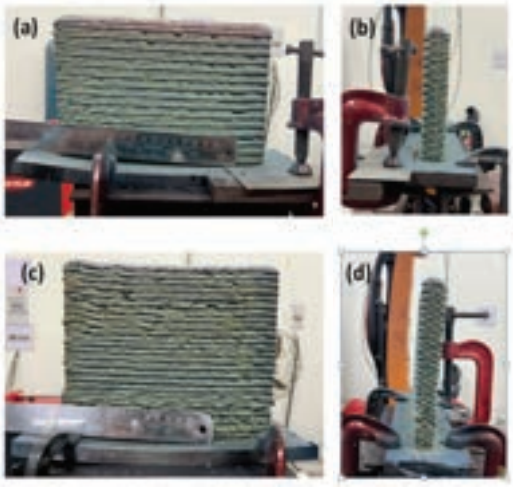


Figure 13: The Wire Arc Wire Arc Additive Manufacturing Samples of rectangular block type (200 X 140 X 23) with (a)-(b)high heat input and (c)-(d) low heat input

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

The development of additive manufacturing is one of the new areas of modern materials science. These technologies, which are a symbiosis of powder metallurgy and casting, allow us to produce ("print") products of a very complex or even unique shape. In this regard, it is expected that their use will contribute to the technological breakthrough, and, thus, can bring the level of production to a qualitatively new altitude. One of the promising areas for the use of additive manufacturing is high-tech industries, in particular, the manufacture of biomedical implants. The first studies in the field of additive manufacturing of medical steels showed that the products obtained were characterized by a low level of service properties. This result was largely associated with a low surface quality, as well as a relatively high level of porosity of the "printed" material. However, the improvement of "printing" methods (in particular, the development of a progressive method of selective laser melting), as well as the optimization of their regimes, helped to eliminate these shortcomings. In this regard, a further way to increase the service properties of 3-D printed products is to improve their internal microstructure. The objective of this project is to develop methods for engineering the microstructure of additive manufactured products from a medical grade austenitic stainless steel so as to ensure enhanced fatigue and anti-corrosion properties. Under the project, 4 numbers cuboidal shaped samples of type 316L Austenitic stainless steel through SLM technique with different Power (240 & 210 W), Scan speed (950, 1070, 1400 mm/sec), and Hatch spacing (70 & 80 µm) were prepared. Microstructural characterization of as-received 3D-printed specimens has been evaluated employing optical microscope, SEM-EDS/EBSD analysis techniques. Influence of scan speed and hatch spacing on the evolution of microstructural features (i.e., grain size, grain boundary, texture, residual strain, segregation) during 3D printing have also been examined. Further work is in progress for understanding about the influence of 3-D printing process parameter, and annealing treatment on mechanical properties and corrosion behavior in simulated body fluid environments. Heat treatment of 3-D printed samples for optimization of microstructural features (i.e., grain size, grain boundary and triple junction character distribution, residual strain, texture) has been planned as future course of action.

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

A few studies on techno-economic feasibility of Concentrated Solar Power (CSP) technology in India are available wherein it has been suggested that a significant amount of energy can be harvested through the CSP technology. However, to the best of our knowledge, no research work has been reported in the open literature on the high temperature corrosion behavior or even on the structural materials of the Thermal Energy Storage (TES) system in the CSP plant. Since past two year, a corrosion

engineering research group at CSIR-National Metallurgical Laboratory undertook an in-house project to develop grain boundary engineered microstructure in stainless steel and Ni-base superalloys by thermo-mechanical processing to combat molten salt corrosion in concentrated solar power plant. During the progress of the project work, the group came across some crucial findings about the dependence of molten salts corrosion resistance on the microstructural features of the materials. It has been realized that molten salt corrosion resistance can be enhanced significantly through optimization of grain boundary character distribution. The project has multiple objectives viz. a)To study the influence of molten chloride salts composition on the corrosion behavior of the TES-tank alloys employing electrochemical test; b)To determine the in-situ corrosion rate and to understand the corrosion mechanisms of the TES-tank alloys in molten salts; c)To develop high corrosion resistance TES-tank alloys through modifying microstructural features viz. grain boundary character distribution, grain size, residual strain and texture; d)To optimize the size and mass of the inhibitors to minimize the corrosion rate of the TES-tank alloys in concentrated solar power plant. Under the project, the influence of cold work deformation on molten nitrate salt corrosion behavior (isothermal condition at 550 deg C for 300 hr) have been examined; and studies regarding dependency of molten nitrate salt corrosion rate on extent of cold deformation during cyclic corrosion test (up to 300 hr) are going on. In order to determine the in-situ corrosion rate and to examine the corrosion mechanisms of the TES materials in molten salts, the high temperature electrochemical corrosion tests will also be carried out using a potentiostat with three-electrode high temperature electrochemical cell. The successful execution of this proposed project would essentially provide the guidelines for design of microstructurally engineered materials, which are adequate corrosion resistance in next generation thermal energy storage salts. It will also provide the guidelines to achieve significant corrosion resistance of the TES-tank alloys by addition of suitable inhibitors to the molten salts without compromising the efficiency of the concentrated solar power plant.

Enhancement of molten salt corrosion resistance of thermal energy storage materials in concentrated solar power plant through doping inhibitors

Recently, concentrated solar power (CSP) technology is considered as economically viable technology among the future renewable energy systems. The CSP technology is commonly associated with thermal energy storage (TES) system, which provides the storage of solar thermal energy for a longer duration and allows producing energy according to the demand, even during the night or adverse weather situations. In the TES system, common molten salts (i.e., nitrates, carbonates, chlorides, fluorides) are recently used for thermal energy storage media due to their excellent thermo-physical properties and cost effectiveness. However, severe corrosion of the TES materials with these molten salts at elevated temperature is one of the major issues among others. In this regard, currently, numerous researches have been carried out to overcome the hot corrosion of TES materials through various preventive methods like regular monitoring of salt composition, microstructural engineering, coating, inhibitors etc. Among these methods, doping inhibitor to the molten salts has been considered as a simple and cost effective technique. However, till now, this technique is not available at an industrially viable state due to lack of understanding of the exact role (working principle/mechanisms) of inhibitors in molten salts. Therefore, it is very essential to do a further in-depth study and to establish the exact mechanisms that can be helpful to overcome the aforementioned difficulty. The project has following objectives: a) Development of high temperature electrochemical cell for various molten salt corrosion study; b) Determination of the in-situ corrosion rate and to examine the corrosion mechanisms of the TES containment materials in molten chloride salts; c) Study the influence of inhibitors on the corrosion phenomena of TES materials in molten chloride salts. Under the project, the role of inhibitor (i.e., Mg powder) on the hot corrosion behavior in molten chloride salts has been examined and the high temperature Electrochemical corrosion set-up has been installed. The effect of inhibitor (i.e., Mg powder) on the hot corrosion behavior in molten chloride salts need to be examined through electrochemical corrosion test. After successful execution of this project work, a better understanding of the role of various microstructural features and inhibitors on molten chloride salt corrosion behavior of TES materials can be obtained.

Characterization and corrosion behavior of potential anode material for Al-air battery

Due to the finite energy resources of fossil fuels and growing demands for energy/power, it is essential to develop an alternate energy source. Moreover, conventional fossil fuels such as petrol and diesel produce harmful gasses, e.g., CO_x and NO_x that degrade environmental values and generate new issues such as greenhouse effects/global warming. To overcome this, an aluminum-air battery has been proposed as an alternate energy source that provides clean and affordable energy. The aluminum-air battery can be a good source of energy for the future of India. However, the battery performance mainly depends on the anode's (aluminum) efficiency which further depends on the anode

material's processing routes, microstructure, electrochemical behavior, and presence of impurities/second phase particles. Additionally, the main challenge here is to reduce the self-corrosion rate of an anode (i.e., aluminum). Hence, it is essential to tailor the alloy composition, microstructure, and processing route to achieve higher anodic efficiency and favorable electrochemical activity for battery application. The objectives of this project are: a) Design and development of Al alloy containing Mg/Sb/In for the Al-air battery anode; b) Investigation of microstructures in terms of grain size and homogeneity of prepared Al alloys along with second phases; and c) Investigation of corrosion behavior of developed Al alloys. Under the project, Al-alloy containing Mg/Sb/In for the Al-air battery anode has been developed and microstructural features of the developed alloy has been thoroughly examined employing SEM-EDS/EBSD. Preliminary investigation regarding corrosion behavior of the developed Al-alloy is also completed. In order to understand the exact mechanisms regarding the role of microstructural features on electrochemical behavior of the developed alloy, a comprehensive study will be carried out further. In the context of sustainable energy technologies, it is an emerging area of research and any development in new alloy compositions will assist in the preparation of efficient and eco-friendly batteries.

Development of Fe-rich cost-effective high-entropy alloy for high-temperature applications

The development of new types of metallic materials always gained significant attention because of their potential engineering applications. In this regard, in 2004, a new class of metallic materials designated as high entropy alloys (HEAs) gained significant attention in the material science community. This concept of alloy design provides an infinite compositional space with unique and excellent properties. To date, the HEAs literature suggests that the viewpoint of their applicability considering the cost-property relationship is missing. Undoubtedly, the costs of the raw materials of previously developed HEAs are relatively higher than the conventional alloys. This point has motivated me to develop new alloy systems with better cost/performance balance compared to conventional alloys. In this regard, iron-based alloys are usually low-cost and show a variety of excellent properties. Taking this as an advantage attempt will be made to design and develop iron-based high-entropy alloys by melting/casting route. Moreover, the partial substitution of other alloying elements into Fe will provide the possibility of possible manipulation of the strengthening mechanism, leading to excellent strain hardening capability with a better combination of strength and ductility. It has been found that the strength of most engineering alloys, especially at high temperatures depends mainly on the precipitation hardening. It may be noted that the precipitation hardening in HEAs such as the B2 precipitate in the BCC matrix generally deteriorates the ductility, and L12 precipitates in the FCC matrix decrease strength. A complete picture of the balance of strength and ductility with better phase stability at higher temperatures is yet to be developed. Hence, it will be worthy to investigate this issue in this direction.

The objectives of the current project are**: a) D**esign and development of Fe-rich cost-effective high entropy alloys for high-temperature applications. Alloys should have a better combination of strength and ductility; b) Non-equiatomic composition of AlCrFeCoNi and AlCrMnFeCoNi - high entropy alloys will be taken as the starting material to develop the superalloy-like microstructure; c) Microstructural evolution and their stability in time-temperature space will be evaluated; and d) Mechanical properties both at room temperature and high temperatures along with the strengthening mechanism will be studied. Currently under the project, a cost-effective iron-rich non-equiatomic FeMnAlNiCo high entropy alloy (HEA) was synthesized by vacuum induction melting. Figure 14 (a,b) confirms a three-phase structure of ordered B2, disordered BCC and FCC phases were observed in as-cast state. The optical micrograph of the as-cast alloy exhibits the formation of columnar grains. The FCC phase forms near the grain boundary area confirm through the EBSD phase maps Figure 14 (c and d). Figure 15 shows Al-Ni-rich B2 precipitates are formed in the BCC phase and FCC phase near to the grain boundary area in the high-magnification SEM micrographs. The SEM-EDS line analysis through the modulated structure confirms the Ni-Al-rich composition of the B2 precipitates (Figure 15 (f)). The B2 precipitates are rich in Al and Ni elements confirmed by STEM-EDS elemental maps (Figure 16). The alloy demonstrates the yield and ultimate compressive strength of ~1250 MPa and ~1675 MPa, respectively, with compressive ductility of ~42% in Figure 17(a). These values are comparable to the other reported HEAs. The alloy exhibited a high hardness value of ~450 HV in the as-cast condition. A new Fe-rich alloy composition was designed and developed that is showing the FCC and B2 phase in the heat-treated condition. The alloy has shown an improved mechanical property i.e., strength ~ 1 GPa and appreciable ductility along with higher microstructural stability in the temperature range of 600-800°C for the longer duration of annealing treatment. The exciting results are in embryonic condition and suitable thermo-mechanical processing is required to meet the objective. Alternatively, more Fe-rich alloys are needed to be designed and developed to abridge the shortcomings of this work. The high-temperature mechanical properties,

creep resistance, hot corrosion and oxidation results need to be investigated with the enhanced working temperature range of 650-700°C to meet future power generation requirements. The encouraging results of the as-cast alloy at room temperature, particularly the microstructural evolution and mechanical properties, have shown that the properties of such materials can further be improved by following suitable thermo-mechanical processing techniques. The outcomes of these results will create an impact in direction of the development of cost-effective materials for high-temperature applications to meet future power generation requirements.

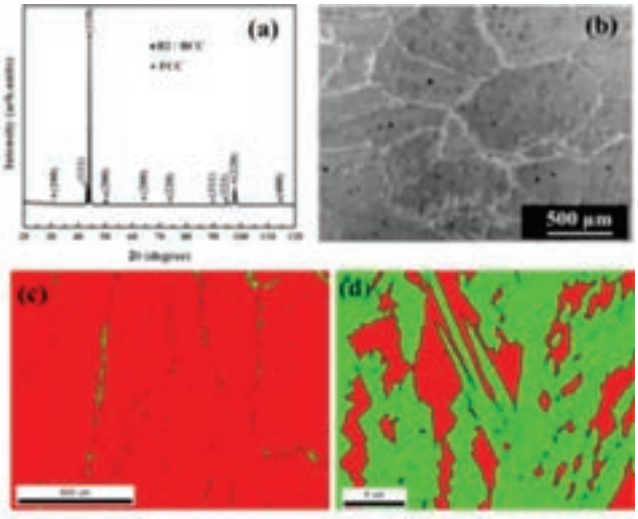


Figure 14: (a) X-ray diffraction pattern (b) optical macrographs of as-cast FeMnAlNiCo HEA. The evolution of the B2/BCC and FCC phases could be discerned. The columnar grains of varying sizes could be observed in the optical micrographs (c) low magnification phase map and (d) high magnification phase map along the grain boundary for as-cast HEA. The colors red and green in the phase map represent the BCC and FCC phases respectively.

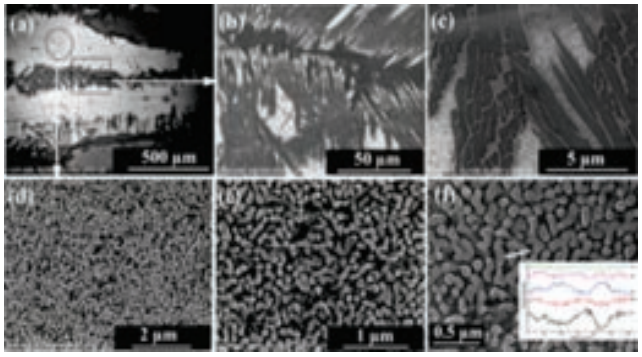


Figure 15: The high-resolution SEM micrographs of as-cast FeMnAlNiCo HEA. Marked rectangular FCC region magnified in (b) and (c). Marked circular BCC region magnified in (d, e and f). The EDS showed in the insert of (f) indicates the formation of the Ni-Al-rich B2 phase.

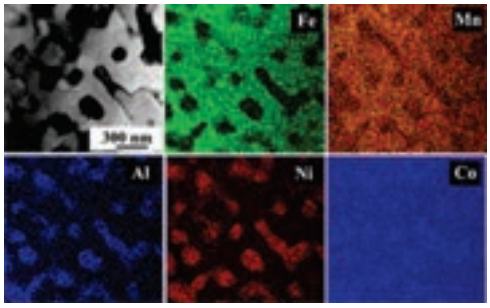


Figure 16: The STEM-EDS elemental maps of the as-cast FeMnAlNiCo HEA. The B2 precipitates richer in Ni and Al, and the BCC matrix richer in Fe and Mn could be depicted. However, Co is ingressed in both phases.

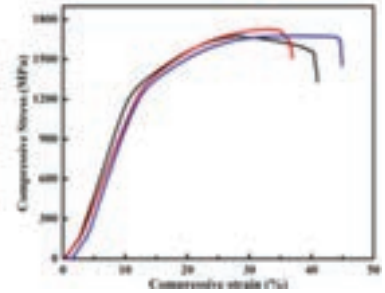


Figure 17: (a) Compressive stress-strain plots of room temperature compression of as-cast FeMnAlNiCo HEA.

Design of efficient corrosion inhibitor for mild steel surfaces using density functional theory and reactive molecular dynamics simulations.

Steel has wide applications in the area of automotive, construction, defense, production and bio-medical. Despite significant progress in the development of steel components, protection of steel components in a saline environment is not resolved fully as steel is prone to react with corrosive ions. Consequently, the life of steel components decreases which imparts negative effects on the economic growth of a country at large. To enhance the life of a steel component, the general practice is that the surface of the component is coated by using organic or inorganic materials. This has motivated many researchers to design new coating materials both theoretically and experimentally in order to extend the life of steel components. Some notable international studies have explored phase transition, grain growth and refinement under various processing conditions. They have shown that the above characteristics of steel powder are very critical and extremely difficult to control. In national status, people have investigated the corrosion mechanism of steel using density functional theory and molecular dynamics simulations. However, both national and international studies indicated that it is very critical and difficult to explore phase transition and corrosion mechanisms using existing

experimental simulation and experimental methods. Therefore, it is very important and required to use new and impactful simulation methodology such as reactive during rapid solidification of steel powder to study phase transition and corrosion behavior.

The objectives of the current project were: Developing computational design and synthesis of steel powder; b) Identification of phase transition mechanism during rapid solidification; c) Chemical reaction mechanism during corrosion of steel powder; d) Selection of organic compounds containing N, S and P, and to identify which one is having good corrosion inhibition. The *reactive molecular dynamics simulations* were carried out under the project. It is a computational simulation technique used in materials science and chemistry to model chemical reactions and the dynamic behavior of molecules at the atomic and molecular level. It is a subset of molecular dynamics (MD), which simulates the time evolution of a system of interacting particles (atoms or molecules) under the influence of forces derived from interatomic or intermolecular potentials. LAMMPS and OVITO software will be used for the synthesis and characterization of steel powder. *Density functional theory* is a computational quantum mechanical method used to study the electronic structure and properties of atoms, molecules, and solids. It has become a fundamental tool in the field of computational chemistry and materials science. Quantum Espresso, Burai and Xcrysden software will be employed to explore diffusion of hydrogen, oxygen, nitrogen etc. into crystal lattice. Also, this software will provide information about energy barriers for possible reactions during chemical reactions. Figure 18 shows the reactive molecular dynamics simulation visuals for the atomistic reaction of water with the iron. It can be observed that the formation of an atomically thin layer of a new chemical compound consisting of Fe-O-Fe and Fe-H-Fe chemical bonds at the interface between water and iron. Gray, red and green atoms are named as iron, oxygen, hydrogen respectively. Corrosion inhibitors are important and have a multifaceted role in safeguarding mild steel against corrosion, offering benefits such as increased longevity, reduced maintenance costs, enhanced safety, and improved environmental sustainability. Their importance extends across various industries where mild steel is utilized, contributing to the reliability, efficiency, and longevity of critical infrastructure and assets.

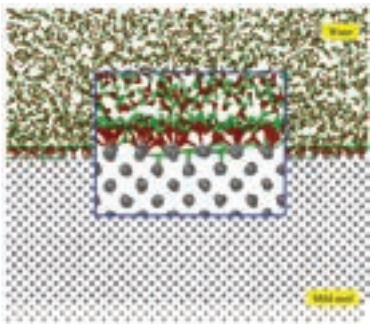


Figure 18: The reactive molecular dynamics simulation visuals

Remaining Life Assessment of Crude and Vacuum Heater tubes

The H39WM Paralloy tubes were in operation for about 25 years in an Ammonia plant. These primary reformer tubes are prone to creep failures due to stringent operating conditions for longer duration. The main objective of the present investigation is to assess the remaining creep life of the service exposed reformer tube. The investigation involves characterization of mechanical properties, microstructure and prediction of remaining creep life using time-temperature parametric method. Remaining life prediction of the H39WM reformer alloy is estimated less than 10 years at 900°C under 15.65 MPa. The findings of the project investigation suggested that if the operating temperature would be maintained at the temperature range of 815-820°C. Therefore, life of the component would be more than 10 years under constant operating pressure of 38 kg/cm^2. After completion of five years in service, it was recommended to take-up another RLA study for evaluation of stress rupture and tensile properties along with characterization of the service exposed materials. Operating parameters were maintained and controlled to avoid the overheating failure during service. However total economic loss occurred during shut down of the plant.

Low cycle fatigue behaviour of additively manufactured Ni-base superalloy IN-625

Additive manufacturing (AM) is attracting a wide-spread interest due to greater flexibility in components with complex geometry, shorter lead-time, low wastage of materials and batch production efficiency. Laser Powder Bed Fusion (LPBF) process is increasingly becoming popular for producing components which are used in aerospace, automobile and biomedical industries. Extensive studies have been carried out for optimization of AM process parameters, subsequent post-processes and tensile behavior. However, advanced mechanical property characterization of AM-IN-625, such as, high temperature Fatigue Crack Growth (FCG), Creep Crack Growth (CCG), high temperature fracture, Low Cycle Fatigue (LCF) have not been dealt with in depth. The aim of this work is to study the LCF behaviour of AM-IN-625 at temperature 923K and 973K, and studying the microstructural features for understanding underlying damage mechanisms. IN-625 has found a prevalent and diverse applications at both ambient and

elevated temperatures in the aerospace, marine and petro-chemical industries. The past decade has seen a significant advancement in fabrication of superalloy components by AM, especially LPBF process. Such components are also made for replacing the older one in existing turbomachines during overhauling/refurbishment. The performance of such materials should not be equated with that of conventional material. Therefore, for better design and life estimation, it is necessary to understand the mechanical performance of AM-IN625. The objectives of the project include: a) Study of the LCF behavior of AM-IN-625 at 923K and 973K; b) Study of the effect of strain amplitude on LCF life and microstructural changes; c) Comparison of the LCF behavior of AM-IN-625 with conventional IN-625; and d) Comparison of the deformation mechanisms of AM-IN-625 with conventional IN-625. A thorough study of the fatigue behavior of AM-IN625 has been conducted (Figure 19). The tensile behavior of AM alloy was found to be superior to conventional alloy however the fatigue performance was not as good due to the presence of carbides at the grain boundary. Also, the detail microscopy and fractography of tested material revealed the prevalent deformation and fracture mechanism. This information generated by this study will help in optimization of process parameters to enhance the fatigue properties of AM-IN625. A detailed study is planned further to optimize the effect of precipitates. Also, more mechanical characterization viz. fracture toughness and fatigue crack growth behavior of AM alloy will be studied and compared with the conventional alloy. A thorough knowledge of mechanical behavior of AM material will help in using the AM component under the stringent industrial regulation. Additive manufacturing is a worthy alternative for batch production of the critical components where time and cost reduction is important.

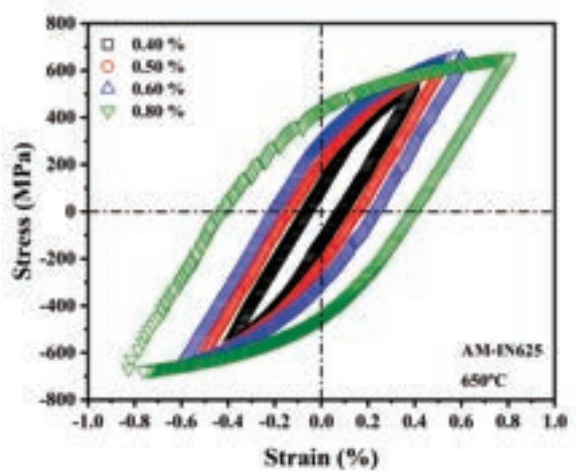


Figure 19: The fatigue behavior of AM-IN625

The ongoing AM technology research and development efforts continue to expand the capabilities and applications of additive manufacturing technology.

Hybrid Heusler-Glassy Magnetic Alloy Composites for Caloric and Shape Memory Applications

CSIR-National Metallurgical Laboratory, Jamshedpur is working on a project titled Hybrid Heusler-Glassy Magnetic Alloy Composites for Caloric and Shape Memory Applications" sponsored by SERB-DST, New Delhi. There is a worldwide research endeavor towards achieving high entropy and Relative Cooling Power (RCP) in magnetocaloric materials while in the case of FSMAs, efforts are targeted towards achieving high recoverable strains with preferable low magnetic fields. The on-going project is aimed to develop magnetic composites comprising of Heusler and amorphous-nanostructured alloy systems for caloric and shape memory applications. Master alloys of Heusler system based on NiMnGa were prepared though vacuum arc melting in Argon atmosphere. The alloys with typical compositions of $Ni_{53}Mn_{18}Cu_6Ga_{23}$ (at %) and $Ni_{52}Mn_{25}Ga_{23}$ (at %) designated as Alloy-1 and Alloy-2 were prepared in the form of ribbons. To understand the transformation temperature, Differential Scanning Calorimetry (DSC; Make: TA instruments) thermograms were obtained for Alloy-1 for both heating and cooling cycles at a ramp rate of 20K/min in inert atmosphere and shown in Figure 20(a). From the plots, the Austentic start (A_S), Austenitic finish (A_F), Martensitic start (M_S) and Martensitic finish (M_F) were found to be 56°C, 70°C, 60°C and 45°C respectively. These transformations were closer to room temperature for prospective magnetocaloric application. Magnetostriction was measured for Alloy-2 using 2-terminal capacitance technique developed in the laboratory. The variation of Magnetostriction for Alloy-2 is shown in Figure-20(b). In the as-spun state, the ribbon of Alloy-2 displayed a magnetostriction of 275ppm at an applied magnetizing field of 1.0 Tesla.

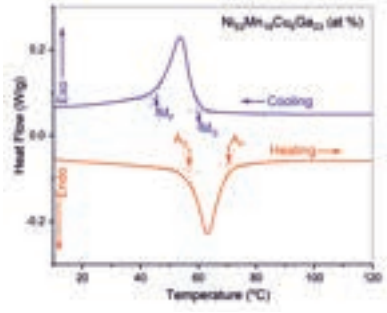


Figure 20(a): DSC thermograms obtained for as-spun $Ni_{53}Mn_{18}Cu_6Ga_{23}$ (at %) ribbons showing the transformation characteristic temperatures.

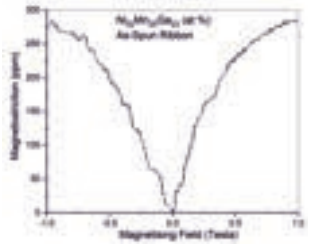


Figure 20(b): Magnetostriction plot for as-spun $Ni_{52}Mn_{26}Ga_{22}$ (at %) ribbons obtained upto a magnetizing field of 1.0 Tesla.

Metallurgical Failure Investigation on the Developed cracks over Horizontal Web Plate Girder of Gates of Farakka Barrage

Six samples (Sample-1, Sample-2, Sample-3, Sample-4, Sample-5 and Sample-6) and one scrap (old plate) of Frakka gate (Gate No. 15 and Gate No. 17) having one crack in sample-2 and sample-4 in the horizontal plate at weld from Farakka Barrage Project, Murshidabad, West Bengal were received for failure investigation to CSIR-NML Jamshedpur. Failure analysis of these gate plates, containing crack in sample-2 and sample-4 of Frakka Barrage Project (FBP), Murshidabad, West Bengal. As Received of Frakka gate materials are shown in Figures. The cracks are indicated by an arrow (Figure 21 (a-b)), which passed through the weld junction. Traverse section of weld (weld of horizontal web plate and vertical plates) show weld cavity/discontinuity. This weld cavity arises due to lack of fusion/ incomplete of fusion during welding (Figure 22 & Figure 23). Crack nucleation and progress was occurred due to weld defects/discontinuity in weld followed by dynamic loading. A lot of pressure was generated on web plates and vertical plates in gate under operation by fast flowing water (tides), which cause the crack nucleation from weld defect/discontinuity in web plates. Hot crackings and slag



Figure 21 (a,b): The photographs of as received gate materials of Frakka Barrage Project (FBP) which showing significant crack passing through weld junction (a) Horizontal web plates welded with stiffener vertical plate (Sapmle-2) having small crack passing through weld junction and normal to stiffener plate (b) Horizontal web plates welded with stiffener vertical plate (Sample-4) having one big crack passing through weld junction and normal to vertical stiffener plate.

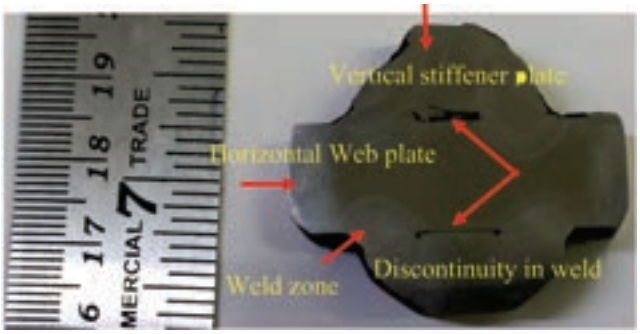


Figure 22: Macrograph in etched condition of weld cross of weld of horizontal web plate and vertical plate showing discontinuity in weld.

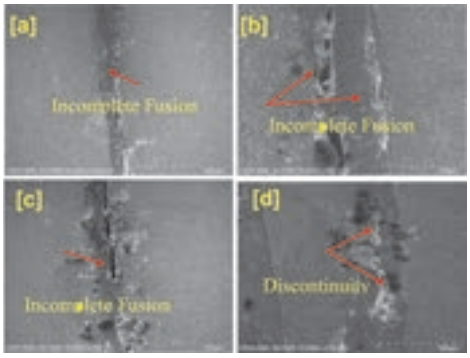


Figure 23(a-d): Scanning electron micrographs of sample-4 at weld region (a-d) showing weld discontinuity and defects/ incomplete fusion during welding.

inclusion were also observed in the weld zone in weld of web plates, which are prone to micro crack generation. Therefore, weld discontinuity/ weld defects were primary cause of crack initiation from weld junction in weld. It is recommended for to make defect free weld of horizontal web plates and vertical plates to prevent the crack generation and apply the paint on web plate of surfaces regularly.

The project aimed for Metallurgical Failure Investigation of Horizontal Web Plate Girder of Gates of Farakka Barrage. The following key findings were drawn from the failure investigation: The crack in web plates of Frakka Gate materials was developed from weld junction due to weld defect/ weld discontinuity due to incomplete fusion/ lack of fusion/ lack of penetration/incomplete penetration during welding. These weld defect causes crack generation at weld junction followed by dynamic pressure by flow water with gate under loading and finally crack growth was occurred under loading conditions. Moreover, hot cracking and slag inclusions in weld zone are also observed, which causes micro crack generation from these. However, weld defects/ weld discontinuities are primary cause of crack generation from weld junction under dynamic loading conditions. The identification of root cause of recommendation will prevent

occurrence of such cracks in gate materials of barrage. It is recommended that weld of gate materials should be defect free (like cavity, discontinuity, lack of fusion/incomplete fusion, hot cracking and slag inclusions in weld etc.) weld of horizontal web plates and vertical stiffener plates to prevent crack generation in web plates. The welding should be carried out by experience and skill person to avoid welding defects/discontinuities. It is also recommended that, to choose suitable welding parameters/technique for welding of web plates and vertical stiffener plates for preventing defect in weld and to apply the paint regularly on both surfaces of gate materials to prevent surface corrosion and failure.

Metallurgical Failure Investigation of Line Pipe Steel API 5LX70M PSL2 (SSP 1373)

A crack (24 mm length) occurred during hydrotesting of API 5LX70M PSL2 grade line pipe steel at the site; the client approached CSIR-NML to find out the root cause of cracking and failure and suggest remedial measures. The objective of the project is to identify the root cause of crack in the API 5LX70M PSL2 line pipe steel. The study involved examining two segments of the pipe: the damaged section with the crack and an undamaged portion away from the crack site. A comprehensive approach was taken, including visual inspection, non-destructive assessment, chemical analysis, microstructural evaluation, fractography, hardness and tensile testing, and impact toughness assessment, to pinpoint the root cause of failure. The chemical composition and tensile properties conformed to the standard specification. However, the microstructure beneath the fracture/crack surfaces revealed multi-pass overlay welding (of approx. 26 mm length comparable to the crack length) with presence of typical welding type gradient microstructure comprising of fine grain and coarse grain heat affected zones; this strongly suggested localized intense heating due to welding. Moreover, presence of complex oxide heterogeneities over fracture surface also endorsed the application of some kind of fusion welding over the component. The reason of such kind of welding cannot be figured out as it was related to fabrication-installation-commissioning-subsequent testing. It is also noteworthy in this context, that the primary welding was at notable distant (6 inches) from the cracked region, thus the observed welding in proximity to the crack was likely incidental in nature / related to commissioning. The aforementioned efforts facilitated the client in implementing measures to prevent similar failures from happening in the future.



Figure 24: Photographs of the damaged region of the as-received pipe part

Metallurgical investigation to explore the root cause of U1 Boiler Super Heater Tube Failure

Occurrence of pinhole and crack was found in super heater tubes installed in boiler; the client approached CSIR-NML to find out the root cause of occurrence of pinholes and cracks and suggest remedial measures. The objective of the project was to identify the root cause of pinholes/crack in the U1 Boiler Super Heater Tube. A comprehensive approach was taken, including visual inspection, non-destructive assessment, chemical analysis, microstructural evaluation, fractography, hardness and tensile testing to investigate the root cause of pinholes/cracks in U1 Boiler Super Heater Tube. The superheater tube's chemical composition conformed to the ASTM A213 TP304H standards. Mechanical properties at room temperature meet standard requirement; however, fractographs of the fracture surface, which was tested at ambient temperature, had large voids/cavities in significant numbers. Microstructure analysis revealed Cr-rich carbide formation along grain boundaries, leading to Cr depletion and susceptibility to corrosion. Segregation of Nb in stringers/bands contributes to crack initiation and growth, especially under high-temperature conditions. Pitting corrosion is evident on the inner tube surface, possibly due to Zn-rich deposits accelerating corrosion. These inconsistencies may lead to macro defects like pinholes, posing structural integrity risks. The aforementioned efforts facilitated the client in

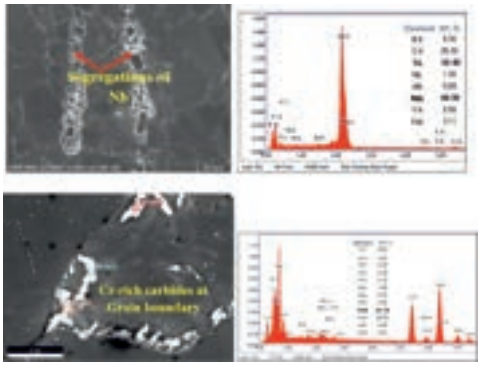


Figure 25: SEM micrographs of the tube showing extensive segregation of Nb and grain boundary Cr-rich carbides along with their respective EDS spectrum

implementing measures to prevent similar failures from happening in the future.

Metallurgical failure investigation of Inner Rocker Arm of Flap No. 05 (RH) at starboard upper air intake of MiG-29

Air officer Commanding, Air Force Station Adampur, Jalandhar assigned to CSIR-NML, Jamshedpur, for Metallurgical failure analysis of inner rocker arm of flap no.5 (RH) at starboard upper air intake of MiG-29 (Figure 27(a-c)). The investigation of failure consisted of visual observation and photography, bulk chemical composition analysis, evaluation of microstructure, determination of bulk hardness and tensile properties and fractography analysis. Specimens for microstructure evaluation were prepared as per standard metallographic procedures. Fractography of the failed component was carried out by Scanning Electron Microscope, equipped with Energy Dispersive X-ray Spectroscopy (SEM-EDS). The main fracture was observed on the inner rocker arm of flap. The impact marks are observed on the both arm of flap (Figure 16). Chemical composition, mechanical properties and microstructure of arm of flap material conform to the specified standard AA2024-T3 Al alloy grade /ASTM B209. Chemical composition of this alloy is as per AA2024-T3 Al alloy grade. However, Fe was significantly higher was observed than as per specified limit. Rough marks and dent grinding marks and were observed on arm surface of flap at near fracture. Dent mark/rough mark was more prone to corrosion attack. Tensile properties of the arm of flap are observed lower values than the designated standard 2024-T3 Al alloy grade (ASTM B209). Hardness of fracture and unfracture arm of flap are ~75 HV and ~70 HV respectively. The failure of the arm of flap was initially through fatigue crack growth. Beach marks were evident over the fracture surface (Figure 28). The rest of the fracture surface carried the overload. Crack initiation location revealed the presence of a substantial quantity of oxygen and chlorine along with Ca, S, and Ba came from the saline environment. These dent mark/ rough surface at near the fracture encouraged local corrosion attack, which initiates the fatigue crack nucleation and growth. The crack moved over the surface with time and reached a critical length, at which the load bearing ability of arm of flap was reduced drastically. Therefore, the rest of the component failed due to overload fracture. The overload fracture zone contained the characteristics of cleavage indicating limited ductility. Therefore, a primary cause of the failure was the localized corrosion attack followed by fatigue crack initiation and growth, which led to fracture of inner rocker arm of flap. Impact marks on both arms were secondary in nature.



Figure 27: The photographs of as received fractured flap component (a) Full view of fractured arm and impact marks of flap and fracture indicated by an arrows, (b) View of fracture and impact of fracture of flap, (c) Close view of fracture in arm of flap indicated by an arrow.

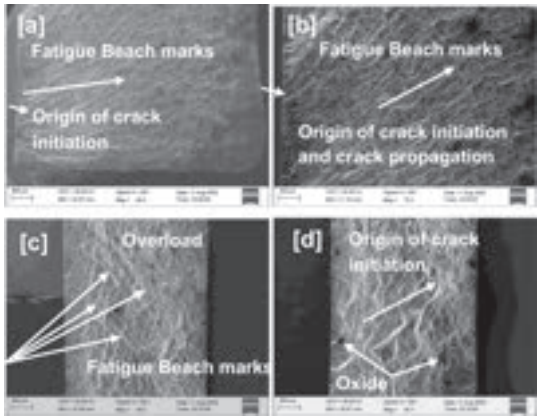


Figure 28: Fractographic analysis of fractured arm of flap revealing (a) Overall appearance of crack initiation location and showing fatigue beach marks, (b, c) enlarged view of the area through which crack propagated, (d) Showing corrosion product entering from surface entering to material.

The project aimed for the metallurgical failure investigation of Inner Rocker Arm of Flap No. 05 (RH) at starboard upper air intake of MiG-29. The following key findings were drawn from the failure investigation: Bulk chemical composition of fracture arm and un-damaged arm of flap was equivalent to the specification of AA 2024-T3 Al alloy. In this respect Cu, Mn and Fe content displayed significant deviation with respect to equivalent specification. The microstructure of arm of flap material consisted of α-Al matrix with polygonal grain structure. Microstructure contained intermetallic phases like Al_2Cu (θ-phase), Al_2CuMg (θ-phase) and Mg_2Si. The size distribution of precipitates was highly assorted in both specimens. The distribution pattern was also heterogeneous like a few locations qualitatively density was very high and at some other location their presence was scanty. The tensile properties of arm material of flap were

considerably lower with respect to designated equivalent standard of 2024-T3 Al alloy grade (ASTM B209), perhaps owing to embrittlement by oxide particles and large second phases. Bulk hardness of the investigated component did not exhibit much variation with respect to specification. Primarily the component failed due to fatigue. Fatigue crack was initiated near open surface containing high density of oxides a/ large size second phases. During service under differential loading, the crack propagated creating the signature of beach mark. The crack propagation was accelerated by the presence of oxides over fracture surface. When the crack attained a critical length, rest of the component failed owing to overload, manifesting dimple fracture. The identification of root cause of failure and recommendation will prevent occurrence of such failure. To prevent dent mark/ impact mark/ corrosion pit on outer surface of inner rocker arm in future non-occurrences.

Destructive test and analysis for establishing life estimation matrix (lem) of vikramaditya boiler tubes

The project aimed to establish a correlation chart between the thickness of the boiler tubes and the remnant safe exploitable life of sample Russian Boiler tubes for the Indian Navy in order to assess the residual life of the boiler tubes based on the rate of degradation of tubes in service. The aforementioned chart will aid in forecasting the following downtime of the Russian boilers for replacement of tubes on culmination of their safe exploitable life. The present case deals with formulation of a Life Estimation (LEM) for boiler tubes of Russian origin wherein the Russian OEM has recommended estimated life of boiler tubes for fixed numbers of steaming hours. The recommendation needs to be reassured since a vast difference exists in the operating conditions of boilers in Russia and Indian Ocean region. Under the project, the LEM is constructed and underlying methodology has been shared with Indian Navy. Also, a significant material database was generated for mechanical behaviour of the material, which was earlier not available. This work has resulted in maximum utilisation of boiler tubes and thereby saved the revenue by mitigating import of the tubes. Now it is easier to make accurate prediction of re-tubing duration therefore the utilisation time of the vessel may be increased.



Team MTE

Metal Extraction and Recycling

Metal Extraction and Recycling (MER) Division carries out basic research, technology development and provide industrial solutions in its core competence areas. The division has its expertise in the area of ferrous and nonferrous metals, value addition and value extraction from various secondary's and industrial wastes. The division is well equipped with lab scale to pilot scale experimental facilities. The division consists of three major groups, namely, Ferrous Process, Nonferrous Process, and Secondary and Resources Utilization. The Ferrous Processing group is primarily involved in process advancement in agglomeration and utilization of iron ore fines and ferruginous wastes of steel plant, and preparation as well as quality improvement of different ferro-alloys. The Non Ferrous Process group is actively pursuing research activities in harnessing secondary and lean grade resources for extraction of nonferrous metal values in either elemental form or as useful compounds and extraction of strategic metals for specialty applications. The activities in Secondary and Resources Utilization group is directed towards use of secondary for rare earth extraction and value addition to all types of industrial wastes by converting them to products for a variety of applications such as refractory, construction materials and cementitious products. This division has chart out its future research planning that are important for national economy, strategic sector, mobility, and infrastructure. These include technology establishment for the extraction of critical metals including REE from secondary resources, development of hybrid materials for specialty applications, use of geopolymer matrix for immobilization of low level radioactive wastes and others.

Recycling of wastes

Process technology for the recycling of waste c-Si PV modules

This project aims to devise a holistic approach for the solar PV waste recycling involving both the aspects of metal recovery and glass utilization into suitable products. The EOL solar PV cells are subjected to disassembly and downsizing to separate the crystalline silicon fraction and glass by removing EVA. The ground crystalline fraction is utilized for the dissolution of metallic values in aqueous leaching. The parameters have been optimized for the quantitative leaching of silver and aluminium. A multi-metal leach liquor has been successfully obtained after separation of silicon. Quantitative separation of silver with 95% purity and separation of aluminium has been achieved from the multi-metal leach liquor. The optimization of parameters to increase the purity of metallic values during the purification process is ongoing. Another aspect of the project aims to use the glass fraction into glass ceramic products with suitable applications. Based upon the thermal analysis of glass, the sintering temperature range for glass was selected, so as to produce glass ceramics. The selected formulations and the sintering temperature satisfied the requirement of the compressive strength of glass ceramics to comply with ASTM C 1272 standard specifications for heavy vehicular paving brick. Detailed characterization studies and mechanical property assessment of the glass ceramics has been carried out. Structure-property correlation in glass ceramics illustrate that the compressive strength is mainly influenced by the crystallinity developed in the products at different temperatures. Glass ceramic products with enhanced mechanical strength demonstrate a dense and well-sintered microstructure. Physical property assessment of the products is ongoing. A proper recycling technique not only reduces the effects caused by the waste but also recovers the valuables for circular economy. The proposed technology will be very much useful to solar PV along with allied industries and will manifest new market potential from the recycled disintegrated components through reuse. The data and results will also help in the formulation of solar PV waste management policy at national level. This technology will significantly reduce the biggest problem of amount of waste PV panels being dumped into landfills.

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

This project is funded by the Waste Management Division of DST, and executed in the close knit association of IISER-Tirupati, CSIR-NML Jamshedpur and Industrial Partner. The project is based on the objectives of recovery and purification of graphite from spent LIB followed by production of high energy and power LIC (>150 Wh kg^{-1}). The high pure graphite synthesised at CSIR-NML has been submitted to IISER, Tirupati for trials. The analysis of graphite shows >95% purity on chemical analysis basis and >99% on SEM mapping. The recovered graphite was mixed with TiO_2 for fabrication of electrode-cum-cell and tested for electrochemical performance. The AC/TiO2 at 5%RG LIC delivered a maximum energy density of ≈50 Wh kg^{-1} at a power of ≈352Wkg^{-1} at an ambient temperature conditions with a capacity retention of over 90% after 1000 cycles. Figure 1 shows the 1st and 100th cycle discharge capacities of TiO2 at RG and TiO2 at AB at different % composition.

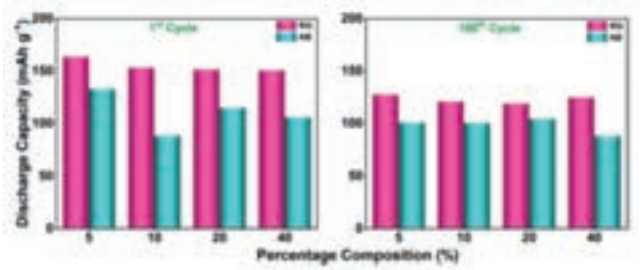


Figure 1: The 1st and 100th cycle discharge capacities of TiO2 at RG and TiO2 at AB at different % composition, RG: Recovered Graphite & AB: Acetylene Black.

Recovery of Rare Earths/ Metals

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

It is to be highlighted that as per Global E-waste Monitor 2024, 42 lakh ton of e-waste generated in India currently where ~3% of the component corresponds to spent NdFeB Magnets. The project aims to extraction of rare earth elements like Nd, Pr, Ce and Dy as oxides/salts via combination of pyro and hydrometallurgical routes from spent NdFeB magnets from various sources of e-waste. The developed technology is shown in Figure 2 which helps to reclaim the rare earth metals from spent magnets to ensure the circularity of the supplied material. Currently, two process patents have been filed by CSIR-NML. In addition, ~35 lacs of funding for the process validation was acquired from TATA STEEL to validate the process using different sources of spent NdFeB magnets. In the current market, total demand of Nd –Pr oxide corresponds to 8000 TPA and expected to rise to 30000T by 2030. In this respect, the developed technology will have major role to ensure circularity of Nd-Pr oxide through spent magnets.

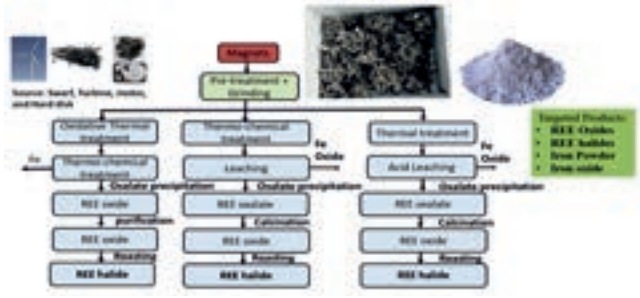


Figure 2: Process flow sheet for recovery of rare earth elements like Nd, Pr, Ce and Dy as oxides/salts from spent NdFeB magnets from various sources of e-waste.

Filling the gap in silver recovery process

The sponsor approached CSIR-NML, Jamshedpur, with a problem statement regarding silver recovery fluctuations (between 95% to 99%) during the processing of raw material to final products at their Metal Plant in Uttarakhand. To address this problem a visit to their silver plant at was performed to observe and analyze the complete process chain of silver recovery from raw material collection system to storage of final products. Based on the observation and subsequent discussion with the personnel present at the plant, a list of necessary activities to be carried out by CSIR-NML has been finalized which includes detailed characterization and material balance for each unit operation/process followed by theoretical analysis of various unit operations and processes by thermodynamic tools to formalize a standard operating procedure (SOP) for metal accounting with respect to silver(Ag). The project will assist the sponsor in properly accounting for silver during raw material processing till final products are produced at the industry, as well as in taking the necessary measures to achieve the goal of consistent recovery and increased profitability.

A process for the recovery of copper powder and tungsten-oxide powder from hard tungsten-copper composite scrap by selective electrodeposition and oxidation process

The present work relates to a process for producing copper and tungsten oxide powder from hard tungsten-copper (W-Cu) composite scrap, utilizing selective electrodeposition and oxidation processes. The selective electrodeposition process is employed to recover copper powder from the hard W-Cu composite scrap in an appropriate electrolyte solution. This work is beneficial for selectively recovering copper (Cu) powder from hard W-Cu composite scrap housed in the anode support cylindrical system. In this system, the hard W-Cu composite scrap pieces in contact with a graphite rod are used as the anode, while a titanium plate serves as the cathode. Copper powder is deposited through a selective electrodeposition process in the electrolyte solution. Further, the residual sample containing tungsten values remaining in the sample is then recovered as tungsten oxide powder through a subsequent oxidation process using air.

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

The project sponsored by MoS was undertaken in collaboration with BITS Pilani and Industrial Partner. Having continuous operation, the pickling activity decreases with increasing dissolved metal concentration and 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, it

incurs huge loss of revenue. Therefore, the main objectives are (i) to develop a flow-sheet for recovery of Ni, Cr, Mn from spent stainless steel pickling liquor in the form of saleable products (ii) fixing of toxic component of process residue and assessment of environmental impact using Lfe Cycle Assessment. Both SS spent liquor and sludge sample collected Jindal Stainless Ltd. and characterized. Iron in the pickle liquor is about 80% of the total metallic content and create difficulty during recovery valuable metal. A two-way approach was explored to remove iron from pickle liquor for easy recovery of Ni and Cr. A selective precipitation method is optimized to produce hydroxide/oxide sludge with high Cr:Fe ratio which can further be smelted to produce Fe-Cr alloy. Selective removal of iron by solvent extraction is also carried out to enrich Ni and Cr through continuous recycling iron depleted liquor. More than 98% iron could be removed under optimised condition without co-extraction of Ni and Cr.

Holistic Utilization of Zinc Dross for Recovery of High Value Zinc Products

This project aimed to recover zinc as value- added products from zinc dross, a waste product from galvanizing industry. The targeted products were zinc sulfate monohydrate, zinc metal, zinc metal powder, and zinc oxide. The project dealt with the scale-up of the developed process at 20 kg scale is shown in Figure 3, and the proposed scale was validated using commercial-grade chemicals. The developed process has been licensed to an industry and the trails at Industrial scale have been planned at 20,000 L facility at 1TPD scale. The project met the proposed deliverable, and further attempts are underway to scale the process at 5TPD with a couple of industry partners.



Figure 3: Process flowsheet for recovery of Zinc products from Zinc dross.

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

Copper slag is a waste produced from copper manufacturing through the pyrometallurgical process. Globally, each ton of copper metal production generates about 2.2-3.0 tons of slag, which is estimated at approximately 40 million tons of slag generation annually. India is generating about 1.7 million tons of copper slag annually. A significantly minimal percentage is utilized for low-end applications and rest is mostly dumped, thus occupying large space for a longer duration. Till date, this slag has been mostly utilized as aggregates in road construction and concrete, mine backfilling, etc. Few studies highlight to use as supplementary cementitious materials after granulating the molten slag by water quenching. However, its high iron content (~35-60%) and lack of suitable oxide components limit its utilization into blended cement. Therefore, a process that can address both the recovery of high iron value at the molten stage and modify the resulting slag by adjusting chemical composition for subsequent use in blended cement.

The carbothermic reduction smelting of the copper slag by using carbonaceous material, metallurgical coke is carried out to remove Fe from the FeO-SiO_2-(Al_2O_3) slag vis-a-vis modify the liquid slag composition using lime (CaO) to create CaO-SiO_2-(Al_2O_3), which can be a suitable component for blended cement. The raw or pre-calcined limestone is used as a flux. The smelting of the charge mixture is carried out into a 50kVA electric arc furnace at 1500-1600°C temperature and reduced the FeO content into pig iron, which accumulated at the bottom due to inherent high density and finally tapped from the bottom. The chemical composition of extracted metal was 94-96% Fe, 3.5-5% C, and Si 0.5-2%, which can find application in general usage similar to cast iron. The resulting slag is tapped and water quenched in an indigenously developed granulation tank to get a high reactive glassy material. This modified slag after granulation is grinded and mixed with clinker and tested for Portland slag cement composition. The cement properties of different basicity slags are studied thoroughly. Slag cement using 40% modified slag of 1.0 basicity of both HCL and BC meets the necessary Indian standard (IS) for Portland slag cement (PSC). TCLP test of the cement mortar samples are carried out. The results are satisfactory and meets the obligatory specification. The physical properties of the mortar samples are meeting the Indian standard IS4031:1988.

Recovery of Metal Values from Mining and Steel Plant Wastes

In the present R &D activity, it is envisaged to develop a process for recovery of metal value from mining and steel plant waste such as iron ore slime, iron ore fines, BF sludge, LD sludge, and mill scale. It has been planned to carry out

project in two stages: 1. Laboratory scale investigation (1-5 kg scale) which involves fundamental investigation on preparation of suitable agglomerates (hollow cylinder) without pre-processing of iron ore slime, iron ore fines, BF sludge and LD sludge and its solid state reduction with lean grade non-coking coal in electrically heated furnace simulating tunnel kiln condition, reduction kinetics studies of prepared agglomerates (hollow cylinder) and optimisation of process parameters. 2. Pilot plant trials (15-18 TPD) which will involve (a) Validation of laboratory scale findings through plant trails in commercial tunnel kiln furnace, (b) Fine tuning of process parameter in commercial tunnel kiln furnace, (c) Production of 100 T of directly reduced iron cylinder with high degree of metallization, (d) Melting behaviour of directly reduced iron cylinder in commercial induction furnace (5-10 ton) and (e) Development of technology. In view of the above, required raw material has been procured and characterized for their physical and chemical properties. Design of experiments is carried out for blending of raw materials in different ratio to obtain the optimum Fe contents. Hollow cylindrical preformed/ agglomerates of different diameter are prepared for solid state reduction in laboratory scale muffle furnace simulating tunnel kiln condition. Reduction kinetics study of the hollow cylindrical preformed is in progress. Detailed characterization of reduced DRI cylinder will be carried out to achieve the metal value. Process parameters will be optimized for optimum recovery of metallic value. Based on the laboratory scale investigation, pilot plant trials will be conducted in a commercial tunnel kiln in 5-6 tpd scale. Fine tuning of the process parameters will be carried out to obtain optimum metallic yield in the commercial production. After fine tuning of the process parameters in commercial tunnel kiln, continuous production at the rate of 15 -18 TPD will be carried out to ascertain the techno economy of the process. The produced DRI cylinder will be melted in 5 to 8 tons induction furnace to establish comparative yield, power consumption, tap to tap time etc. The DRI cylinder thus produced will be suitable as a substitute of scrap for iron and steel making in IF, EAF and BOF. Patents will be filed and DPR will be prepared for transfer of technology to user industries.

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

This project intends to up-scale the lab scale process for the production of potash fertilizer and iron oxide from Indian glauconitic rocks up to pilot scale level (10-20 kg) for better assessment of techno-economic feasibility. Glauconite is a naturally occurring group of dioctahedral, potassium, iron-rich micaceous clay mineral of marine origin with very low weathering resistant and easily available at surface to sub-surface level. The structure of glauconite consists of dioctahedral T-O-T (Tetrahedral-Octahedral-Tetrahedral) sheets. Potassium and iron were the part of this stable alumina-silicate T-O-T matrix. The biggest challenge in order to utilize glauconite is to break the alumina-silicate structure to recover potassium from this matrix in an economical and eco-friendly way. Along with potassium, iron is also considered as valuable element present in the glauconite. The previously studied and reported processes use high concentration of acid, high solid to alkali ratio, hazardous salts such as fluorides, chlorides etc. to achieve high dissolution of potassium only. For one reason or another, mainly due to availability of highly soluble potash salt of marine origin and process economics, none of these processes has been commercially successful. A careful study of these attempts warrants the statement that solution of this problem depends entirely upon simultaneous recovery of high value by-products along with low value potash.

The process developed at lab scale is economic, environment friendly and sustainable in comparison to earlier developed processes. From the overall composition of glauconite and basic structure analysis it is evident that iron is only the week link present in the complex structure of glauconite. It can easily change its oxidation number under different oxidizing and reducing atmosphere thus can break the matrix easily during its conversion to form different species. Therefore, subsequent attempt was made to break the structure by reduction roasting and redox roasting of glauconite before acid dissolution to recover maximum potassium values. The process uses very mild acid for its dissolution that make process cleaner. This process had added advantage of simultaneous recovery of iron oxides along with the recovery of potash fertilizer. The overall research showed that the recovery of potassium is more than 98% and recovered in the form of soluble salts along with valuable by-product in the form of nano-sized iron oxide particles.

Ore Beneficiation

Feasibility study on reduction of Manganese ores using sulphur

The study explores the feasibility of using sulphur as an alternate reductant for manganese ore reduction. Sulphur offers several advantages, including energy efficiency, cost savings, and reduced emissions. It can reduce MnO_2 ores at lower temperatures than current alternatives, and value-added products like sulphuric acid can be produced from the gases generated during reactions. Additionally, the conversion of MnO_2 to MnO occurs during pre-reduction,

reducing the carbon requirement for further smelting operations. The optimal pre-reduction temperature is 800 °C, with a holding time of 4 hours at 0.5 S/Mn ratio. The project will help to reduce carbon footprint in the ferro manganese production along with production of sulphuric acid as a byproduct. Figure 4 shows the Mn Ore pre reduced to MnO & by product – sulphuric acid.



Figure 4: Mn Ore pre reduced to MnO & by product – sulphuric acid.

Thermodynamics and kinetic investigation on the gas-solid reduction of premixed lean grade Mn/Fe Ores

This project intends to investigate the feasibility study about thermodynamics and kinetics for lean grade manganese /iron ore in the form of pre-mixed condition at the presence of hydrogen gas as gas-solid reduction. Using low-grade manganese-iron ore, which is used as a substitute of high-grade ores in the present study. Replacing carbon with hydrogen as a reductant offers a pathway to reduce carbon footprint. The pre-reduction temperature reduces due to using hydrogen gas and generate minimum amount of H_2O as a product. The gas-solid reduction of manganese ore is performed in a horizontal tube furnace at a range of 700-900ºC. The process uses very less hydrogen (gm) for its reduction and produce H_2O as a by-product that makes process cleaner. The overall research showed that the reduction of manganese/iron oxide is more than 90% and negligible harm by-product. The process parameter and kinetic study has been optimized. The final product of this process is ferromanganese, which is used as degasser, deoxidizer, and desulphurizer in steel production, removes nitrogen and other hazardous elements that are found during iron melting.

Calcined colemanite / calcined ulexite addition in pelletizing hematite ore to develop pellet for using in blast furnace

Colemanite and ulexite are two boron-containing minerals wherein B_2O_3 contents are approximately 45% with other gangue minerals viz. CaO, MgO, SiO_2 Al_2O_3, etc. The feasibility of their use in hematite ore pelletizing is studied in this investigation. These materials were added after calcination. Although the green pellet strength has not been found to improve for this addition, indurated pellet strength has been improved. Colemanite shows better performance in pellet than ulexite. 0.4% colemanite addition in either basic or acidic conditions showed an appreciable increase in cold crushing strength (CCS) and a good decrease in reduction degradation index (RDI) in the presence of bentonite binder. For ulexite, up to 0.3% addition in the pellet was advantageous only in basic conditions. However, for either colemanite or ulexite addition, RI decreases and the swelling index increases to a small extent. In the acidic condition, ulexite addition is not at all advisable because of a severe decrease in reducibility index (RI). The use of colemanite and ulexite also can reduce the induration temperature of around 25-50 °C; i.e. it may reduce the power consumption in the induration of pellets. Thus, 0.4% colemanite (in basic and acidic pellets) or 0.3% ulexite (in basic pellets) can be used in hematite pellets as there are several advantages in CCS, RDI, and induration temperatures. As obtained RI and swelling index (SI) are within the tolerable limit, their (RI and SI) small deterioration due to these additions in pellets may require to be compromised to get other benefits of improved CCS, RDI, and induration temperature. The actual performance of colemanite/ulexite-added pellets needs to be examined in a blast furnace.

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

This project is aimed to scale up the vacuum distillation process at 5-6 kg scale from the developments achieved in earlier activity at 1 kg scale. The activities involved are to refine the commercial magnesium (99.80% purity) to ultra-high Magnesium (>99.95% Mg , Fe &Al < 40 ppm) and recovery of high pre Mg from Mg alloys/scraps. Towards scaling up the process, an equipment “Semi-Continuous Mg Distillation” is designed with facility to charge Mg feed intermittently, which will be melted in upper crucible and the liquid feed will fall into the bottom vaporization crucible. It is basically a two zone heating system with vacuum retort and accessories to monitor and control. This facility will be integrated with existing condenser-vacuum controls to carry on experiments at targeted scale of 5-6 kg. In parallel, 06 nos. of campaigns at 1.5 kg feed scale had been conducted with two kind of Mg scraps, namely gear box (91% Mg, 7-8% Al) and aeronautical scraps (94% Mg, 5% Al). 01 campaign is conducted with commercial magnesium (99.8%, 940 ppm Fe, 240 ppm Al). Predetermined process conditions

(achieved in prior stage) i.e. 950-1000 °C boiling, 5-12 mbra vacuum, connector temperature >920 °C and condenser temperature 300-600°C, experimental campaigns were used to carry out experiments. Magnesium is collected at thick and thick dendrites, droplets and ingot form. About 100% Mg is recovered with a distillation rate of 1 kg/hr in the present system. The single stage distilled-recycled Mg purity is 99.9-99.95%. Fe content is under control, whereas the Aluminium content is found to be ~60 ppm. The residual Al and other components are reported as greyish powder form. Studies are ongoing to do SEM/XRD analysis of products. Second stage distillation will be done to study the Aluminium content variation in final ingot/product. For the analysis, standards, glassware and chemicals were procured, whereas graphite based waiting parts and consumable were fabricated to conduct trails. The outcomes of this project may lead establish strategic technologies for high pure Mg from titanium and zirconium programs for DAE and ISRO. The recycling of Mg scrap may be helpful in greener ways for Mg metal towards strengthening Indian economy and "Atmanirbhar Bharat".

Carbon Capture

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

The objectives of the project are: (a) Selective CO_2 absorption and mineral carbonation experiments using aqueous formulated amine solvents and steel plant slags respectively, in order to understand the fundamentals that affect the CC and MC processes, (b) Generate quantified data on thermo-physical properties of formulated amine properties with vapor-liquid equilibrium and reaction kinetics data in industrial flue gas P-T conditions for best CC process and simultaneous reaction condition and capacity for carbonation reactions in MC process, at RKDF and NML. (c) Comparative optimization and assessment in 10kg scale of absorption and adsorption process using amine solvent and amine impregnated on a suitable substrate. (d) Optimization of factors and load for sequestration of CO_2 in steel/ferroalloy slag and other matrices, and (e) Assessment of the waste heat and optimization of parameters for its recovery. First phase experimental trial run of onsite dynamic CO_2 absorption using aqueous amine solvents is completed at pilot plant facility at RKDF University Bhopal. (Figure:5) Bench scale mineral CO_2 sequestration study using mineral waste of steel industry is ongoing at CSIR-NML facility (Figure 6). Presented work progress in 2nd Monitoring committee meeting at NCL-Pune on 22nd Feb,'24. First phase Pilot Scale trial run with 100 Lit each of two different aqueous amine solvents for selective CO_2 absorption is successful at RKDF University facility under CSIR-RKDF umbrella MOU.



Figure 5: Carbon capture pilot plant at CSIR-RKDF

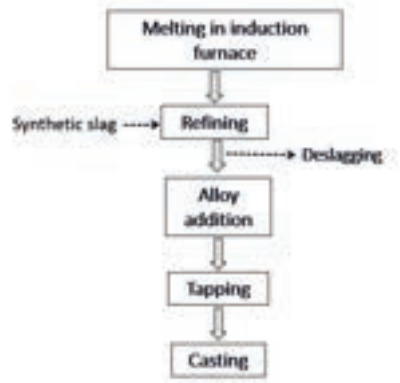


Figure 6: Solid and porous block at CSIR-NML



Team MER

Mineral Processing

Mineral Processing (MNP) Division comprises three major research areas. They are Mineral Characterization, Beneficiation, and Agglomeration towards the exploitation of low-grade ores and minerals, processing of slimes, mines waste, etc. The division has the state of art laboratory facilities for characterization, bench and pilot scale beneficiation. The main research focus of this division are: Development of process flowsheet for ores, minerals, low-grade ores and coals; Dry beneficiation of various Coal, Minerals, and Ores; Beneficiation of critical and strategic; minerals from primary and secondary sources; Design and development of mineral processing equipment; Physical modeling for particulate flow Simulation and Modeling; Plant auditing to improve the performance of the existing plants; Based on the know-how provided by CSIR-NML, a number of commercial beneficiation and agglomeration plants have been commissioned in the public and private sectors. It has contributed significantly to the development of mineral-based industries. In addition to catering to the needs of the mineral processing industry in India, it has maintained a strong international presence and successfully executed a large number of projects on samples of foreign origin from countries like Bhutan, Egypt, Syria, Sri Lanka, Sweden, Australia, Canada, Mali, Morocco, South Korea, Nepal, Zambia, UAE, Malaysia, Indonesia, Ukraine, Verma, Philippines, Oman, Uganda, Kazakhstan, Thailand, Ethiopia, etc.

Effective Utilization of Middlings and Fines of Coking Coal Washery for Recovery of Carbon Values

This collaborative R&D project was undertaken for the effective Utilization of Middlings and Fines of Coking Coal Washery for recovery of carbon values. Coking coal is a scarce commodity in India. Its reserve is about 9.7% of the total reserves of 361.411 Billion tonnes (as of 01-04-2022). The demand for coking coal in the steel sector is increasing gradually due to the expansion of existing steel plants and the addition of Greenfield projects in the country. Meeting the demand of quality coking coal for steel plants is a great challenge. Indian coking coals are characterized by high ash owing to their drift origin. The coking properties of indigenous coals are considerably inferior. Only 15% of India's coking coal requirements are met through indigenous supply. Therefore, to meet the desired grade of coking coal for blast furnace coke, imported coking coals are blended with indigenous coal. India imported 57.16 million tonnes of coking coal in FY22-23.

The quality of coking coal is deteriorating day-by-day due to the depletion of the reserves of a good grade. Usually, three types of products– clean coal, middling and reject are obtained from the Indian coking coal washeries. The generation of middling progressively increases because of the gradual depletion of the high-grade raw coal. As a result, the yield of clean coal decreases substantially with the increase of middlings. Presently, these middlings generated from the coking coal washeries are used for the power plant. It contains a good amount of carbon values which could be recovered. In view of the conservation and scarcity of coking coal reserves in the nation, it could be an excellent potential source of coking coal. The low ash coking coal can be produced from this washery middlings by suitable beneficiation processes.

Keeping in view of the above, the present investigation is undertaken in collaboration with Coal India Ltd. to develop a suitable process for gainful utilization of the middlings of the coking coal washeries towards the enhancement of the carbon recovery for coke making. In the proposed R&D studies, two middling samples of different characteristics were collected from coking coal washeries of CIL for the project work. These middling samples are also called Washed power coal as they are used for thermal power plants. The detailed characterization of the middling samples, washability, and wet beneficiation using gravity and flotation techniques were used towards the development of a process flowsheet for the recovery of carbon values from the middling samples.

Washability studies were carried out for different top sizes of the crushed samples of as-received middling samples, viz. -6mm, -3mm and -1mm. From the results, the -1mm top size of feed was selected for the beneficiation study. Beneficiation studies were carried

out using the Wilfley Shaking table to understand the response to gravity separation. A spiral concentrator was used to replicate the tabling results for the -1+0.15mm feed size. Column flotation studies were carried out for -0.15mm size fraction. Column flotation tests were carried out under different conditions using diesel oil as a collector, and two different frothers, namely MIBC and Nalco frother. The performance of two frothers was compared, and MIBC was found to be better than the Nalco frother with respect to yield and ash of the products. The flotation concentrate obtained from column flotation studies is 10.5% by weight with 17.48% ash and tailing contains 38.43% ash. Simple process flowsheets were developed to produce the low-ash product. The total weight of the beneficiated washed product (concentrate) from the first middling sample was 22.2% with 18.46% ash and the gross calorific value of the beneficiated product was 6989.5 kcal/kg (Figure 1). The second sample was inferior in nature. Therefore, the yield of the washed product was 12.1% with 18.57% ash content and the gross calorific value of the beneficiated product was 6386.6 kcal/kg

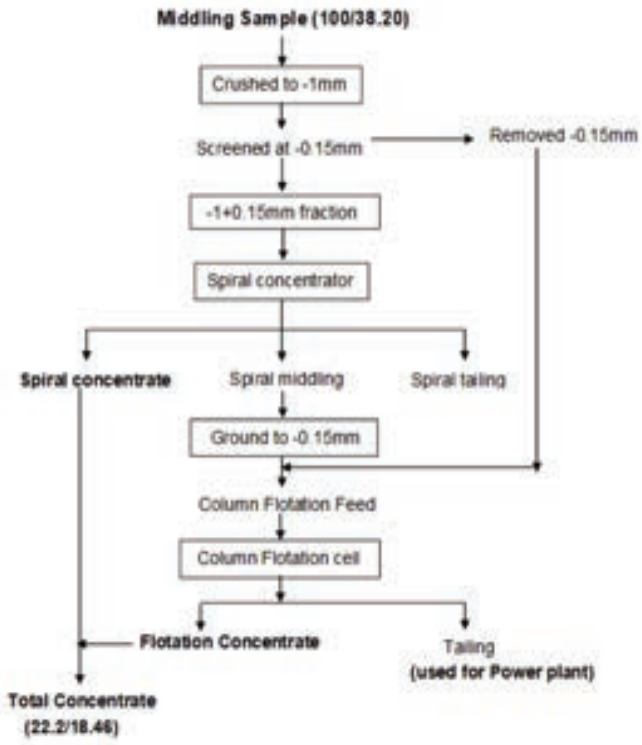


Figure 1: Process Flowsheet Developed by Involving Spiral Concentrator and Column Flotation Cell.



Figure 2: Process Flowsheet Involving Dry and Wet Processing of Coking Coal Middling Sample.

Processing of High Ash & High Sulphur Containing Lignite Coal

Lignite samples containing high Sulphur and ash were studied for carrying out the detailed characterization and dry processing for lowering the ash and sulphur content in the product. Samples from different seams were individually characterized with respect to Proximate analysis, Ultimate analysis, Calorific value, Hardgrove Grindability Index, Tumbler Index, Abrasion Index, Shatter test, and particle size distribution in as-received lignite samples. The Composite Lignite sample was prepared by mixing different seam samples in equal proportions. The detailed characterization and physical properties of the composite sample were studied. From the washability study of the Composite sample, it was found that the yield could be 95% at the ash level of 17%.

Composite Lignite sample was processed by a dry method using a dry high-intensity magnetic separator (DHIMS), and FGX-dry coal separator for different feed sizes. As the -150+50 mm fraction of the composite sample contains 14.79% ash, it did not require any processing and could be used directly as a product. The fraction -50mm contains 19.3% ash and was subjected to dry processing using DHIMS and FGX-dry coal separators for lower the ash level to 17%. Based on the results of dry processing studies of composite lignite samples, different process schemes were developed. The product yield of 84.8% with 16.6% ash and 3.79% Sulphur could be achieved using FGX- FGX-dry separator.

Performance Improvement of Coking Coal Washery Through Simulation Analysis

In the present work, modeling and simulation analysis of the existing Moonidih washery of BCCL was undertaken in collaboration with CMPDI to improve its performance. In order to predict the optimum operating parameters, a simulation-based approach was applied during the entire project. Samples were collected from different streams of the washery while conducting the project work and were analyzed for size distribution, percent solid, and ash% content. This is followed by an analysis of the data quality by mass balancing and model fitting. A mathematical model of the plant was constructed by using the balanced data set. The final step in the project work was to conduct simulation analysis and report the results which include clean coal yield, clean coal ash%, model parameters, and expected bottlenecks. Simulation analysis indicates that the -1 mm fraction in the secondary crusher product can be taken directly as a product using a dewatering screen. Also, an operating cut density in the range of 1.58-1.62 is required to achieve the product with 17% ash from the feed coal having 28-32% ash (Figure 3). Similarly, predicted cut density is in the range of 1.68-1.72 for coal with ash content of 26-28% in feed. With the help of simulation, the product yield was benchmarked, which is 50% for high ash content feed coal (28-32%) and 70% for low ash content feed coal sample (26-28%).

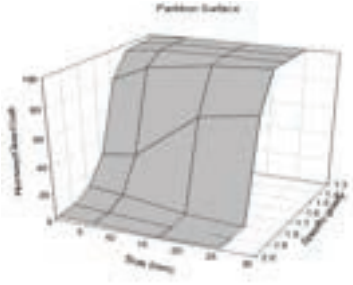


Figure 3: Size-wise Partition Curve

Flowsheet Development to Set Up a Commercial Plant for Meghnagar Rock Phosphate Ore

To generate the basic engineering data for setting up a commercial plant for the Meghnagar rock phosphate, grinding, and flotation test works were undertaken at CSIR-NML. The ROM sample contained 15.84% P_2O_5, 14.42% SiO_2, 9.38% MgO, 34.57% CaO, and 0.20% Fluoride which was upgraded to 26.90% P_2O_5 with 48.70% recovery. The SiO_2 content in the concentrate was also reduced to 6%. The flowsheet mainly includes grinding of the ore to 80% passing 63 micron followed by a combination of direct and reverse flotation. Sodium silicates, sodium oleates, and orthophosphoric acids are used as depressants, collectors, and pH modifiers. The results obtained in open cycle flotation tests were also confirmed by conducting locked cycle tests. The major outcomes include the development of a beneficiation flowsheet, solid and water balance, prediction of mill powers, and estimation of recirculation load for both grinding and flotation circuits.

Processing of Lead Concentrate towards Improving its Quality by Reducing Graphitic Carbon in the Concentrate

Lead-Zinc ore concentrators operating at various locations in the state of Rajasthan involves size reduction, flotation for separation of lead and zinc concentrate followed by dewatering of products generated during flotation. It was observed that graphitic carbon present in the ore floats naturally and reports to lead concentrate, deteriorating its quality and also creating problems in the downstream metal extraction process. In view of this, studies were carried out at CSIR-NML to explore the possibility of reducing the graphitic carbon in lead concentrate via two different routes i.e. desliming and enhanced gravity separation. The lead concentrate from Rampura Agucha (RA) mines was selected for the test work. Desliming tests using 1-inch and 2-inch Mozley hydrocyclone and enhanced gravity separation tests with Mozley multi-gravity separator (MGS) were performed at different parameter combinations. The as-received sample (lead concentrate) contained 57.45% Pb and 10.08% graphitic carbon in which 32.43% graphitic carbon was present is less than 7µm fraction. Graphitic carbon rejection was better achieved in Multi Gravity Separator (MGS) compared to desliming hydrocyclone despite having the same cut size of separation. Test results indicate that graphitic carbon content in the lead concentrated could be achieved up to 6.58% with loss of 8.5% lead recovery. Also, 95% of lead misplaced in the product (Tailing) of MGS is in the locked form.

Pilot Scale Oily Bubble Flotation of Coal Fines from West Bokaro

Coal flotation is the widely practiced technique to beneficiate coal fines (-0.5 mm) by diminishing impurities. Coal flotation is a multi-phase, complex operation (particles, oil droplets, and air bubbles). The molecules of a reagent and the dissolved ions in water are two examples of additional species with which these phases simultaneously interact. The outcome of the flotation process is determined by the physical and chemical interactions. The main cause of the selectivity issues in coal flotation could be attributed to non-selective particle aggregation resulting from physical and chemical interactions. It can be addressed by physical (conditioning) or chemical (promoters) pre-treatment before or during flotation.

In the present work, the collector reagent is introduced in the form of vapour along with the air into the flotation cell to enhance the bubble particle attachment as compared to the Conventional flotation technique (Figure 4). Bubble coated with a thin layer of oil will act as a carrier in flotation ensuring a high collecting efficiency. Oil-coated bubble flotation can eliminate the addition of a collector to the aqueous phase. Coal fines (-0.5 mm) samples from two different seams were analyzed and found to compose ash content of 26.7% and 27.4% respectively. Studies were carried out with varied parameters like dosage of collector, frother, and oil bubble on the flotation of coal fines at the pilot scale of 1100 litres per hour feed rate. It was noted that around 13% absolute ash rejection was achieved with a significant yield (Figure 5). The tested process at CSIR-NML has been implemented in West Bokaro Coal Washery.

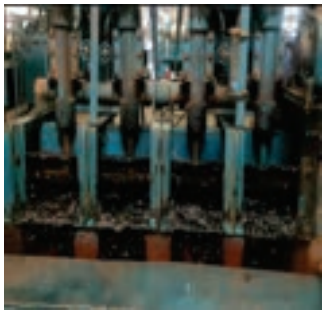


Figure 4: Froth Collection During Pilot Scale Trials

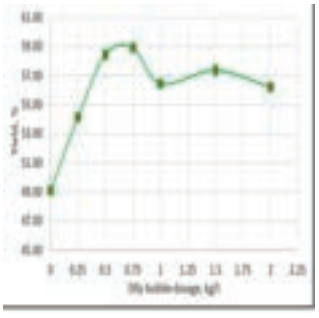


Figure 5: Effect of Reagent Dosage on Clean Coal Yield.

Beneficiation Study of Quarzitic Sand to Produce a Sand Glass Grade

This project was aimed at developing a beneficiation flowsheet for quarzitic sand to produce a sand glass grade. The project was initiated with a comprehensive wet sieve analysis of the sample, providing crucial insights into its granulometry distribution. This set the stage for subsequent investigations, including meticulous single and two-stage grinding studies, magnetic separation experiments, scrubbing studies, and spiral gravity separator studies.

The grinding circuit was optimized to control the fine generation. Around 9% of fine material of below 0.106 mm. generated during grinding. Grounded product was subjected to magnetic separation to reduce the iron content to 0.08% from 0.34%. Further scrubbing was done followed by Spiral concentrate to reduce the heavy mineral content. Based on the comprehensive analysis and studies conducted, two alternative flowsheets were proposed, providing a roadmap for silica sand beneficiation.

The project has made a significant impact on both society and the industry, primarily due to its environmentally friendly approach to the beneficiation of sand. The most notable achievement of the project is its chemical-free approach to sand beneficiation. By avoiding using chemicals, the project has significantly reduced the potential environmental impact associated with chemical waste and pollution. This approach aligns with global efforts towards the sustainable and environmentally friendly industrial practices. The project is completed, marking a significant milestone in the field of sand beneficiation.

Beneficiation of Coking Coal by Hybrid Mode: Dry and Wet Processing to Reduce the Ash Forming Impurities

Coal is one of the primary sources of energy, accounting for about 67% of the total energy consumption in the country. Despite sufficient coal reserves, India is importing low-ash coking and non-coking coal to meet the demand for its industrial production as the availability of high-quality coal (low-ash coal) in the country has been limited. Coal processing is needed to increase thermal efficiencies with an accompanying reduction of CO_2 emissions, to

reduce the erosion rates and maintenance cost for equipment. It is expected that the demand for coking coal will be increased to 65 MT in 2022-23 due to the growth in steel production. The import of coking coal increased to 51.20 MT during 2021-2022. The import cost of coking coal from foreign countries is very high and this causes considerable pressure on the foreign exchange reserve of the country. It has been found that during coal processing, there is a loss of 10 to 20% of the feed and report to the reject stream. The estimated loss of feed from the coking coal washeries is 64% of the total reject generated from the coking and non-coking coal.

In the present investigation, the primary objective is to carry out dry de-shaling to improve the quality of the feed material before subjecting it to wet beneficiation and generating the pre-concentrate. Another objective is to beneficiate the high ash coking coal in combination with dry and wet methods (hybrid mode) to generate the metallurgical coal grade of 14 to 17% ash with maximum yield towards the development of the process flowsheet.

This investigation is envisaged to have a significant impact on the industries as de-shaling and washing of coking coal will lead to a reduction of energy consumption and will increase in the thermal efficiencies along with an accompanying reduction in erosion rates, equipment maintenance cost, etc. With the washing and de-shaling, beneficiated coal will help in the reduction of COx, SOx, etc. emissions, thereby controlling the environmental pollution. It will also significantly decrease the amount of fly ash or bottom ash generated by a power plant.

Dry processing has certain advantages as no process water is required, it prevents the generation of slime water, clean product with higher heat value, and it is environment-friendly and cost-effective. Hybrid mode (dry and wet method) beneficiation of coking coal may be effective in reducing the ash level to a desired level and will help in the reduction of water consumption, as it is a scarce commodity in many places. The developed process flowsheet may have a good impact on the Indian coking coal washeries as well as steel-making Industries.

A Study on Hydrodynamics Characteristics in Separation of Minerals in a Monolithic Flotation Column

Flotation is one of the important and most used mineral processing techniques for beneficiating the finer size, lean grade, and complex ore bodies in the mineral and chemical industries. Many researchers have studied the hydrodynamic characteristics of cylindrical and rectangular flotation columns. It has been reported that there is a considerable degree of back mixing, low interfacial area, short residence time of gas bubbles, channeling, non-homogeneous bubble size and its distribution, uneven flow pattern, and pressure drop in the flotation column. To minimize the effect of these factors, a monolithic flotation column has been fabricated (Figure 6). The present investigation aims to explore the effects of mixing characteristics and separation efficiency analysis by kinetic models in monolithic flotation columns. Mixing characteristics of a flotation process is one of the parameters that determine the particle suspension, fine bubble generation, dispersion, and pulp recirculation. The Residence Time Distribution (RTD) study determines the degree of mixing.

The flotation rate constant determines the floating intensity of particles. The flotation kinetics in column flotation can be studied by analogy to chemical kinetics. The particle collection process in a column is assumed to be a first-order reaction relative to the solids concentration with a flotation rate constant (K_c). Three variables, namely the rate constant (K_c), the mean residence time (τ), and the extent of mixing (N_d, vessel dispersion number) are the main factors for the recovery of the flotation process. All the hydrodynamic characteristics research findings will be useful in eliminating the back mixing, reducing channeling, and providing homogeneous bubble size distribution. Modeling and simulation will also be carried out to validate the experimental findings. The present study aims to explore the effects of mixing characteristics and separation efficiency analysis by kinetic models which will be advantageous in up-scaling the monolithic flotation column.

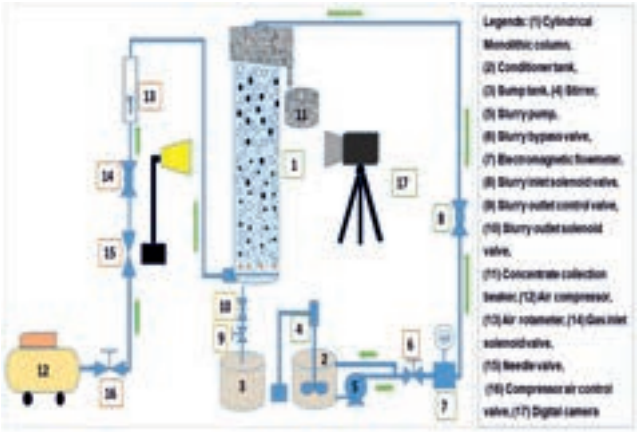


Figure 6: Monolithic Column Set-up Layout

Understanding the occurrence of Rare Earth Elements and Yttrium within coal beds, partings, and overburden

The comprehensive study of the petrology, mineralogy, and geochemistry of trace elements present in coal, partings, and overburden could be beneficial to deduce the channelling path for inferring the economic utilization of the coals or overburden in different sectors other than metallurgy and energy sectors. Considering the Indian coal deposits, although trace elemental characterization studies have already been done with great concern, the extensive mineralogy in addition to the geochemistry of rare earth elements (REE) has not been carried out in detail yet. This in-house exploratory project aims for obtaining the comprehensive knowledge of mineralogy and geochemistry concerning the utilization of coals as alternative resource for trace elements, especially the rare earth elements (REE). The objectives comprise the detailed mineralogical study of coal and shaly coal samples collected from Mand-Raigargh Basin, Chhattisgarh, India. The SEM-EDS analysis of the shaly coal sample has demonstrated the presence of minerals like siderite, ankerite, plagioclase feldspar, clay minerals i.e., illite, kaolinite, rutile, quartz, etc (Figure 7). The presence of certain rare earth minerals like Eu, Sm, and Nd, etc., are witnessed in the given sample. Most of them are present as cation exchange mechanism in siderite or ankerite or feldspar minerals. The project further aims to go for the detailed geochemical study of the coal, and overburden samples like shaly coal, coaly shale, shale, sandstone, etc.

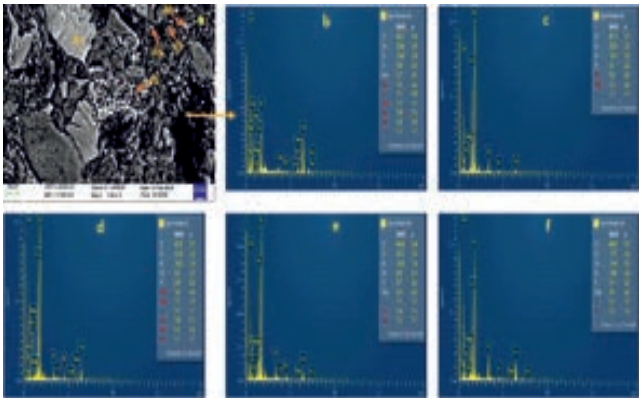


Figure 7: SEM-EDS od Shaly Coal

Development of a Process for the Production of Chromic Oxide from Chromite Beneficiation Plant Tailing

Around 95 % of chrome ore being produced is used by the metallurgical industry primarily for the production of ferrochrome, and the remaining is used in the chemical industries, refractory, and foundry industries. High and medium-grade 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 a loss of chromite value in addition to its adverse impact on the environment. The storage, handling, and processing of fine tailing are also the major concerns of the operating process plants. It has been observed that the fine-grained tailing poses difficulty in processing by conventional physical separation methods and producing a high-grade concentrate with reasonable chromium recovery. In the present study, it is proposed to develop a process for the synthesis of chromic oxide from the chromite beneficiation plant tailings leading to its rational utilization. The process includes two main stages: (a) Pre-concentration of chromite beneficiation plant tailing by advanced physical beneficiation process, (b) Conversion of pre-concentrate product to the chromic oxide by liquid-phase oxidation techniques, involving decomposition of chromite by oxidation followed by separation, filtration, and purification. The research work is on-going.

Feasibility Study on Reduction Roasting of High-Iron Bauxite Ore

The sponsor approached CSIR-National Metallurgical Laboratory to enrich the high-iron bauxite ore for their end utilization in metallurgical industries. It was proposed to carry out the feasibility study on the roasting of high-iron-rich bauxite samples followed by magnetic separation for their enrichment. The sample assayed 26.61 % Al_2O_3 with 44.54% Fe_2O_3, 6.98% SiO_2, 2.83% TiO_2, 16.10% LOI. Detailed mineralogical characterization of as received sample was carried out separately using an optical microscope and XRD. It has been observed that the sample contains mainly gibbsite as the major aluminum hydroxide mineral and goethite as the dominant iron oxy-hydroxide mineral. The received sample was ground to 0.5 mm and laboratory-scale roasting was carried out. The roasted sample was subjected to magnetic separation to separate the magnetic and non-magnetic fractions present in the roasted product (Figure 8). The final product was chemically analysed for assessment of the enrichment process.

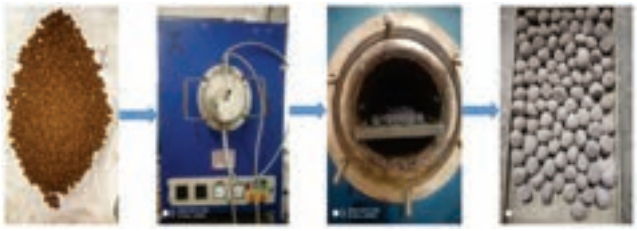


Figure 8: Pictorial view of Reduction Roasting Experimentation

It was noted that Al_2O_3 content is enhanced from around 26% to 46% and Fe_2O_3 from around 44 % to 59%. However, significant amount of iron mineral reported in non-magnetic fraction and alumina mineral reported in magnetic fraction. This happened due to the poor liberation of an as-received sample. It is difficult to improve the recovery of iron and alumina recovery further through the reduction roasting method. Chemical processes may be explored depending on the economic feasibility.



Team MNP

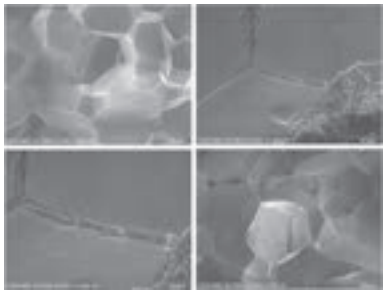
CSIR-NML-Madras Centre

Research and Development activity related to Flotation and Column flotation of different minerals has been the mainstay of CSIR-NML Madras Centre (CSIR-NML - MC) for the past three decades, as flotation accounts for more than fifty percent of the ore/mineral concentrates generated globally. Additionally, materials evaluation activities are also carried out. The research carried out in the reporting year are indicated below.

Failure Investigation of Molybdenum Electrode in Glass Melting Furnace

Molybdenum electrode is considered as potential material for high temperature application. With increase in temperature the Mo began to form oxides of Molybdenum. The magnitude of increase in temperature decides the type of oxide forms on the surface namely molybdenum oxide (MoO), molybdenum dioxide (MoO_2) and Molybdenum trioxide (MoO_3). Generally, MoO_3 destroys the protective oxide layer formed by the MoO and MoO_2 and thereby exposes the fresh molybdenum surface for the oxidation. This continuous process of formation of oxide and subsequent damage by the molybdenum trioxide facilitate the natural corrosion on the molybdenum electrode in glass melting furnace.

An insurance company from Chennai approached CSIR-NML - MC nfor carrying out a comprehensive study on “Failure Investigation of Molybdenum electrode in glass melting furnace” installed at the premises of sponsor's client i.e. a company dealing in breweries and distilleries at Puducherry. Various metallurgical characterisation techniques were used to establish the failure namely Optical microscopy for micro-structural studies, Scanning Electron Microscopy for microstructural analysis and Fractography studies and energy dispersive spectroscopy for surface corrosion deposits analysis. Based on the results obtained on the failed molybdenum electrode were supported with relevant scientific literature. The molybdenum electrode in the glass melting furnace failed mainly due to the intergranular corrosion / grain boundary corrosion resulted by the exposure of Mo electrode material to corroding elements present in the glass melt. Grain boundary corrosion or intergranular corrosion happened due to possible formation of corrosive oxide deposits at the grain boundaries in different combinations which resulted in the grain boundary weakening.



Failure analysis of rollers in slew bearing of GOTTWALD make Harbour Mobile Crane

Bearings are machine elements that enable the low-friction relative motion of a rotative component around a line or a plane. They are also able to accurately position moving parts relative to fixed ones and transmit load. A cyclic stressing of bearing steel can cause microstructural changes, which then have damaging macroscopic consequences on the life of bearings. An insurance company from Tamilnadu approached CSIR-National Metallurgical Laboratory Madras Centre for carrying out a comprehensive study on “Failure Analysis of rollers in slew bearings of GOTTAWALD make Harbour Mobile crane”, which were located at in the premises of an engineering works company at Odisha. Various metallurgical characterisation techniques are used to establish the failure namely Optical microscopy for micro-structural studies, Scanning Electron Microscopy for microstructural analysis and Fractography studies and energy dispersive spectroscopy for surface corrosion deposits analysis. Microstructural studies indicating the pitting on the surface and *Martensite Decay* in the microstructure. A clear presence of a sub-surface crack in elliptical shape originated from the surface of the roller. The propagation of these sub-surface cracks happened by joining of the micro cracks. A clear branching of micro cracks was observed during propagation of sub-surface cracks, hence the initiation of sub-surface crack and its elliptical shape during propagation indicated the operation of *rolling contact fatigue (RCF)* on the roller surface.

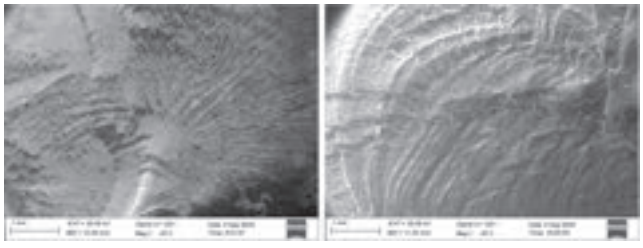


Figure 2: Branching of Sub-surface cracks.

Sustainable technology for the production of high grade synthetic rutile (tio_2) from Orissa Ilmenite WOS

The OSCOM or Orissa ilmenite deposit is formed along the coast is the largest mineral deposit in India with a length of 18 KM and a width of 1.5 KM. This project uses Orissa Ilmenite for its beneficiation study. The project is funded by the Ministry of Science & Technology, DST. Ilmenite is a mineral resource of great importance in light of the production of TiO2 rich pigment. The demand for TiO_2 pigment, a specialty chemical, is increasing rapidly in the paper, plastics, and pigment industries. India's ilmenite resources are one of the richest grades in the world. However, the ilmenite from Odisha Sands Complex (OSCOM) at Chhatrapur, Odisha, India, is inferior in grade containing about 50% TiO_2 content in comparison to Chavra deposit of Kerala, India. These lower TiO_2 ilmenite resources are suitable for TiO_2 production by direct smelting as the high iron content provides suitable thermodynamic conditions for smelting. This work involves an enviro-friendly processing for the production of Synthetic Rutile from the ore which contains the following steps i.e. Reduction, Magnetic Separation, Aeration Leaching, Rutilation and Mild acid wash. Reduction:

The ilmenite concentrate obtained from OSCOM, Chhatrapur, Odisha, and coke fines and coal were used as raw materials in this study. The chemical composition and mineralogy of the concentrate were characterized by chemical analysis, XRD. The typical composition of the Ilmenite is give below

Chemical Composition of Orissa Ilmenite (%)

Constituents In %TiO_2 50 FeO 34 Fe_2O_3 12 SiO_2 0.8 MnO 0.5 V_2O_5 0.2 MgO 0.7 Th 42 ppm U<3 ppm

The XRD pattern of raw ilmenite is shown in Figure 3. Ilmenite was mixed with coking coal and reduced at various temperatures which is shown in Figure 4(a). The reduced ilmenite was subjected for aeration leaching and studies are on progress. A leaching reactor was fabricated which is shown in Figure 4(b).



Figure 3: XRD pattern of raw ilmenite

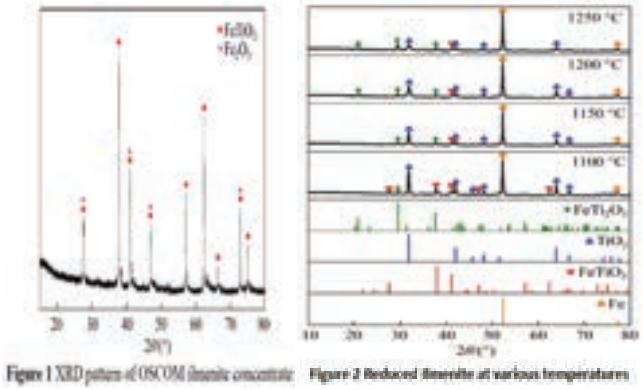


Figure 4: (a) Mixed Ilmenite with coking coal (b) Fabricated leaching reactor

Flotation Kinetics and Feasibility Studies of Silica Reduction from Pre-concentrate of JSW BHQ Ore Processing Pilot Plant Using Froth Flotation

The project is to study the feasibility of flotation as a method for silica reduction (silica to ≤ 5%) in the pre-concentrate generated by existing pilot plant of a steel production company at Karnataka using new flotation reagents developed by the sponsor. This pre-concentrate sample (feed to flotation) obtained from the sponsor's pilot processing plant (BHQ) assayed 59.37% Fe, 12.62% SiO2, 0.92% Al_2O_3 and 1.095% LOI and from the mineralogical studies hematite and quartz (gangue) were found to be present as the major mineral phases. The morphology of the BHQ sample was studied using SEM analysis as shown in the Figure 5. Laboratory scale flotation tests were carried out for silica reduction from pre-concentrate obtained from the sponsor's BHQ ore processing pilot plant using proprietary silica collectors (Collector G and Collector H). The objective of the study was to reduce the silica content from 12.62% to 5% (max.) so as to make the flotation concentrate generated suitable for pellet-making. Collector G resulted in a reduction of silica to 2.46% with a weight recovery of 56.27% in the iron ore concentrate assaying 56.27% Fe. Collector H resulted in a reduction of silica to 3.44% with a weight recovery of 59.31% in the iron ore concentrate assaying 59.31% Fe. Further discussions are initiated for conducting pilot-scale flotation tests at the sponsor's pilot column using the chosen collector (G or H, depending on desired trade-off between silica reduction and recovery). This will validate the laboratory findings in a more realistic production environment and provide valuable data for process design. The futuristic plan is to establish a collaborative framework for ongoing reagent evaluation to optimize the process and explore further applications in other mineral processing industries.

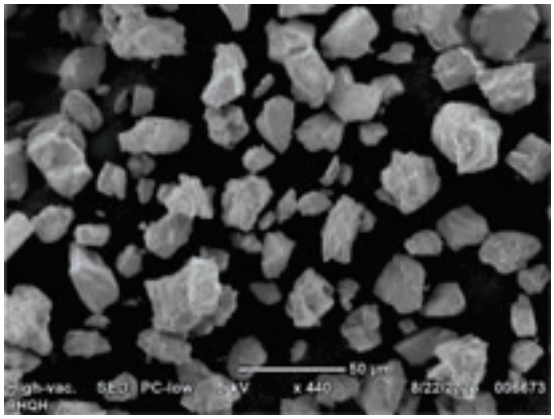


Figure 5: SEM analysis of BHQ feed to flotation

Evaluation of performance of newly developed flotation reagents

The project is a comprehensive evaluation of new flotation reagents developed by the sponsor. The assessment encompasses both laboratory-scale testing and, potentially, pilot/commercial plant-scale feasibility studies. The objective is to determine the reagents' efficacy in achieving targeted mineral separation metrics (grade and recovery) through laboratory flotation experiments. The project involves detailed performance evaluation at the laboratory scale to ascertain the reagents' suitability for their intended industrial application. Furthermore, the evaluation of the reagents' performance efficacy at pilot or commercial plant-scale trials, depending upon the accomplishment of the laboratory phase, is conducted at the facilities of an interested industry partner or client. This approach ensures a robust evaluation process, translating from controlled laboratory settings to real-time industrial applicability. The silica collectors developed were evaluated for their effectiveness through laboratory tests on BHQ sample from Bellari, Karnataka. At laboratory scale studies, the developed coal collector and frother yielded about 67% with 9% ash content from a coal of 27% ash. Another coal sample from West Bokaro with 26% ash content yielded 57% with 14% ash with the use of these new coal collector and frother and based on the laboratory studies, plant trials were executed. Out of the few coal flotation reagents tested at laboratory scale, one collector and frother system were found effective, and commercial plant trials for studying their performance at 58 tonnes/hr feed coal capacity flotation circuit of the sponsor's Coal Washery (with total reagent consumption of 1850 litres and 250 litres frother during the trial period) was carried out as shown in figures 6 & 7, which yielded a positive and promising performance at plant scale evaluation. This successful pilot trials at Coal Washery validated a new collector-frother system for coal flotation and plant scale commercialization via partnerships with coal washeries promises process improvement and industry-wide adoption. Hence, the future plan of action could include large-scale commercialization in collaboration with the sponsor by partnering with coal washeries/mineral processing industries to implement the new reagents in full-scale operations.



Figure 6: Commercial scale evaluation of developed coal reagents at the Coal Washery



Figure 7: Reagent dosing setup at the washery



Team - CSIR-NML MC

Strategic Sector

Railways

Corrosion behavior of different rail steels in varied environments

The rail steels often seen to be susceptible to three types of corrosion namely atmospheric, microbial and stray current corrosion which result into reduced service life and premature replacement of rails. This study aims to evaluate the comparative corrosion performance comprehensively through standardized test exposures in weathering, saline and microbial environments of six different rail steels developed by SAIL, India. This investigation will facilitate Indian Railways in selection of appropriate rail grade for application in corrosion prone sections based on severity of atmospheric exposure and microbial corrosion.The objective of the present investigation is to study the corrosion behavior of six different grades of rail steel (*Plain carbon 90 UTS rail, Ni-Cu-Cr rail, Cu-Mo rail, High toughness corrosion resistant rails (HTCR-3 and HTCR-4 grades) and 1080 Cr)* in varied environments as mentioned below: a) Evaluation of relative corrosion resistance of different rail steels through salt spray exposures in 5 % NaCl solution (as per standard ASTM B117); b) Evaluation of relative corrosion resistance of different rail steels through cyclic humidity exposures in 1 % NaCl, 1 % $CaCl_2$ and 0.1% H_2SO_4 solution (as per standard ASTM G60-01); c) Evaluation of relative corrosion resistance of different rail steels through spray exposures in synthetic urine solution with or without bacterial species. The outcomes of the project are as follows: Initially, six different grades of rail steels were evaluated for their relative corrosion performance in 5% NaCl foggy environment through salt spray chamber at temp 35 ± 1°C. The time to first rust (yellowish) spot appearance was recorded around 65 min, 50 min, 45 min, 60 min, 70 min and 60 min for NCC, Cu-Mo, 1080Cr, 705, 699 and 90UTS steels, respectively. Further, the corrosion rate trends (in ascending order) were found to be as follows **Cu-Mo < 1080Cr < NCC < 705 < 699 < 90UTS** (pictorial depiction is provided in Figure 1)**.**

The localized corrosion (pitting, pit depth) trends were

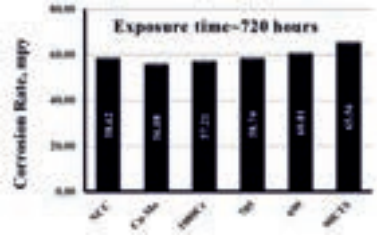


Figure 1: Corrosion rate of different grades of rail steels in 5% NaCl solutions, exposure time ~ 720 hours.

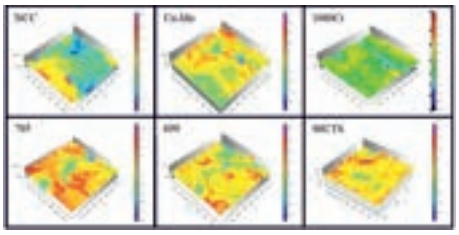


Figure 2: 3D topographical view of corroded surface (after cleaning) after 720 hour's exposure (as per ASTM B117) (Blue color indicates the depth-pit).

found to be as follows (3D view of topography is represented in Figure 2); ***1080Cr < NCC < 90UTS < 699 <Cu-Mo < 705,*** whereas uniform thickness loss trends (in ascending order) determined as follows; ***1080Cr < NCC < Cu-Mo < 90UTS < 699 < 705.***

All six grades of steels were further exposed to 1%NaCl + 1%$CaCl_2$ + 0.1%H_2SO_4 Solutions at 52 °C with varying relative humidity in the chamber. The corrosion rate trends (in ascending order) were found to be as follow (pictorial depiction is provided in Figure 3); ***Cu-Mo < 90UTS < 705 < 699 < NCC < 1080Cr***

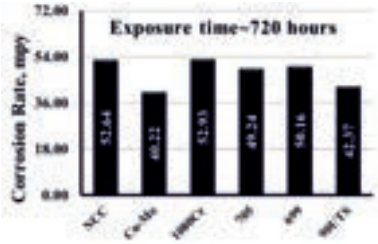


Figure 3: Corrosion rate of different grades of rail steels in 1% NaCl + 1% $CaCl_2$ + 0.1% H_2SO_4 solutions with varying humidity at a temp.~ 52 °C, exposure time ~ 720 hours.

The localized corrosion (pitting, pit depth) trends were found to be as follows (3D view of topography is represented in Figure 4); ***1080Cr ~ 699 < NCC < Cu-Mo < 90 UTS < 705,*** whereas uniform thickness loss trends (in ascending order) determined as follows; ***699 < Cu-Mo < 1080Cr < 705 < 90UTS < NCC.***

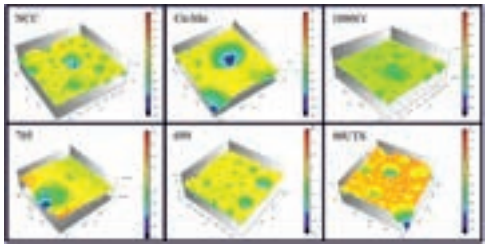


Figure 4: 3D topographical view of corroded surface (after cleaning) after 720 hour's exposure (as per ASTM G60-01) (Blue color indicates the depth-pit).

The various rail steel grades mentioned above, were evaluated for the corrosion resistance in synthetic urine solutions (urea (7 g/l), creatinine (3 g/l), potassium chloride (2 g/l), magnesium chloride (0.5 g/l), calcium chloride (0.25 g/l), sodium sulfate (2 g/l) and ammonium phosphate (0.85 g/l) in double distilled water) inoculated with or without microbial species through direct spray or immersion methods. Initially, the steel specimens were exposed to synthetic urine solutions containing no bacterial species at room temperature. The corrosion rate trends (in ascending order) in, were found to be as follow (pictorial depiction is provided in Figure 5); ***NCC < 705 < Cu-Mo < 699 < 90UTS < 1080Cr.*** The corrosion rates were found to be almost 10-12 times lower as compared to both salt spray and cyclic humidity environments. The area covered with rust was found to be ~ 29-41% and 42-54% after the completion of 480 and 720 h of exposure, respectively. The localized corrosion (pitting, pit depth) trends were found to be as follows (determined through 3D profilometry); ***NCC < Cu-Mo < 90 UTS < 1080Cr < 705 < 699,*** whereas there wasn't any measurable thickness difference after completion of the exposure duration for all the steels.

Further, the steel specimens were exposed to the synthetic urine solutions inoculated with microbial species through immersion method. The bacterial species were isolated and sub-cultured from the corroded rail specimens collected from in-service railway lines (Ranchi & Hatia Railway stations). The corrosion rate trends (in ascending order) in, were found to be as follow (pictorial depiction is provided in Figure 6); ***NCC < 705 < Cu-Mo < 699 < 90UTS ~ 1080Cr.*** The corrosion rates found to increase by around three folds in presence of the bacterial species in the synthetic urine solutions. Thus, it is concluded that the corrosion of the rail specimens is guided by the bacterial species which further confirmed by the scanning electron microscope (SEM) which shows well grown bacterial colonies on the specimen surface (Figure 7). The localized corrosion (pitting, pit depth) trends were found to be as follows (3D view of topography is represented in Figure 8); ***NCC ~699 < Cu-Mo < 1080Cr < 705 ~90 UTS,*** whereas uniform thickness loss trends (in ascending order) determined as follows; ***NCC < Cu-Mo < 699 < 1080Cr < 705 < 90UTS***.

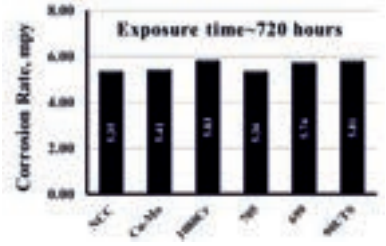


Figure 5: Corrosion rate of different grades of rail steels in synthetic urine solutions without bacterial species at room temperature, exposure time ~ 720 hours.

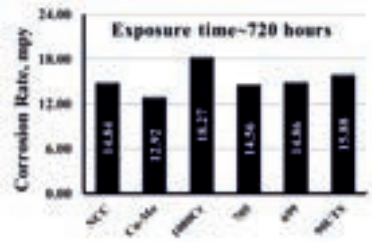


Figure 6: Corrosion rate of different grades of rail steels in synthetic urine solutions with bacterial species at room temperature, exposure time ~ 720 hours.

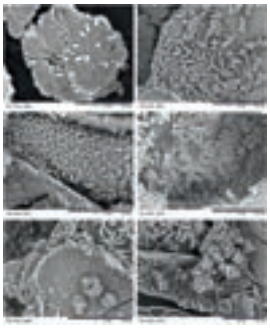


Figure 7: SEM micrographs of the corroded specimens showing the presence of the bacterial colonies on the steel surface; microbial corrosion.

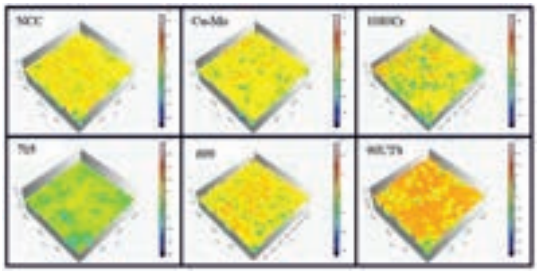


Figure 8: 3D topographical view of corroded surface (after cleaning) after 720 hour's exposure (cleaned as per ASTM G60-01) (Blue color indicates the depth-pit).

Evaluation and assessment of field withdrawn CBC components

Centre Buffer Couplers are used for joining freight cars of Indian Railways. Earlier, the CBCs were imported and were expensive. The indigenized CBCs that were later supplied to Railways suffered many field failures resulting in revenue losses. 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 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) Indigenization of Grade E castings used for manufacturing of Center Buffer Couplers (CBC); (ii) Safety in rail transport; (iii) Revenue saving. The standard WD-70-BD envisages that the CBC manufactured by foundry need to be evaluated at CSIR-NML for soundness of casting, mechanical properties, microstructure etc. Presently, several manufactures in India

have started manufacturing and supplying CBC to Railways and some vendors are under 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 and spin off projects.

Defence

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

High nitrogen steel (HNS), often referred to as nitrogen-alloyed steel or nitrogen-strengthened steel, represents a significant advancement in materials science and engineering. It is a type of steel that contains a substantial proportion of nitrogen to the tune of 0.4-0.7% as an alloying element, which is a departure from traditional steel compositions. This seemingly minor alteration, however, the introduction of nitrogen, imparts a remarkable range of properties and capabilities that have garnered attention across various defence sectors and aerospace industries. The inclusion of nitrogen in the steel matrix bestows it with exceptional strength, hardness, and wear resistance. Despite having the desired combination of the properties in the base metal, the weldability of HNS could be an issue due to higher nitrogen content. The objectives of the project are: a) Optimization of the process parameters in welding HNS of thickness 8 and 20 mm and to evaluate the microstructure, mechanical properties and susceptibility of cracking of welded samples. b) To adopt suitable methodology in controlling porosity within the acceptable limits in the weldments and develop a new filler wire in welding HNS plates with SMAW process based on assessing the weldability using available filler wires.

A SMAW power source is used to weld 8 mm thick HNS plates in butt joint configuration employing an E2594 electrode of diameter 3.2 mm. Dye penetrant and radiography tests are carried out to find out the flaws in the weldment. The range of process conditions used in the present study is around 478 ~ 713 J/mm. Microstructural observation has been carried out in stereo, optical and scanning electron microscopes to examine the characteristics of various zones across the fusion boundary. Figure 9 shows the optical images of the weld zone, and it reveals three distinct zones, namely unaltered base material, narrow heat affected zone (HAZ) and central re-solidified dendritic structure of the fusion zone. The base metal contains austenitic phase. The HAZ width increases with an increase in heat input. With increased heat input, prolonged exposure of grains to elevated temperatures induced grain growth, resulting in grain size. The elemental mapping adjacent to fusion boundary has also been carried out in EPMA to reveal new phase formation and elemental segregation, specially related to low atomic number elements like nitrogen and carbon. The finding envisaged absence of carbide / nitride bearing compounds within the adjacent area of the fusion boundary. The micro-hardness distribution across the welded joint has been done at an interval of ~1 mm along the transverse direction of the weld. The experimental values indicate that minima have been appeared at fusion zone for all specimens, irrespective of welding parameters. Tensile test of the assemblies has been performed as per ASTM E8M-16 standard in a 50 kN INSTRON 8800 universal tensile testing machine at a crosshead speed of 0.5 mm/min. The strength of the joint has been gradually reduced as heat input increases. In this respect, total elongation did not exhibit significant change. The maximum joint strength is found to be around 82% of the base metal strength. All samples fail from the fusion zone of the joint. The outcome becomes at par with the results of the micro-hardness profile of the assemblies, which showed the weld fusion zone as the weakest region across the specimen. Two novel SMAW electrodes have been developed and coated with commercially available flux. The following electrodes have been utilized to weld 8 mm thick plate and a preliminary quality check is carried out with radiography test. The measured maximum strength using novel electrodes is found to be around ~ 850 MPa, which is 70% of the base metal strength. Indigenously developed electrodes and achieving adequate joint strength using those electrodes lead to broadening the area of application of HNS plates in the defence sector.

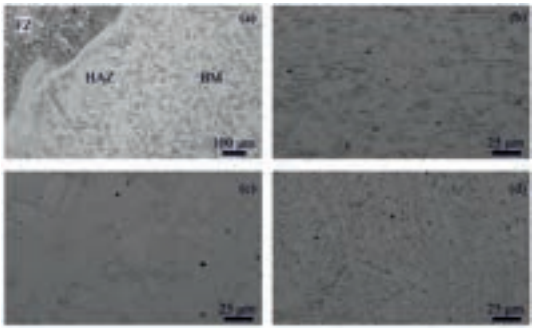


Figure 9: Optical micrograph at different locations of welded joint (a) global image across fusion boundary, (b) BM, (c) HAZ and (d) FZ

Power

High temperature oxidation and hot corrosion behavior of selected materials for clean coal technologies for power plant applications

In recent years, hybrid laser-arc welding (HLAW) has gained widespread importance for joining thick sections over the conventional welding techniques. Low alloy steel such as

P91 & T22 and SS347 and Ni-based superalloys are commonly used in thermal power plant and aerospace industries due to their superior mechanical, creep and high temperature properties. The low-alloy steels are widely used in the power plants because of ease of weld ability, cheaper cost, and reasonable corrosion resistance. However, these power plant materials, while operating at high-temperatures, found to degrade severely due to accelerated corrosion in the presence of fused salt thin films deposited from the surrounding atmosphere. The present Investigation is aimed to evaluate the oxidation and hot corrosion behavior of base and weld of IN617 and P91 alloys in flue gas environment with or without coated with salt and synthetic coals ash at 600-800°C for 600-1000 h. The specific objectives of the project are optimization of laser hybrid (LH) welding parameters for their influence on oxidation; hot corrosion and creep behavior; oxidation and hot corrosion studies (varied salt elements and proportion thereof) of boiler materials (IN617, P91, T22 and SS347) under varied salt proportions and cyclic loading effects during short and long term exposure; creep-hot corrosion simulation at predefined loads/stress and time; post exposure characterization of specimens and oxide scales subjected to creep-hot corrosion tests; evolution of possible degradation mechanisms. Currently the achievements in the projects are: oxidation of as-received P91, IN617, T22 & SS347 and laser hybrid welds of T22 & SS347 at 600- 800 °C in air for 100 hours is completed; cyclic hot corrosion of laser hybrid welds of P91, IN617, T22 & SS347 alloys at 600 and 700°C in flue gas for 1000 hours is completed; post oxidation/hot corrosion characterizations of P91, IN617, T22 & SS347, using XRD, SEM and Raman spectroscopy for 600-800 °C for 100h exposures is completed; creep rupture test at 650 and 700°C at stress (90, 110 & 127) MPa for P91 alloys, whereas 650 and 700 °C at stress (236, 268 & 308) MPa for IN 617 alloy is completed; creep rupture test at 650 and 700 °C at stress (216, 196, 177 & 137) MPa for SS 347 alloys is completed; creep rupture test at 600 and 650 °C at stress (98, 80 and 70) MPa for SS 347 alloys is in progress; post-creep rupture test characterizations of T22 & SS347 using XRD & SEM for 600-800 °C for 100 -1000 h exposure is in progress; oxidation and hot corrosion behavior of the base and weld of SS347 is much better than that of T22 alloys, as depicted in Figure 1 and Figure 2, respectively.

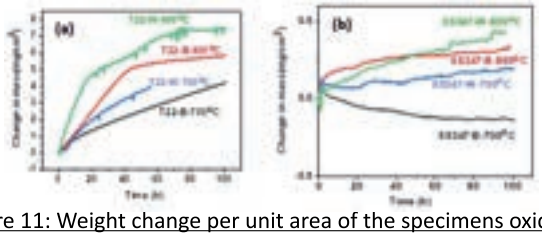


Figure 11: Weight change per unit area of the specimens oxidized at 700 & 800 °C for 100 h: (a) Base and weld of T22 alloys and (b) Base and weld of SS347 alloys.

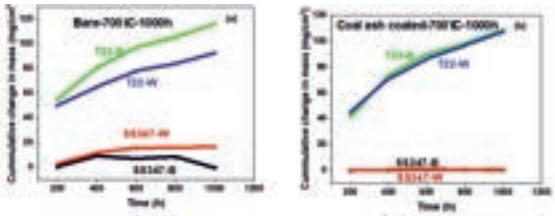


Figure 12:Weight change per unit area of the specimens hot corroded at 700 °C for 1000 h for base and weld of T22 and SS347 alloys: (a) Bare (b) Coal-ash coated.

Space

Effect of processing parameters on cryo impact properties of cast alloys.

The project aimed to investigate the phase evolution with different heat treatment conditions (quenching and tempering route) and their effect on cryo-impact properties of super-martensitic stainless steel grades. The output of the work would be the assessment of heat treatment parameter on cryo impact properties of existing alloy grade and the design of new alloy composition with its Quenching & Tempering parameter that would give desired mechanical properties. The major objectives of the project were: assessment of the effect of heat treatment parameters on cryo-impact properties of as-cast alloy; design of an alloy composition and its Q&T parameter which would give 100 J impact energy at 77K, Room temperature properties: YS 800 MPa, UTS 1050 MPa and Elongation 14%. The project delved into the detailed investigation of two investment cast alloy grades, namely alloy-2 (6.8 wt.% Ni) and alloy-3 (8.5 wt.% Ni), following initial research on alloy-1. Alloy compositions were selected based on findings from the preliminary investigation on alloy-1, which was cast at a scale of 30 kg at NML. Alloy-1, initially cast at CSIR-NML, aimed to scrutinize the impact of tempering temperature and retained austenite (RA) content on yield strength (YS) and the evolution of microstructure. A comprehensive thermodynamic analysis, including the prediction of martensite start (Ms) temperature and RA at room temperature and -196°C, preceded the design of appropriate heat treatment schedules and subsequent experimentation. Tensile testing at room temperature (RT) ensued, followed by microstructural characterization. Alloy-1 findings indicated that achieving the targeted YS of 800 MPa necessitates a lower tempering temperature (< 600 °C). Transmission electron microscopy (TEM) analysis revealed notable Ni partitioning to austenite in the two-stage 550°C tempered sample, alongside the presence of fine precipitates (<5 nm). Subsequently, alloy-2 (6.8 wt.% Ni) and alloy-3 (8.2 wt.% Ni) investment cast test bars underwent a similar processing and tempering treatment. Tensile and impact property evaluations at RT and -196°C, coupled with microstructural characterization, were conducted. Alloy-2's

optimally tempered sample, demonstrated commendable tensile properties (YS: 843 MPa, UTS: 1077 MPa, % El.: 15%), meeting the specified requirements. Moreover, this sample also exhibited good cryogenic impact properties of 74 J at -196°C. TEM analysis indicated minimal partitioning of substitutional solute elements between martensite and austenite during low temperature tempering, although fine precipitates (<5 nm) were observed. Alloy-3, having 8.2 wt.% Ni, showcased promising cryogenic impact properties alongside desired tensile properties. Tempering within desired temperature range yielded a Charpy impact energy of approximately 90 J at -196°C, with a yield strength ranging from 822-834 MPa, tensile strength between 1160-1213 MPa, and % elongation of 15-19%. Additionally, a significant transformation-induced plasticity (TRIP) effect was evident, characterized by the transformation of RA to martensite during tensile deformation. Overall, these comprehensive investigations shed light on the intricate interplay between alloy composition, heat treatment, microstructure, and mechanical properties, providing valuable insights for the development of super martensitic stainless steel tailored to specific performance requirements and environmental conditions. The alloy developed will be utilized in the indigenous production of turbo fuel pumps for rockets, thereby making a significant contribution to Indian space programs.

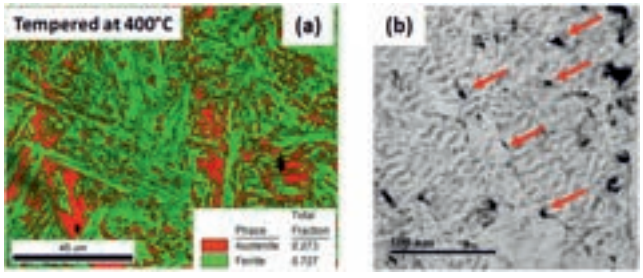


Figure 15: Microstructure of the 8.2 wt.% Ni added alloy after tempering (a) EBSD phase showing martensite-austenite microstructure and (b) TEM micrographs showing presence of fine precipitates

Navy

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

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

Influence of precipitation on the threshold intensity factor for environmental assisted cracking of AA 5083-H111

AA5083 is an Al-Mg alloy widely used in naval applications for hull structures, superstructures, and deck panels of ships due to their high corrosion resistance, specific strength, good weldability and ease of processing. In service, these alloy components experience temperatures of 40-80°C, where they undergo sensitization due to precipitation of Al_3Mg_2 along the grain boundaries and suffer environmental assisted cracking (EAC), that significantly limiting the component's service life. Consequently, this incurs huge maintenance costs. Furthermore, it was found that sensitization significantly reduces the threshold intensity factor for EAC (K_{IEAC}), which is an important design parameter. Therefore, understanding the mechanism of environmentally assisted cracking associated with the degree of sensitization of the AA-5083 is essential for better prediction and mitigation of the EAC. Most EAC studies were carried out sensitizing the alloy in the air at temperatures in the range of 100-175 °C in different tempers, viz. H116, H131, H138. Further, it is important to mention that sensitization at < 100 °C, i.e., service temperature of such components (40-80°C), results in precipitates with relatively different amounts of Mg than that formed at > 100 °C. The effects of such precipitates on the EAC can only be understood by heat treatment/sensitizing at relatively lower temperatures. Therefore, the present proposal is envisioned to study the influence of the low-temperature sensitization on the K_{1SCC} of AA5083-H111 alloy. Further, the influence of the NaCl environment on sensitization behavior is also investigated. The objectives of the project are: a)

Determine the threshold stress intensity factor with different degrees of sensitization of AA 5083-H111; b) Understanding the mechanism of environmentally assisted cracking behaviour of low-temperature sensitization of AA 5083-H111 alloy.

Sensitization of the AA 5083-H111 alloy was carried out at 60 °C for different periods up to 2500 hr in the Air. Similarly, the sensitization of samples immersed in 0.1M NaCl solution at 60 °C for the same periods was carried out to see if the environment influenced the sensitization behavior. The intergranular cracking (IGC) susceptibility of the sensitized AA5083-H111 was analyzed by Mass Loss After Exposure to Nitric Acid according to ASTM G67 standard. A higher degree of sensitization (DOS), i.e., increased susceptibility to IGC, of the alloy sensitized in the air than that of the alloy sensitized in the 0.1M NaCl solution was observed. This could be due to the difference in the magnesium percent in the grain boundary precipitates sensitized in the air and the NaCl environment, as shown in Figure 17. That is magnesium depletion near the grain boundaries is higher in the samples sensitized in the air. The increased susceptibility to intergranular cracking of the alloy (S-T orientation) can be seen in Figure 18 in the samples sensitized in the air than in the 3.5%NaCl. Further, the IGC susceptibility is lower in the L-T orientation of the sample. K_{1EAC} tests up to K = 34 MPa*$m^{1/2}$ were carried out in L-T orientation, and no significant crack growth was observed after approximately 2000 hr. The tests are continuing. The project outcome leads to a better understanding of the low-temperature sensitization of AA-5083-H111 alloy on the IGC susceptibility and mitigation of environmentally assisted cracking (EAC) for the safe operation of these material components in hostile environments.

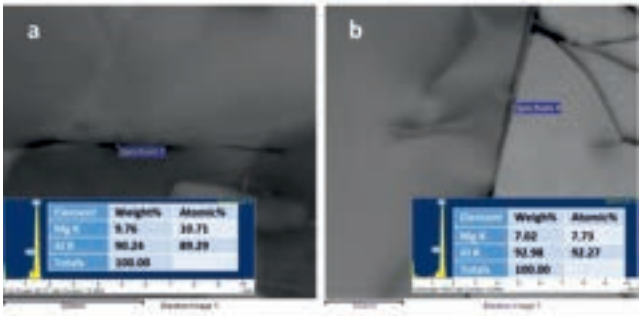


Figure 17: Effect of low-temperature sensitization (a) in air and (b) in the 0.1M NaCl solution on the precipitation of the b phase.

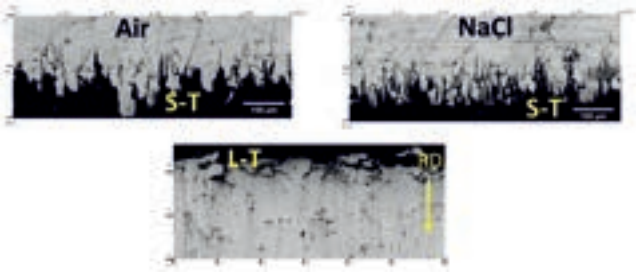


Figure 18: IGC of AA 5083-H111 alloy after sensitization in Air and 0.1M NaCl in different sample orientations.

Elevated temperature tensile and creep deformation behaviours of different grades of steels

Creep tests were carried out at a given stress and temperature based on recommendation of the Indian Boiler Regulation (IBR). The creep tests were un-interrupted for 1000 hours and few more tests undergone till failure. The obtained data is being compared with the standard creep data sheet of NIMS, Japan for respective grades of steel to meet the minimum creep rupture strength. The deformation strain as a function of time was also measured till failure of the specimen at different stresses and temperatures. The operating temperature of the steel was recommended by IBR board in the range of 550-625°C. So as to make life of the component safe for more than 10 years in the thermal power plant under the lower operating pressure. The project aimed for the evaluation of stress rupture and tensile properties along with characterization of creep failure specimens. Operating parameters were maintained and controlled to avoid the overheating failure during service. However, total economic loss was unavoidable during shut down of the thermal power plant.

Research Planning and Business Development

The Research Planning and Business Development (RPBD) Division is engaged in the management of R&D Projects of the laboratory as well as a range of other essential functions for the laboratory. The division interactions with both internal and external stakeholders.. Its primary areas of work include: *Research Management, Business Development & Client Interfacing, Negotiations & contracts, Technology Marketing, IP Services, Development & Management of Information Systems & Databases, Tender Management & Annual Procurement Plan , Documentation & Reporting to stakeholders.*



Research Management, Business Development & Client Interfacing

RPBD takes care of the CSIR guidelines in the R&D activities of the laboratory as well as tries to align the objectives of the laboratory with the CSIR mandates. RPBD has the central role in project approvals and funds allocation. The division functions, as the primary point of contact for prospective clients and sponsors seeking solutions for their research and development (R&D) needs. This includes finalizing new contracts with various clients from Government Bodies, PSUs and Industries by participating in their Tendering Processes and Agreements. During the reporting period, the Division participated in 86 tenders, out of which the Lab was awarded with 71 projects. A total of 21 new MoUs/agreements were entered into with various national and international industries and academia. To name few of the clients and collaborators*: TATA Steel; Indian Navy; NTPC; L&T Energy; GTRE; Jindal Stainless; Man Industries; Hindustan Zinc; Bhilai Steel; ISWP; Vedanta; Jindal Saw Ltd.; RDSO, Indian Railways; Naval Metallurgical Res. Lab (NMRL); NMDC; GMDC; Korba West; SAIL; Jindal Steel & Power Ltd.; Kalyani Steel; Siemens; KU Industries, Vedanta Limited, Mumbai,Sree Chitra Tirunal Institute for Medical Sciences, Kashi Vishwanath Steels Pvt Ltd, BHEL, Aquatic Industries Private Limited, Novasensa, New Delhi, Refosteel, Jamshedpur, RDCIS-SAIL, Ranchi, Vedanta Limited, Mumbai, Advanced Metals, BARC, Mumbai, Global Nanotech* . The division also generated 1031 tax invoices and 103 proforma invoices for payments. The Division also remained instrumental to collect customer satisfaction and evaluations of more than 16 completed projects (through online platform).

Information Systems & Databases

The division develops and maintains various web-based information systems and associated databases in-house, with the aim of promoting digital inclusion and enhancing the overall efficiency of the laboratory. The e-information systems and databases facilitate managerial decision-making. These databases include information on several aspects including projects, manpower, external cash flow, intellectual property, agreements, and more. RPBD is responsible for the preparation and dissemination of a diverse range of reports to both internal and external stakeholders on a regular basis throughout the year.

Reporting: Some of the significant institutional documents are the Key Performance Indicator (KPI) Document, the PMO Portal Data, the Research Utilization Data, the Monthly Reports, the Quarterly Reports, the Annual Procurement Plan Document, and

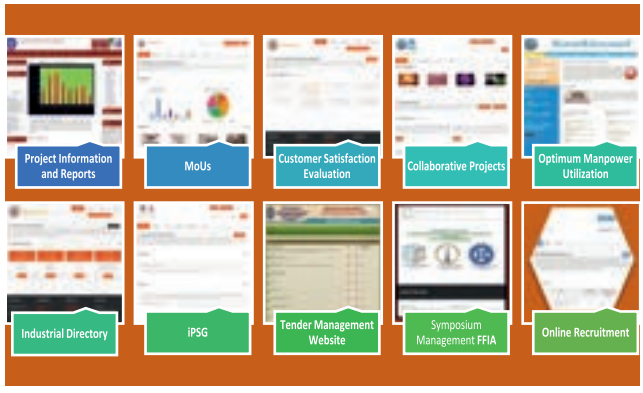


Figure 1: A glimpse of websites/databases maintained at the division.

the Replies to PMO & Parliament Queries, among others. The available databases help for the reporting purposes as well as the R&D management of the lab. In the reporting year around 50 such reports were prepared and sent to various stakeholders of the laboratory, by the division.

Institutional Publications

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.

IP Services

RPBD group offers IP search and analysis services to both external customers and internal users, with a particular focus on those engaged in the creation of new technologies or processes. The extent and proficiency of the department in these domains. During the 2022-23 period, the division offered a range of IP services in the field of Minerals, Materials, and Metals.

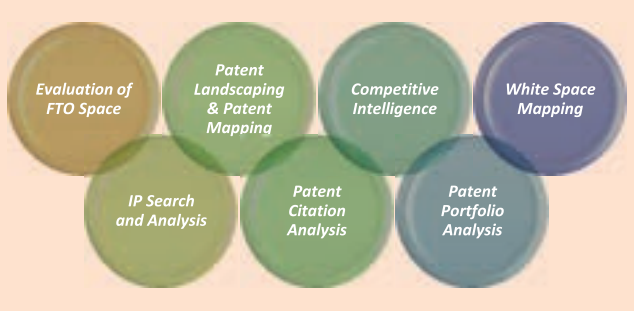


Figure 2: IP Services

Scientific & Technical Services

RPBD coordinates provision of S&T Service to customers. Testing as per standards are carried out for various organizations every year. Last year over 600 customers were provided testing services.

Intellectual Property Facilitation Center (IPFC)

IPFC is the brainchild of RPBD Division of CSIR-NML which is established in the year 2020. In fact, the center was founded under the aegis of Ministry of MSME, Govt. of India with an objective of "Building Awareness on Intellectual Property Rights (IPR)" for the MSME. The ambitious project has a budget of 100 Lakhs with an objective to bring awareness about IP and exploit IP for the MSMEs competitive business advantage. It's a project of national importance which would create a surge in IP based start-up eco-system in the country and eventually it leads to knowledge based thriving economy.

The center is fully equipped with all the necessary amenities, infrastructure and manpower competencies to provide IP related services to MSMEs. Since Its inception, IPFC center has organized several webinars to bring awareness about IP and the importance of IP protection for a competitive business sustainability. As a part of this program, NML-IPFC organized more than 20 webinars so far wherein around 1700 people got trained in the subject matters of IP. The center has already started providing IP related services like patentability, patinformatics, patent landscaping analysis, copyrights registration services, trademark & design registrations, and other techno legal advisory services. So far, the center has registered 18 trademarks, filed 05 patens, 03 industrial designs registered, and 01 copyright registered.



Figure 3: IP Services Provided 2023-24



Team - RPBD

Knowledge Resource and Information Technology

The division deals with knowledge resource management and offers IT infrastructural support to CSIR-NML. There are two independent groups, led by group leaders:

- Knowledge Resource Group (KRG)
- Information technology Group (ITG)

Knowledge Resource Group (KRG)

KRG manages the library resources including e-library, develops multimedia content, publishes the Journal of Metallurgy and Materials Science (JMMS) and conducts CSIR integrated skill trainings. The other significant activities of KRG includes website development and maintenance, maintenance of Online Public Access Catalogue (OPAC) and institutional repositories (e-prints), development of contents for CSIR Virtual Laboratory, public information delivery through RTI responses and PG Portal, scientometric analyses, conducting CSIR Jigyasha - an outreach program for schools and colleges, taking responsibility of the institutional branding through exhibitions, press releases, advertisements, and, maintenance of the archives and museum.

- ***CSIR-NML Library***

During the financial year 2023-24, Knowledge Resource Center(KRC)/library has subscribed to 9 Nos. of Elsevier online journals through the CSIR-NKRC consortia, and a few more Elsevier group materials science journals are also accessible online as informed by the CSIR-NKRC. New Delhi. As of this date, the library has maintained 55941 nos. of documents per accession register records. During this financial year, we switched from print subscription to digital mode through the CSIR-NKRC consortia. Besides these, the CSIR-NML, KRC has received e-resources/databases and standards through CSIR-NKRC, like ASTM standards and digital library, Clarivate Analytics- Web of Science, and iThenticate. In contrast, Grammarly software has recently been added to the collection. The library currently has various collections, including textbooks, reference books, technical reports, conference proceedings, standards, and bound volumes of journals.

- ***Digital Library***

The CSIR-NML has installed KOHA software. We have provided access to library holdings through e-catalogue. Since the primary sources are the backbone of the R&D Library, the online access facilities have been made available to library users to link with the online journals, which are being provided now through the CSIR- NKRC consortia. Besides these, an effort has been made to put all the digital resources on a single platform, like CSIR-NKRC consortia resources, abstract databases, open access resources, union catalogues, patents databases, standards, in-house publications, etc.

The NML digital library has also incorporated various important events these are being organized by the laboratory in different occasion. We have also made NML in-house publications, transparency portal, and the NML Achieves accessible on a button click.



- ***Transparency Portal***

The CSIR-NML Transparency portal (http://nmlindia.org/tp/index.htm) launched in May 2012, containing various /all information pertaining to human resources, data, budget, pay and allowances, engineering tenders and job, organization & functions, human resource, projects & programmes, target & milestones, budgets & expenditure, procurement data etc. has been updated frequently.

In-house Publication:

Journal of Metallurgy and Materials Science (JMMS) publishes original articles, review reports and short communications in the areas of minerals, metals and materials, tracing the overall life cycle of structural as well as functional materials. The JMMS is a quarterly publication. In 2022-23, the volume 64 consisting of two issues (January to June) were published. The issue no.3 & 4 is under processing.

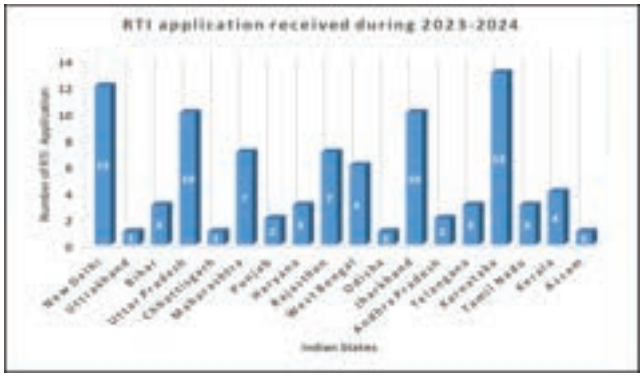
Knowledge delivery

The laboratory is implementing CSIR Integrated Skill Training Initiative since 2017, with the objectives of utilizing CSIR knowledgebase and infrastructure for contributing to national skill mission through special up-skilling/training for societal benefits and improving national skills, and promoting entrepreneurship/ technopreneurship.

The different categories of training programs provided at CSIR-NML include Corporate Training Programs (PTP), and Professional Training Programs (PTP), which are paid trainings for professionals, NSDC Training Programs (NTP) and Societal Training Programs (STP), which are low cost or free training provided to school drop outs, and, International Training Programs (ITP) for international clients on demand. Special free training is also conducted for women from economically weaker sections.

Public information delivery

During 2023-2024, CSIR-NML received 89 RTI applications from 19 states and union territories of India. A maximum 13 application received from the Karnataka followed by the New Delhi has filed 12 applications whereas from the Jharkhand and the Uttar Pradesh sent us an equal number of the ten application. The overall distribution of the RTI application among others states are highlighted in fig. We have also received 4 appeals, which were successfully disposed of as per RTI guidelines. Most of the RTI queries were related to the Administration. The CSIR-NML Transparency portal (http://transparency.nmlindia.org) contains all the information as per the requirement of The Right to Information Act, 2005. This information is updated periodically.

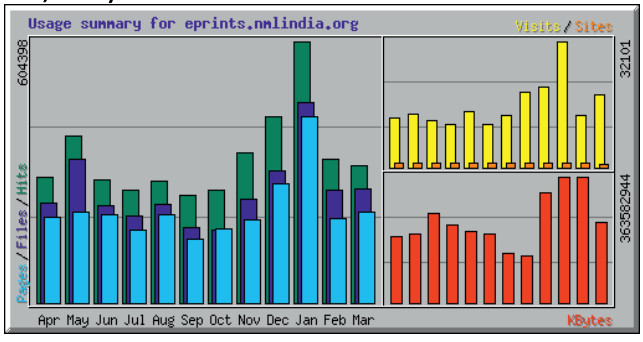


Status of RTI application received during 2023-2024

- **E-Prints**

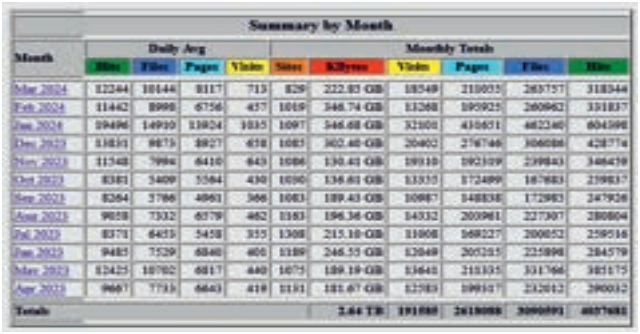
Eprints@NML is the Open Access Institutional Repository of CSIR-National Metallurgical Loboratory-Jamshedpur. This repository encourages scientists of CSIR-NML to self-archive post-prints (peer-reviewed draft in word or pdf form) of the journal papers as soon as it is accepted by the journal publishers. Mediated archiving service is also provided by the repository administration team. In case of non-availability of post-prints with authors or any publisher embargo, published version of the papers are allowed to be self-archived with restricted access to NML users. Any other interested users outside NML, who wish to use the article may use **"Request Copy"** facility that has been provided for every restricted access article. Apart from journal article, the repository facilitates self-archiving/mediated archiving of conference papers, theses and patents.

Following two graphs represent usage statistics from April 2023 to March 2024 for eprints.nmlindia.org (as on March 26th, 2024)



Information Technology Group (ITG)

The Information Technology Group [ITG] caters to and co-ordinates the lab-wide needs for IT resources and



Summary by Month

Month	Daily Avg				Monthly Totals					
	Hits	Files	Pages	Visits	Sites	KBytes	Visits	Pages	Files	Hits
Mar 2024	12244	10144	8117	713	829	222.83 GB	18549	219035	269757	318344
Feb 2024	11462	8998	6756	457	1019	346.74 GB	13268	189325	260962	321837
Jan 2024	19486	14910	11824	1035	1097	546.68 GB	32101	430651	462340	604398
Dec 2023	13831	9875	8927	658	1083	302.40 GB	20402	276746	306086	428774
Nov 2023	11548	7994	6410	643	1086	130.41 GB	19310	192309	239843	346459
Oct 2023	8381	5409	5364	430	1090	136.61 GB	13335	172499	167683	259837
Sep 2023	8264	5766	4961	366	1083	189.43 GB	10987	148838	172983	247926
Aug 2023	9058	7332	6579	462	1183	196.36 GB	14332	203961	227307	280804
Jul 2023	8378	6455	5458	355	1308	215.10 GB	11008	169227	200052	259516
Jun 2023	9485	7529	6846	400	1189	246.55 GB	12049	205295	225898	284579
May 2023	12425	10702	8817	440	1075	189.19 GB	13641	233335	331766	385175
Apr 2023	9667	7733	6643	419	1131	181.67 GB	12783	199317	232012	290032
Totals						2.64 TB	191888	2618088	3000891	4057681

management in terms of creation of IT infrastructure, its services & maintenance. The group is mainly looking after the development and services of IT facilities & infrastructure at the laboratort from basic to advanced needs. The group is well equipped with computational facilities in terms of hardware and software. The team ITG consists of scientists and technologists who are actively involved to support the lab level R&D activities by providing reliable and efficient IT infrastructure with uninterrupted Internet service. CSIR-NML is making use of the IT infrastructure primarily for data transfer, communication, exchange of manuscripts and data with authors and referees, generation of knowledge base through internet, Email communication, E-office, conducting HR interviews/assessments, important project meetings around the globe through video conferencing/ Skype/ MS Team, website & transparency portal maintenance etc. Besides day-to-day routine activities, following are some of the major milestones achieved while equipping the three campuses of CSIR-NML and two residential dispensaries with the requisite IT infrastructure during 2023-2024:

- Upgradation of existing server in terms of hardware & software.
- Planning, estimation & installation of IT facility required by users at various renovated sites of CSIR-NML.
- Coordination and management of lab wide maintenance services of CSIR-NML's IT assets.
- Preventive maintenance of IT infrastructure installed across campuses of CSIR-NML.
- Provisioning of IT facilities in terms of network connections and utility services to new recruits.
- Development and maintenance of several in-house utility web applications.
- IT support to Human Resource Group (HRG) for performing various HR activities (interviews/ assessments/DPCs).
- Conduction of Video Conferencing for important meetings and various project review activities.
- Procurement and installation of Large Format Display (LFD) for various locations of NML.
- Resolution of various technical issues and upgradation and hardware maintenance related to CCTV.
- IT support for conduction of seminars, workshops & conferences at NML.
- Upkeep of turnstile based attendance system at CSIR-NML for employees, project linked staffs and pensioners.
- Verification of data and printing of employee identity cards.

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



Team - KRIT

Leading Women of India...

Women Heading Financials Institutions#

Indian Women who have vast experience in banking industry and leading financial institutions of the country.

"Advocacy is the way for the regulator to understand ground reality"

Chairperson of the securities regulatory body Securities and Exchange Board of India (SEBI). She is the first woman chairperson to lead SEBI. She aims for making regulation more lively. She has over three decades of experience in the financial markets. During her tenure at SEBI, she handled portfolios such as surveillance, collective investment schemes and investment management. She is an alumna of the Indian Institute of Management (IIM), Ahmedabad and has a graduate degree in mathematics from St Stephen's College, New Delhi.



MADHABI PURI BUCH
FIRST WOMAN CHAIRPERSON, SEBI



ANSHULA KANT
FIRST WOMAN MD & CFO,
WORLD BANK

"If we can come together as institutions, as governments, as donors as shareholders, that has the power to translate into the trillions of dollars needed for development"

First woman managing director and chief financial officer of the World Bank. Managing finances of the State Bank of India , she is one of the most respected bankers since last four decades. She also is trying to fight with the global challenges such as climate change and inequality. At the World Bank, she takes care of risk management and the mobilisation of financial resources and aims for ending extreme poverty by 2030 . She has a bachelor's degree with honours in Economic from Lady Shri Ram College for Women and a master's degree in Economics from Delhi School of Economics. She has been titled as one of the World's Most Powerful Women by Forbes (2020), India's Top Self Made Women by Forbes (2024).

Engineering

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

Project Planning and Engineering Group:

The activities of the group are varied. Under the **prototype/ product design & development activity,** the division has contributed to the requirements of several projects, the major research projects are: Development and integration of semi-automatic melt ejection and ancillary units for 5 Kg Planar flow casting (PFC) system; Electrodeposition of corrosion-resistant Cr-carbide coatings on SS 316L for Sink Roll applications in Continuous Galvanizing Lines; Unveiling the mechanism of abnormal grain growth in Grain Oriented Si Steel; and Enhancement of molten salt corrosion resistance of thermal energy storage materials in a concentrated solar power plant through dropping inhibitors. Under r**esearch and consultancy activity,** the division has also undertaken a major research project entitled as "Near net shape 3D manufacturing of Inconel 718 by optimizing controlled parameters of wire arc additive manufacturing with Cold metal". In the reported period the division has been working on the following areas for **setting up and operation of critical infrastructure development**: Facility maintenance for 24×7 controlled atmosphere testing conditions for the Creep Laboratory; Setting up of infrastructural requirements for the successful installation and trial runs of following major procurements during the period: Rolling Mill and Inert Gas Atomiser; and Operations of 493KWP solar power plant for catering the electrical load requirement of Laboratory, due to which significant monthly saving of around two lakhs in the running expenditure is observed. The division is also active in **CFD (Computational Fluid Dynamics)** and providing **Numerical Modeling and Basic Engineering Packages for the R&D projects of the laboratory.** he division is actively contributing in process modeling activities of major research projects and involved in Preparation of Detailed Project Report(DPR) for the laboratory upscaling projects of major research projects as well**.** The division has been continuously providing services in the p**ilot plant operations and maintenance** for the laboratory R&D projects. To name a few: Construction of energy efficient brass melting furnaces in various clusters of Bengal, Jharkhand and Odisha, and demonstration to artisans to construct themselves; Support in carrying out pilot scale campaigns; and Support in revival of critical R&D equipment's. Along with this, the responsibility of regular **maintenance and up-keeping of equipment** also lies with this division. The division is actively involved in the in-house maintenance to support the high-value equipment of the laboratory. This saves a lot of AMC cost and reduces the breakdown time of the equipment. The division is also involved in **skill development** training activities in the area of welding and carpentry under CSIR Skill Initiatives. In this connection, the division is participating in the major project entitled as "Women Technology Park (WTP) for capacity building and entrepreneurship development".

The division is operating a **central workshop that** receives jobs from various divisions, for specimen preparation of different materials, fitting, machining & fabrication of prototypes and repairing of miscellaneous jobs. All these jobs are completed in time to the satisfaction of the indenters. Major facilities available in the workshop are: CNC Lathe, Universal Milling, Shaper, Radial drill, Pillar Drill, Double column band saw, Shearing, Pipe bending M/C,

TIG/ MIG welding, EDM wire cut machine. Major achievements made during the period are: No. of job-sheets served are 807 in FY 2023-24; Average time to complete a job also has come down with emphasis to complete the given job in less than a week of its requisition; Upgradation of workshop facilities by utilization of Robotic MIG and CMM.

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 and refrigeration & air conditioning, lifts, water supply etc. The work accomplished by the group can be categorized into- New infrastructure, renovation jobs and routine maintenance jobs.

New Infrastructure Jobs:



Figure 1: Creation of work space for installation of Inert Gas Atomizer (IGA) at LSTF Area in CSIR-NML.



Figure 2: Design, fabrication, supply, installation, testing and commissioning of New ring fountain with RGB LED Colour lighting in existing pool at CSIR-NML, Jamshedpur.



Figure 3: New rolling mill foundation

Renovation Jobs

The infrastructure management team has successfully completed new facilities creation jobs as per the requirements of the laboratory. In addition, we take annual Maintenance & Overhauling of infrastructure & maintenance jobs. Some of the new facilities developed are Renovation of entrance gate, housing complex and boundary wall Widening of main gate and making of security room in CSIR-NML Housing Complex(es).

New Facility Creation

The infrastructure management team has successfully completed new facilities creation jobs as per the requirements of the laboratory. In addition, we take annual maintenance & Overhauling of infrastructure & upgradation of existing facilities. Some of the new facilities developed were: *Installation of Inert Gas Atomizer (IGA); Renovation and Modification of old shed to use for coal sample stock room and sample logging room; Annual Contract for Cleaning and Garbage removal work of CSIR-NML Main Laboratory and LSTF & Mg. pilot plant area; Replacement of existing (2 Nos. 86TR Units) inefficient creep central A. C. Plant with energy efficient central A. C. Plant in CSIR-NML, Jamshedpur ; Annual Maintenance Contract for all type of civil work in NML Housing Complex; Annual Contract for Cleaning and associated up-keeping, Garbage removal and Cleaning of overhead water tanks, sumps in CSIR-NML Agrico housing complex and CSIR-NML sports ground area; Annual Maintenance Contract for electrical works, Operation & maintenance of pumps & DG set in housing complexes of CSIR-NML; Annual Contract for Maintenance & Operation of Package A.C Plants & AMC of Cooling Appliances at Main Lab., LSTF, Pilot Plant & Housing areas; Operation and comprehensive annual maintenance contract (AMC) of new energy efficient central AC plant.*



Team - Engineering

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 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.



Team - Administration

Stores & Purchase Division

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



Team - Stores & Purchase

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 a central accounting and financial information to Director, NML, CSIR Headquarters and other stakeholders through the management information system.

Following are the major activities

- Preparation of Budget Estimate and Revised Estimate for CSIR-NML and submitting the same to CSIR for allocation of funds.
- 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 transfer of funds from CSIR.
- To prepare financial documents such as 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.
- Processing promptly all payment payable through Treasury Single Account (TSA) at RBI in PFMS system of the Government of India.
- Closing of GPF/CPF accounts, remittance of funds to NSDL relating to National Pension Scheme and Professional tax, income tax, etc. within due date to appropriate authority.
- Accounting, processing and ensuring timely filing of various GST returns and payment of GST due to the Government.

Performance Highlights

1. Utilized Budget Grant allocated by CSIR- Rs.7662.661 lakhs + Rs.5029.063 lakhs (pension)
2. Utilization from Laboratory Reserve-Rs. 325.277 lakhs
3. Generation of interest by investment of surplus funds- Rs. 962.089 lakhs
4. Generation of Lab Reserve - Rs.1716.197 lakhs.
5. Bank reconciliation of the Cash Book completed up to 31st March, 2023.
6. GPF Account as on 31-03-2023 has been reconciled, finalized and closed.
7. During the year new cases of 10 pension and 18 family pension cases have been completed with issuing of PPO and pension papers on time.
8. 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. Provision of QR Code for online money receipt in the NML official Account.



Team - Finance & Accounts

Hindi Cell

Official Language Implementation

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

Publications in Hindi

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

Promotional Activities for Hindi Implementation

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

Hindi Workshop

Four Table Workshops were conducted in the Administrative sections. The objectives of the workshops were to address the issues encoun- tered for preparing the Quarterly Hindi Progress Report, Hindi Noting and Drafting and imparting training of Unicode.

Hindi Competition

Hindi Competitions were organized from 1st to 8th September, 2023, for CSIR-NML Employ-ees. The competitions included discussions on implementation of Hindi, self-written poetry recitations and singing, etc. The program had wide participation by employees.

World Hindi Day

On the **"World Hindi Day"**, technical lectures were organized on 10th January, 2024, on dif- ferent scientific topics. In this event, many sen- ior scientists, research scholars and members of the technical lecture organizing committee of CSIR-NML participated with enthusiasm. The dedicated scientific lectures in Hindi language were simple, easy-to-communicate and very comprehensible.

Activities of Hindi implementation for TOLIC, Jamshedpur

CSIR-National Metallurgical Laboratory is the Secretariat of Town Official Language Imple- mentation Committee (TOLIC), Jamshedpur. It has 67 Members from all the Central Govt. of- fices located in and around Jamshedpur, with the Director, CSIR-NML as Chairman of this committee. Under the aegis of the Town Official Language Implementation Committee, Jamshedpur, a literary and Culture Programme was organized on 8th September, 2023 at CSIR- National Metallurgical Laboratory, Jamshedpur. More than three hundred officers from different Central Government offices graced the occasion. Along with the staging of a short play "Buddha Baccha", Songs, Ghazals by famous artists were also performed.







In-house Project Support Group (i-PSG)

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

- In-house developed High Temperature Electrochemical Cell for the study the in-situ corrosion behavior of the various metal/alloys and coatings in high temperature corrosive environments.
- In-house developed coated membrane for pre-concentration of hydro-metallurgical effluent. The membrane demonstrated more than 90% efficiency for real effluent and will help in significant reduction of energy requirement during crystallization of effluents containing salts.
- Fe-based amorphous spherical powder (50-80 micron size), with smooth surface, has been developed by an inert gas atomizer. The good flowability of powders led to successful preparation of product blocks by directed energy deposition method of additive manufacturing, with ~70% amorphocity.
- "Magnetostriction of Fe-rich FeSiB(P)NbCu amorphous and nanocrystalline soft-magnetic alloys" published in J. Alloys and Comp. 960 (2023) 170760.
- "Enhancement of molten salt corrosion resistance of Ni-based superalloy through adding inhibitor" published in Trans. Ind. Inst. Met., March (2024).
- "Slag Metal Refractory Interactions During Dissolution of Hydrogen Based Directly Reduced Iron (H DRI) in Liquid Iron Melt" published in J. Sustain. Metall., March (2024).

Prof. Shilowbhadra Banerjee award for best in-house project competed in 2021



Dr. Shailendra Kumar Jha



Dr. Gopi Kishor Mandal



Shri Mahesh Gulab Walunj

Dr. S. K. Jha and his team received 'Prof. Shilowbhadra Banerjee award 2023' for the best in-house project in 2021 entitled "Controlled Electrofabrication of Nanostructured Corrosion and Powdering Resistant Compositionally Modulated Multilayer (CMM) Zn-Alloy Coatings on Advanced High Strength Steels Alternate to Galvannealed Products" from Dr. C. K. Asnani, CMD, UCIL, Jadugoda, during 74th CSIR-NML Foundation Day function held on December 11, 2023, at Jamshedpur

AcSIR -NML

New Admission:

The following students were enrolled in the January 2024session

1. S Sivakumar (Industry Sponsored)
2. Kumar Pratim Das (Industry Sponsored)
3. B C Venkateshwarlu (Industry Sponsored)
4. Subhash Chandra Prusty (Industry Sponsored)
5. Kadu Satish Nagorao (Industry Sponsored)

PhD Award:

The studens who was awarded PhD within the period mentioned above:

Sl. No.	Name of the Student	Supervisor/(s)	Date of Award
1.	Dr. Saurabh Shekhar	Dr. K. K. Sahu	8th May, 2023
2.	Dr. Snehashish Tripathy	Dr. Sandip Ghosh Chowdhury Dr. S. Tarafder	17th May, 2023
3.	Dr. E. Z. Chacko	Dr. Sarmishtha Sagar Dr. Suvankar Ganguly	9th June, 2023
4.	Dr. Krishna Kumar	Dr. Manoj Kumar Dr. Suchandan Das	26th June, 2023
5.	Dr. Avanish Kumar Chandan	Dr. Mainak Ghosh Dr. Sandip Ghosh Chowdhury	7th August, 2023
6.	Dr. Sundara Bharathy	Dr. Mainak Ghosh Dr. T. Venugopalan	30th January, 2024
7.	Dr. Rashmi Singla	Dr. Sanjay Kumar Dr. Trilochan Mishra	26th February, 2024
8.	Dr. Gaurav Kumar Bansal	Dr. Sandip Ghosh Chowdhury Dr. V. C. Srivastava	4th March, 2024
9.	Dr. Komal Singh	Dr. Suman Kumari Mishra Dr. Paritosh Dubey	8th April, 2024

The total strength of AcSIR students at NML is 28.

Awards & Recognitions

National/International Awards/Recognitions

Dr. Sanjay Kumar, Chief Scientist

Scientific Excellence Award from the Secretary, Department of Mines & Geology, Government of Jharkhand during the 27th International Conference on Non-Ferrous Metals 2023 on July 7, 2023 held at Ranchi.



Fellowships Received

Dr. Trilochan Mishra, Chief Scientist

Elected as Life Fellow by the Indian Chemical Society on 1st August 2023 2023.





Dr. Sanjay Prasad, Principal Scientist

Selected as a life member of the Powder Metallurgy Association of India.





Paper/Poster Awards

Mr. Mahesh Gulab Walunj, Senior Scientist

Best Research Award 2023 for Excellence in Surface Engineering and Corrosion Protection by the Society of Surface Protective Coatings, at 15th International Conference on Surface Protective Coatings, September 15-16th 2023, held at The Hotel Lalit Mumbai International Airport.



Dr. Sanjay Agarwal, Senior Principal Scientist

Best Oral Presentation for paper "Metallurgical Waste" for Valorization of metallic values (Mo, Ni, Co) as alloy and Al2O3 as construction material from Spent Refinery Catalyst" in the International Conference on Management and Recycling of Metallurgical Waste" "MetWaste-2024," organized by the Department of Metallurgical Engineering, IIT (BHU), Varanasi, during 11th-12th February 2024.





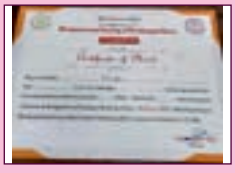
Best oral presentation in Advanced Ferrous metallurgy for "Technological Development on Pre-reduction of Chromite pellets in Tunnel Kiln & its Reduction Smelting in SAF to produce High Carbon Ferrochrome Alloy" in NMD ATM 2023.



Dr. D.C. Sau, Principal Scientist

Best Oral Presentation on the theme entitled "Green Technology" at the international conference on Management and Recycling of Metallurgical Waste, "MetWaste-2024," organized by the Department of Metallurgical Engineering, IIT (BHU), Varanasi, during 11th-12th February 2024.





Ms. Shilpa Kalamani Bawkar, Dr. Pankaj Kumar Choubey, Ms. Ruksana Parween, Mr. Pramod Kumar Singh and Dr. Manis Kumar Jha

Best Paper Award in International conference in powder metallurgy and particulate materials + exhibition 2023 (PM-23) conducted during the period of 13th to 15th March 2023 organized by Powder Metallurgy Association of India (PMAI) on 15th March 2023. The awarded article: "Recovery of copper powder from electronic industry effluent".



CSIR Foundation Day - Meritorious Staff Children Awards

List of Studentship Award to the children of CSIR employees for securing admission in 2023 for B. Tech. course in IITs, Post Graduate Programme (PGP) in Management of two years duration through Common Admission Test (CAT) in IIM after qualifying the relevant competitive examination held in the year 2023:



Mr. Soumyajit Ghosh
IIT (ISM) Dhanbad
2023



Miss. Stuti Dash
IIT (ISM) Dhanbad
2023

CSIR Foundation Day - Meritorious Staff Children Awards

One time lump sum cash award to the children of CSIR employees securing 90% marks or above in each of minimum three science subjects in the Senior Secondary Examination (12th Class) 2023:



Mr. Abhishek Sahu
95.33



Mr. Soumyajit Ghosh
95.00



Mr. Debjit Ghosh
94.00



Miss. Chayanika Chakraborty
93.33

CSIR-NML Foundation Day 2023 Awards (26th of November)

Professor Shilowbhadra Banerjee Award (Best In House Project)





Project Team: Dr. S.K. Jha, Dr. Gopi kishor Mandal and Sh. Mahesh Gulab Walunj

Project Title:

"Controlled Electrofabrication of Nanostructured Corrosion and Powdering Resistant Compositionally Modulated Multilayer (CMM) Zn-Alloy Coatings on Advance High Strength Steels Alternate to Galvannealed Products."



Nijhawan Award (Best Technical Paper)





Authors: Dr. Snehashish Tripathy , Dr. Sandip Ghosh Chowdhury, P.S. Manoranjan Jena, Vikash Kumar Sahu, Dr. S. Tarafder

Project Title:

"Importance of local equilibria in alloy design criteria for bulk nano-pearlitic steels and ensuing mechanical properties."



CSIR-NML Foundation Day 2023 Awards (26th of November)

Professor P. Ramachandra Rao Award (for Best Employees)




Technical:

1. Ramchandra Mahato, Senior Technician-II
2. Shailendra Kumar, Senior Technical Officer (1), Engineering




Non-Technical:

1. Ajay Tirkey, Section Officer(G), Administration
2. Salim Ansari, SSA(G), Stores & Purchase

Altekar Award (Best Technology Transferred/ Commercialized)





Team: Dr. Manish Kumar Jha, Dr. Jhumki Hait, Dr. Ranjeet Kumar Singh, P. K. Choubey, Rekha Panda, O.S Dinkar, R. Parween

Title:

"Recycling of Lithium-ion batteries to recover saleable metal/salt of Li, co, Mn, Ni, Cu, Al, Graphite and Plastics".



CSIR Foundation Day - Meritorious Staff Children Awards

Awards to those children/wards of CSIR-NML employees who have secured 90% or above marks in the Board Examinations (ICSE/ CBSE/ Jharkhand Board) in class 10th and 12th in the year 2023.



Miss. Debadrita Pal
10th



Miss Sourya Roy
10th



Miss Nandini Jha
10th



Miss. Prachi Roy
10th



Mr. Abhishek Sahu
12th



Miss Chayanika Chakroborty
12th



Mr. Soumyajit Ghosh
12th



Mr. Debjit Ghosh
12th

CSIR Foundation Day - Meritorious Staff Children Awards

Awards to those children/wards of CSIR-NML employees who have secured 100% marks in any subject in the Board Examinations (ICSE/ CBSE/ Jharkhand Board) in class 10th and 12th in the year 2023.



Miss. Stuti Dash



Mr. Soumyajit Ghosh



Mr. Debjit Ghosh

Awards won in Sports









CSIR-NML team won in the **51st SSBMT Tournament (Zonal)** held at CSIR-NGRI, Hyderabad held during January 2024. They have qualified for the finals to be played at IMMT Bhubaneshwar. Team- Manjit Singh (Carrom Singles); Manjit Singh & Neeraj Mehta (Carrom Doubles); Ramena Raju, Ved Prakash, Dr. Sanjay Agrawal (Table Tennis Team Event); Ramena Raju, Ved Prakash (Table Tennis Doubles)

SSBMT 2024 Final tournament at IMMT, Bhubaneswar- CSIR-NML won Runner up trophy in Carom team and Carom individual event.









Book Chapter / High Impact Factor/High No. of Downloads Journal Publication



Dr. Sanchita Chakraborty
Chief Scientist



Dr. Saswati Chakladar
Sr. Project Associate



Riya Banerjee
Project Assistant (2)

Publication of Book/Book Chapters

Book Title: Advances in drinking water Purification; Chapter Title: Arsenic removal using iron and manganese based adsorbents:Scope of utilizing natural resources and waste; Authors : Sanchita Chakravarty, Saswati Chakladar, Riya Banerjee; Publisher: Elsevier; Year: 2023





Dr. Saswati Chakladar
Sr. Project Associate



Dr. Ashok Kr. Mohanty
Senior Principal Scientist



Dr. Sanchita Chakraborty
Chief Scientist

Book Title:

Clean coal Technologies; Chapter Title: Oil Agglomeration Towards Quality Enhancement of High Ash coals: The Indian Scenario; Authors : Saswati Chakladar, Ashok Mohanty, Sanchita Chakravarty





Dr. Murtuja Hussain
Principal Scientist

Book Chapter: Part of the book series: Lecture Notes in Mechanical Engineering ((LNME))

Authors: Abdul Rahman, Md. Murtuja Hussain and Naresh Prasad, The Role of Quasi-static Strain Rate on the Mechanical Behaviour of WE43 Magnesium Alloy, 2023, Recent Adv. in Manuf. and Thermal Eng., pp 377-387. https://link.springer.com/chapter/10.1007/978-981-19-8517-1_28





Dr. Trilochan Mishra
Chief Scientist



Dr. P. Bhattacharya
Senior Scientist

Impact Factor: 10.3; S. Das Chakraborty, U Kumar, P. Bhattacharya, T. Mishra*,

Book Title: "Tailoring of visible to near-infrared active 2D MXene with defect-enriched titania-based heterojunction photocatalyst for green H2 generation", ACS Applied Mater Interface, 2024, 16 (2), 2204-2215





Dr. M. Malathi
Principal Scientist



Dr. Dayanad Paswan
Principal Scientist

Book Chapters:

- Adeleke, A.A., Ikubanni, P.P., Odusote, J.K., Muraina, H.O., Harmanpreet Singh, Paswan, D., and Malathi, M. (2024) "Sustainable production of sponge iron through direct reduction process: Waste recovery from mill scale". https://www.routledge.com/SustainableManufacturing-An-Emergence-in-Industry-40/Sandhu-Singh-Kumar-DavimRamakrishna/p/book/9781032313092 (Scopus indexed)
- Dayanand Paswan and Malathi Madhurai (June 2023) "An Innovative Process for Production of TiO2 from Low Grade Raw Materials, Published in IntechOpen, Iron Ores and Iron Oxides, New Perspectives", DOI: 10.5772/intechopen.1001277, Edited by Brajesh Kumar

Book Chapter / High Impact Factor/High No. of Downloads Journal Publication



Dr. Ganesh Chailavadi
Senior Scientist

Book Title:

Current Trends in Mineral-Based Products and Utilization of wastes: Recent studies from India. Chapter Title: Fine Size dry iron ore beneficiation using Thin Bed air fluidized dry separator. Page: 133-138 eBook ISBN 978-3-031-50262-0 Print ISBN 978-3-031-50401-3



High Impact Factor Journal Publication



Dr. Pratima Meshram
Principal Scientist

Impact Factor: 16.2; Emily Grubert, Lira Luz Benites Lazaro, Leon Merfort, Alexander Popp, Tianyi Luo, Vassiliki Kati, Pratima Meshram, Felix Malte Dorn, Diana Hernández, Making low-carbon energy sustainable, One Earth, 2024, 7(2): 163-166; DOI: 10.1016/j.oneear.2024.01.019; https://doi.org/10.1016/j.oneear.2024.01.019; https://authors.elsevier.com/c/1icHL9C~Iu3z6R



Dr. Ankur Sharma
Scientist

Impact Factor: 15.1 ; Rajkamal, A; Sharma, A; et al. Engineering lithium nickel cobalt manganese oxides cathodes: A computational and experimental approach to bridging gaps. Chemical Engg. Journal 2024, 481, 148223. Doi: 10.1016/j.cej.2023.148223



Dr. Mudila D. Rao
Scientist

Impact Factor: 8.1; Life cycle analysis on sequential recovery of copper and gold from waste printed circuit boards' in the 'Waste Management' Journal



Dr. Pallab Bhattacharya
Senior Scientist

Impact Factor = 8.06 ;Nisha Gupta, and Pallab Bhattacharya*. "Microwave-plasma induced one-step synthesis of Ni (PO3)2 nanosphere-loaded bio-waste derived N, P co-doped carbon for an asymmetric supercapacitor with prolonged life." Journal of Materials Chemistry C 11, no. 39 (2023): 13503-13517.

High Number of Reads/Downloads/Cited Journal Publication

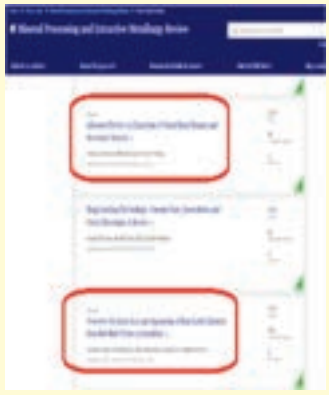


Dr. Pratima Meshram
Principal Scientist

Most downloaded papers In Hydrometallurgy



Most READ PAPERS in Mineral Processing and Extractive Metallurgy Review



Most CITED PAPERS in Mineral Processing and Extractive Metallurgy Review



Editorial Board Memberships, National/International Committee Memberships



Dr. Sarmishtha Palit Sagar
Chief Scientist

- Member of the Editorial board of Journal of Non-Destructive Testing, Indian Society for NDT



Dr. Trilochan Mishra
Chief Scientist

- Open Chemical Engineering Journal (Bentham Publisher).
- Member of Bureau of Indian Standards (BIS) for Inorganic Chemical Section Committee (CHD-1)
- Organizing member of G20 meeting, 2023 at Ranchi on "Sustainable energy materials".



Dr Jagannath Pal
Chief Scientist

- Appointed as Member of Task Force#6 on "Material Efficiency" towards decarbonisation of Steel sector constituted by Ministry of Steel (Govt. of India)



Dr. Pratima Meshram
Principal Scientist

- Editorial Board Member, Austin Journal of Environmental Sciences
- Editorial Board Member, International Journal of Mineral Processing and Extractive Metallurgy
- Editorial Board Member, International Journal of International Journal of Chemical Engineering

Editorial Board Memberships, National/ International Committee Memberships



Md. Dr. Murtuja Husain
Principal Scientist

- Editorial Board Member of International Journal of Materials Science and Applications



Dr. Pallab Bhattacharya
Senior Scientist

- Review editor on the editorial board of electrocatalysis (specialty section of frontiers in catalysis

Participation in DST-Young Scientist Conclave



Dr. Nikhil Kumar
Scientist

Participation in Shanghai Cooperation Organization - Young Scientist Conclave (SCO-YSC) under theme Sustainable energy systems & energy storage organized by DST India at JNCASR Bengaluru from 06-10 February 2023. Under the theme Sustainable energy systems & energy storage, only a couple of Scientists from all over India got selected by DST. Participating countries: The Republic of India, The Republic of Kazakhstan, The People's Republic of China, The Kyrgyz Republic, The Islamic Republic of Pakistan, The Russian Federation, The Republic of Tajikistan, The Republic of Uzbekistan. Young scientists from all the above eight countries participated and presented their research work under five themes: Agriculture and food processing, Environmental protection and natural resource management, Artificial intelligence (AI), Sustainable energy systems and energy storage, Disease biology and healthcare.



Invited Talks Delivered



Dr. Sandip Ghosh Chowdhury
Director, CSIR-NML

- Prof. A K Seal Memorial Lecture 2023, IIM, Kolkata



Dr. Sobhana Dey
Chief Scientist

- Acted as a session chair for the session "Composite 1" of the "International Conference on Advancement in Materials Processing Technology" (AMPT-2023) on 13th July, 2023 at NIT Jamshedpur.
- Advancement in Mineral Processing Techniques with special reference to Iron and Coal. (AMPTIC – 2023); Topic: Coal Processing in India: Problems and Prospects
- Continuous Professional Development (CPD) Program on Advanced Mining Technologies for Senior Executives of OMC on 26th Feb 2024; Topic: Conservation of resources by processing of waste dumped iron ore fines



Dr. Raghuvir Singh
Chief Scientist

- "Metallurgical issues in Oil & Gas Industries" in "R&D Collaboration: Opportunities, challenges and best practices in E & P" and 4th R&D Meet of ONGC institutes organized by ONGC at KDMIPE Campus Dehradun during 17-18 March 2023
- "Corrosion issues and materials integrity in oil & Gas industries" at Two days workshop and training program on Advances in Corrosion technology and Prevention ACTP 2023 during 19-21 July 2023 at IMMT Bhubaneswar
- "Corrosion of steel structures and protection Strategies in power plants" during Head of Technical Services Meet on "Corrosion and its Protection" organized by NTPC is at Vishakhapatnam on 31st Oct & 01st Nov 2023
- "Capacity building for corrosion research and industrial problem solving" Workshop on "Managing Impact of Corrosion on Asset Integrity" organized by India Energy network in collaboration with IISc, Bangalore, RGIPT, InSIS during 19-20 January 2024 at Seminar Hall, Aerospace department, IISC Bangalore



Dr. Jagannath Pal
Chief Scientist

- Delivered invited talk in International Conference on Metallurgical Engineering and Centenary Celebration (METCENT 2023), 26-28 October 2023 at the Department of Metallurgical Engineering, IIT (BHU), Varanasi.
- (II) Delivered invited talk in the Seminar, "Advancement in Minerals Processing Techniques with special reference to Iron and Coal (AMPTIC-2023)" during 04th -08th Sep. 2023, in NIT-Jamshedpur.



Dr. A. Vidyadhar
Senior Principal Scientist

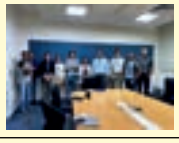
- Invited Talk in Advancement in Mineral Processing Techniques with special reference to Iron and Coal. (AMPTIC – 2023) ; Topic: Beneficiation of Non-coking and Coking Coal: Unlocking the Potential





Dr. Sarmishtha Palit Sagar
Chief Scientist

- Keynote lecture at the National seminar on NDE 2023; 06/12/23 at Pune; Invited talk on "Research activities on NDE @CSIR-NML" on 04/01/2024 at GE, Bangalore





Dr. Jay Chakraborty
Chief Scientist

- Invited talk on 21st March, 2022 at the Satellite session of InPAC, a national conference on " Applications of high energy X-rays in materials science : role of high energy 4th generation light sources" organized by RRCAT Indore (Raja Ramanna Center for Advanced Technology), Department of Atomic Energy. Topic: 'High energy synchrotron X-ray diffraction for solving materials research problems in industry'.

Invited Talks Delivered



Dr. Trilochan Mishra
Chief Scientist

- Invited lecture on "Faculty Development Program" hosted by MSCB university, Baripada during 29-04-23 to 2-06-23.
- Delivered Keynote lecture "Indigenous technology for Viksit Bharat" on the occasion of Science day celebration of MSCB university, Baripada on 28-02-24.
- Invited lecture on "national Conference on Recent Advances in Material Sciences" during 15-03-24 to 16-03-24







Dr. D. C. Sau
Principal Scientist

- Title: Green Steel: Production of DRI fines from Low Grade Iron Ore fines in Fluidized Bed Reactor using Hydrogen Gas; 26-28 Oct. 2023, IIT (BHU) Varanasi, METCENT-2023.
- Title: Iron oxide fines reduction to magnetite powder used for heavy media separation using eco-friendly CNG (Compressed Natural Gas); MetWaste-2024, 11-12 Feb. 2024, IIT (BHU)Varanasi



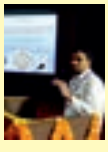
Dr. Ranjeet Kumar Singh
Principal Scientist

- Invited talk as an External expert in 4th Annual Raw Material Workshop - Saint Gobain India " at Chennai on 12th Sept 2023. Image is attached separately. Topic: Sand Beneficiation and its sustainability



Dr. Mudila Dhanunjaya Rao
Scientist

- Title: Effect of size and milling time of Zinc dust on purification of Zinc sulphate electrolyte sing response surface methodology"; Invited talk at METCENT 2023, An international conference on Metallurgical Engineering and Centenary celebrations at the Department of Metallurgical Engineering, IIT (BHU), Varanasi during 26-28 October 2023.







Dr. K. Gopala Krishna
Chief Scientist

- Invited talk delivered at IIT-BHU as a part of one day workshop on "Powders for Additive Manufacturing" organized by Dept of Mechanical Engineering as part of DRDO DIA-CoE, IIT(BHU) Varanasi, 11.12.23





Dr. Sanjay Agarwal
Senior Principal Scientist

- Invited Lecture on "R&D Activities on the production of Electrolytic Manganese Dioxide and Manganese Metal at CSIR-NML" at Manganese/ Chrome Ores, EMD, EMM & Ferro-Alloys Summit, 18th December 2023, Visakhapatnam, India.



Dr. M. Malathi
Principal Scientist

- Keynote Speaker on the topic of "Biomass Torrefaction, Densification and Utilization" at on "Recent Trends in Metallurgy & Material Science" scheduled from the 1st to 3rd of March, 2024, conducted by the Metallurgical & Materials Engineering Student Association (MetSA) at IIT Madras.



Dr. Pallab Bhattacharya
Senior Scientist

- Invited talk delivered at the International Conference on Functional Materials (ICFM) held at materials science centre, IIT Kharagpur during 9-11 january, 2024. Title: "Cost effective development of highly pure Ti3AlC2 MAX for Ti3C2 MXene based supercapacitors"





Dr. Navneet Singh Randhawa
Senior Technical Officer (2)

- Invited Talk in the International Conference on Fundamentals and Industrial Research in Materials (iConFIRM 2023) organized by IIT-Ropar on 12-15 December 2023. The topic of talk was "Unlocking the recycling potential of metallurgical slags: Exploring Sustainable Solutions."
- Chaired the session on "Waste to wealth: Recycling of materials" in iConFIRM 2023.

Media Appearances



Dr. Pratima Meshram
Principal Scientist

Research Quoted in National Newspaper:
https://www.thehindu.com/sci-tech/science/rare-earth-elements-scandium-secondary-source-red-mud-mineralogy/article66690854.ece

Appearance in Cell Press Article about Sustainable Energy (Online)





Dr. Pallab Bhattacharya
Senior Scientist

Featured in the community spotlight blog published by the journal of materials chemistry c of royal society of chemistry (RSC).

Web link:
https://blogs.rsc.org/jm/2023/12/05/journal-of-materials-chemistry-a-b-and-c-10th-anniversary-community-spotlight-first-time-authors-2/?doing_wp_cron=1711534603.7584969997406005859375



Leading Women of India...

Women Leading Government Missions

Indian Women who have been heading government institutions and implemented schemes that have reshaped the country's present & future.

"Actions speak louder than words. If you do your actions to the best you can, you sleep peacefully"

Nivruti Rai is currently serving as the MD and CEO of Invest India. Invest India is the National Investment Promotion and Facilitation Agency that helps investors looking for investment opportunities and options in India As former Intel India head, she spent 29 years as a global business and technology leader. She earlier contributed in the capacity of Vice President of Intel Foundry Services and the Country Head of Intel India. She represents Intel India's product development activities in artificial intelligence (AI) 5G (fifth-generation cellular network technology), autonomous systems for SoC (system on a chip), the Internet of Things (IoT). and cloud computing In charge of IP design services and automotive verticals. Nivruti Rai, a well known tech. expert. She was bestowed with the Nari Shakti Puraskar on International Women's Day 2022 for her remarkable commitment to women's empowerment and contributions to the field of technology.



NIVRUTI RAI

MANAGING DIRECTOR AND CHIEF EXECUTIVE OFFICER, INVESTMENT PROMOTION AND FACILITATION AGENCY (INVEST INDIA)



PRAVEENA RAI

CHIEFOPERATINGOFFICE, NATIONAL PAYMENTS CORPORATION OF INDIA (NPCI)

"The need for modern, efficient, and secure platforms in credit is paramount in the current scenario"

Praveena Rai has played key role in making the present digital India. She has significantly influenced the Indian digital payments scenario by launching the leading products in this sector viz. UPI and RuPay. As COO, she is responsible for supporting the growth of its existing new products and achieving the strategic objectives of the organization. She aims for rapid digitisation of of India and providing secure seamless user experience with the products of NPCI. She is veteran banker, with over three decades of experience in Citi Bank, HSBC Bank, and Kotak Mahindra Bank. She has been listed as India's Top Self Made Women by Forbes 2024.

New Facilities

Laboratory Scale Inert Gas Atomizer for producing high purity spherical metal/alloy powders

Manufacturer: M/s Blue Power, Germany; Model: AUG1000

Gas atomisation involves, breaking up of a molten metal stream using high pressure inert gas & is an effective method of producing fine spherical metal powders; Capable of producing both (i) pure metal powders of Gold (Au), Iron (Fe), Nickel (Ni), Copper (Cu) etc. and (ii) wide range of alloy powders based on Fe, Ni, Co, Au etc.; Includes melting furnace based on induction heating; The melt capacity is 1.0 litre melt with bottom pouring mechanism with close coupled nozzle; Provisions to control the particle size. Typical d_{50} of the produced powders in a batch, found to be about 40±10 m (where d_{50} is mass median diameter); Includes view ports in both melting furnace and atomization chamber. Another port in atomization chamber is fitted with CCD camera; Designed for economical & flexible production of comparably small quantities of metal powders in batches; High yield, low cleaning efforts with little metal loss & contamination; Suitable for precious metals/ alloys; High process stability promising repeatability; Highly suitable for R&D, where frequent alloy changes arises;

Recent contribution towards "Self reliant India (Atma Nirbhar Bharat)": *For the first time in India, we have produced 22K / 18K gold alloy powders having spherical shaped particles with requisite size range.*



Inert Gas Atomizer (AUG 1000) facility at LSTF Pilot plant, CSIR-NML



Gold Powder

Installation & Commissioning of Potentiostat / Galvanostat

Multi-channel Autolab "OUT MAC 204.S" potentiostat / galvanostat with one 10A current booster machine has two channels and extendable to another 8 channels. One channel is connected with EIS. The system is completely independent "NOVA 2.0 Advanced" software controlled. Presently we are using it for energy storage and conversion application. In particular, we are using for development efficient electrocatalyst for overall water splitting for pure green hydrogen production and development of Capacitor.



Carbon & Sulfur Determinator (ELTRA CS-i Carbon & Sulfur Analyser)

ELTRA CS-i Carbon & Sulfur Analyser is used to measure Carbon & Sulfur content in Ores, metals, ferro alloy, refractories, and inorganic materials. It has an advanced induction furnace with along with self-control operating system for more detailed temperature profiles, programmable ramping, and complete control of set points. ELTRA CS-i Carbon & Sulfur Analyser is equipped with automatic cleaning system facility for easy operation. The equipment has facility for drift correction, blank calibration, multipoint calibration as well as gas dose calibration which makes its usable for carbon and Sulfur determination of wide range & variety of samples from PPM to % level. It will be used for development of different grade steel, ferro alloy & Other Ore CRMs under our CRM service activity. It is also extensively use for ongoing and outside R & D project samples.

Specification : Instrument Range at 1 g sample: For Carbon: 1 ppm to 7 % & Sulfur: 1 ppm to 0.4 %. Precision: Carbon: 0.2 ppm or 0.4% RSD & Sulfur: 0.2 ppm or 0.4% RSD whichever is greater. Detection Method: IR Detector.

Blender Retort Furnace Maximum Temperature 1150-1200 Deg. C

This furnace can able to treat the material at high temperature under rotation at fixed angle with efficient mixing. Such furnaces are used to heat treat the material. It can also be used for roasting under a gas atmosphere and the presence of salts.



Rectifier Arc Melting Furnace Transformer Power make 108KVA 415V/ 20- 90V 1200Amps Furnace

Electric furnace transformers are transformers which supply power to the electric furnaces. It can drop high voltage to the working voltage the electric furnaces need. There are many kinds of electric furnaces, so there are many kinds of electric furnace transformers cooperating with them. Now, our company manufactures following electric furnace transformers: electric furnace transformers used in steelelectric furnaces(including on-laod,no-load and enclosed reactor); mineral hot furnace transformers used to smelt kinds of iron alloys, hydrosilicons, carbides, etc (single phase, three phases on-load and no-load tap changer). They are low loss and energy-saving products. Cooling methods are self-cooling, forced oil water cooling, etc.It can be designed specially according with customers' requirements.

High Pressure Stirred Reactor System Titanium Grade II with Accessories HPAL-Ti



This pressure leaching system has a Vessel & head of Titanium grade II and operating capacity of 100mL. The reactor is rated for 70 bar at 250 o C. This system can be used for High Pressure acid leaching (except HF) of various raw materials.

High Pressure Stirred Reactor System Inconel with accessories HPAL-Inconel



This pressure leaching system has a Vessel & head of Inconel 600 and operating capacity of 100mL. The reactor is rated for 200 bar at 350 o C. This system can be used for High Pressure alkali leaching of various raw materials.

Laboratory Scale Solvent Extraction Mixer Settler LAB-SX

The lab scale solvent extraction setup is operational with 5L PLS and consists of 2 Mixer, 1 Scrubbing and 1 Stripping vessel. It is completely assembled on powder coated MS frame and has option to recycle either aqueous or organic and also has adjustable aqueous over-flow weirs for interface level control in the settlers. It has variable speed constant torque mixers with digital rpm indication. It has PTFE impellers and PP threaded fittings. Peristaltic metering feed pumps with digital rpm indication.

Arbitary Waveform Generator Model : WF1968



The Arbitrary Waveform Generator (WF1968 Multifunction Generator) is a multifunctional oscillators based on DDS (Direct Digital Synthesizer). It is equipped with two channels and supports a wide band range with sine wave output from 0.01 µHz to a maximum of 200 MHz, square wave and pulse wave output from 0.01 µHz to 70 MHz. The frequency output accuracy is ± (3 ppm of setting + 6 pHz) and 0.01 µHz (less than 50 MHz) of high resolution frequency settings are available. With its original circuit configuration, this model achieves 16-bit amplitude resolution. Waveforms of every type — sine wave, square wave, arbitrary wave, etc. can be obtained with low spurious signal levels. The maximum output voltage is 20 V p-p below 110 MHz. The minimum setting resolution is 0.1 mV p-p , and a setting of 0 V p-p is also possible. The auto range function enables the optimal output voltage range to always be selected from the



full output voltage range. By setting the level to reduce the degradation of the amplitude setting accuracy, very high amplitude setting accuracy can be achieved. In addition, when amplitude discontinuity due to range switching becomes a problem, it is also possible to select range hold. The basic waveforms as sine wave, square wave (duty variable), pulse waves (pulse width, duty, rising/falling time variables), ramp wave (symmetry variable), noise (Gaussian distribution), and DC can be generated, and preinstalled 25 types of waveforms (parameter-variable waveform) that commonly used in various fields are supported also. In addition, we can define arbitrary waveforms up to 1Mi*(Mi represents 220 = 1048576) words in maximum, and these can be easily set on the control panel or created using the included arbitrary waveform editor.



Creation of National Facilities

E-waste/Urban Ore Recycling Centre- Funded by MeitY, Govt. of India

CSIR-NML received a joint mega project (CSIR-NML, C-MET, CIPET) on e-waste recycling entitled "Informal sector capacity building up-gradation with formation of recycling clusters under MSME scheme and enabling technology for recovery of resources from electronic waste thereby promoting resource efficiency and circular economy" of total project value over 60 Crores. A Centre dedicated for the development of feasible technologies to recover non-ferrous, precious and rare earth metals from secondary resources has been established and named as Urban Ore (E-waste) Recycling Centre, CSIR-NML, Jamshedpur. NML has already transferred number of technologies to various recycling plants for commercial exploitation under the aegis of Urban Ore Recycling Centre with high Customer Satisfactory Index. Using the existing common facilities to recycle Urban Ores, the arrangements are made to train the Master Trainers under this project.

The major activities carried out under the project were as follows:

- *Training of 50 master trainers to handle 15000 informal operators throughout the country, identification of value chain and to convert them to micro entrepreneurs.*
- *Dissemination of technology for recycling PCBs through setting up of recycling common facility in form of clusters of micro-entrepreneurs throughout the country.*
- *Creation of content (manuals) in various scripts, power point presentations and video recordings.*



Facilities to train Master Trainers



Saleable Products

Battery Dismantling Pilot Plant Facility

Realizing the potential of battery recycling to meet the critical demand for Lithium, Nickel, Manganese, and Cobalt, and adhering to India's Atmanirbhar EV mission, the CSIR-National Metallurgical Laboratory, Jamshedpur with the support of CSIR-Bulk Chemical Mission, has commissioned CSIR's First Battery Recycling Pilot Facility at its campus. This facility encompasses 1TPD battery dismantling and cathode material separation setup, apart from the integrated large-scale hydrometallurgical facility for extraction and separation of aforesaid critical metals. The facility is able to tackle any kind of spent rechargeable batteries belonging to the class of lithium-ion batteries (including LFPs), nickel-based batteries, for process validation and technology transfer under HIRE-OPERATE-TRANSFER mode.



1TPD Battery Dismantling and Powder Separation Setup at CSIR-NML

Centre of Excellence (CoE) in Wear and Corrosion Resistant Coatings Technology

The mineral rich Eastern India encompasses a large numbers of industries related to metals and its alloys either its production or its applications. However, the research activities on the wear and corrosion of metals and alloys are scattered and a centre for wear and corrosion for metallurgical materials was thought to create in the eastern region to help the industries and academia, where all the facilities are available within one premises. CSIR-National Metallurgical Laboratory, being one of the premier institutes on metallurgy, is awarded a project to establish centre of Excellence (CoE) in wear and corrosion resistant technology. The proposed centre will host a large numbers of sophisticated equipment facilities including existing facilities and carry out contemporary research on the development of wear and corrosion resistant coating technologies. Thus, the centre will primarily focus on two aspects:

- Creation of integrated facility in eastern zone of India to address the problems of material degradation encountered by industries due to wear and corrosion.
- Translation of laboratory scale research to industries at all levels (small scale, medium, and large scale).

Under the objective integrated facility creation, following major equipments are expected to be added in the centre:

(i) Electrochemical Workstation (PGSTAT) with Temperature, pH and Dissolved Oxygen Sensor

(ii) Bipolar Power Supply for Micro Arc Oxidation

(iii) Coating thickness measurement system on both ferrous and non-ferrous substrates.

(iv) Rebar corrosion detector and resistivity meter

(v) Ultrasonic processor

(vi) Slurry Jet Erosion Tester

(vii) Ultrasonic Shot Peening Machine

(viii) High Temerature Electrochemical cell with Multichannel Potentiostat/Galvanostat

(ix) High Temerature Erosion-Corrosion Test rig

The centre will work on below mentioned work packages for translation of laboratory scale research to industries:

WP-1 : Powdering Resistant and Phase Specific Zinc-Iron-Alloy Electroplated Steel Sheet Similar to Galvannealed Products

WP-2 : Polymer Based Conversion Coating for Production of Ready to Paint Steel

WP-3 : Self-healing Polymeric Coating for Corrosion Protection of Steel

WP-4 : Ceramic Coatings for Corrosion Protection of Steel in Highly Corrosive Environment

WP-5 : Advanced Colorized Hot Dip Galvanising Zn-X (X- Mn, Ti, Co) Alloy Coating with Excellent Powdering and Corrosion Resistant

WP-6 : Development of Fe-based amorphous alloy and its coating by HVOF for hydro turbine components

WP-7 : Engineered Surface with high Stress Corrosion Cracking resistance by Ultrasonic Shot

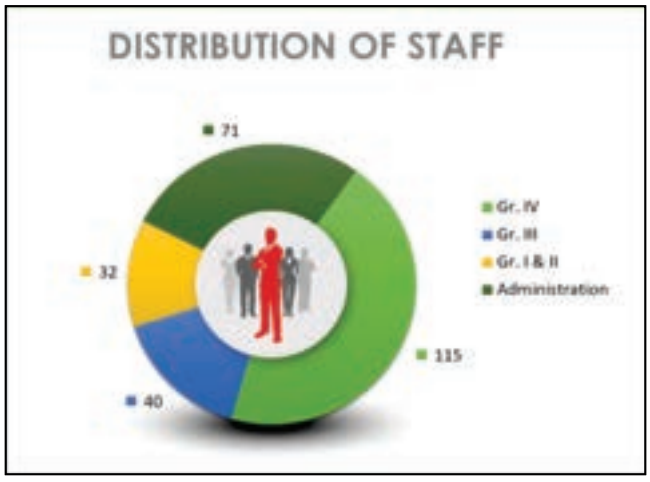
WP-8A: Wear and corrosion resistant metallic coatings for boiler components

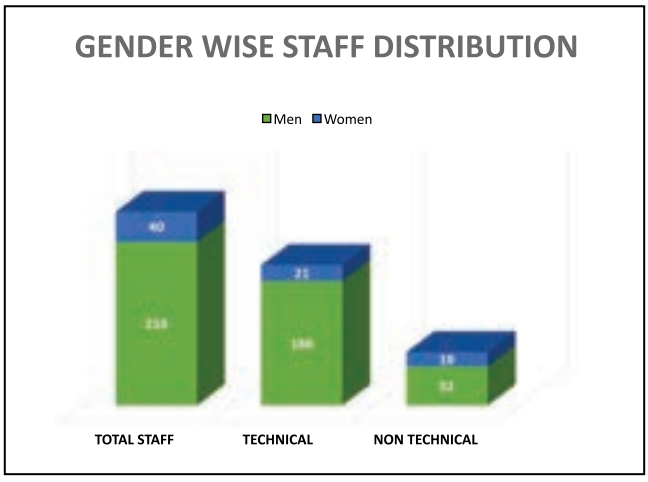
WP-8B: Surface modification process for enhanced molten chloride salt corrosion resistance

WP-9 : Development of MAO coating on Ti2ALNb alloys for high temperature oxidation & hot corrosion resistance

WP-10: Corrosion Resistant Zn-alloy Coatings for Railway Track

Human Resources & Staff News





Staff Joined on Transfer from Sister Laboratory



Shri P. D. Lakra
Section Officer(General)
1st August 2023
CSIR-CIMFR, Dhanbad



Shri. Dayakant Kumar
Finance & Accounts Officer
10th October 2023
CSIR-CIMFR, Dhanbad

Staff Transferred on Promotion to Join Sister Laboratory



Mr. Raj Kumar Droch
Senior CoFA
14th July 2023
CSIR-CSIO, Chandigarh



Shri Amod Kumar
ASO(G)
2nd August 2023
CSIR-CIMFR, Dhanbad

Staff Superannuated



Dr. GVS Murthy
Sr. Principal Scientist
30th April 2023



Shri Mohan Dungri
Bearer
30th April 2023



Dr. J. Swaminathan
Chief Scientist
30th June 2023



Dr. Kanhailal Hansda
Chief Scientist
31st August 2023



Dr. Mita Tarafder
Chief Scientist
31st August 2023



Dr. A. K. Arya
Pr. Technical Officer/
Sr. Medical Officer
30th November 2023



Shri T. B. Thapa
Bearer
31st November 2023



Shri Santosh Kumar Mukhi
MTS
31st December 2023



Md. Salim Ansari
SSA(G)
31st January 2024



Shri Manjit Singh
Principal Technical Officer
31st March 2024

New Joinee



Mr. Abhijeet Manasingh
Scientist
7th June 2023

Staff Resigned



Dr. Sunati Mohanty
Principal Scientist
17th June 2023

Demise of Staff



Shri Chandra Sekhar Singh
MTS
20th September, 2023

Deputations

INTERNATIONAL DEPUTATIONS

#	Name	Place of Visit	Purpose/Role	Start Date	End Date	Organized By
1	 Dr. Sanchita Chakravarty, Chief Scientist	Croatia	To Attend an International Scholarship Programme	24 Apr. 2023	06 May 2023	University of Zagreb, Croatia

NATIONAL DEPUTATIONS

#	Name	Place of Visit	Purpose/Role	Start Date	End Date	Organized By
1.	Dr. Madan M Principal Scientist	Kolkata, India	To Attend an International Seminar on "Preparedness of Indian Ferroalloy Industry Towards Atma Nirbhar Bharat "	24 Apr. 2023	24 Apr. 2023	Steel Tech, Kolkata
2.	Dr. Navneet Singh Randhawa Senior Technical Officer(2)					
3.	Mr. Vikas Shivam National Post Doctoral Fellowship	Mumbai, India	To Attend an International Workshop on "High Entropy Materials"	23 Apr. 2023	25 Apr. 2023	The IIM Mumbai Chapter & Materials Research Society India Mumbai Chapter
4.	Mr. Shubhada Kar GATE Senior Research Fellow					
5.	Dr. Ammasi A Senior Scientist	Mumbai, India	To Attend a National Conference on " India Steel 2023 and Round Table on Circular Economy & By Product Utilization "	19 Apr. 2023	21 Apr. 2023	Federation of Indian Chambers of Commerce & Industry (FICCI) and Ministry of Steel, Government of India
6.	Dr. Jagannath Pal Chief Scientist					
7.	Dr. Animesh Jana Senior Scientist	Ghaziabad, Uttar Pradesh	To Attend a Training Program on "46th Induction Programme for newly recruited scientists "	30 May 2023	08 Jun. 2023	Council Of Scientific And Industrial Research–Human Resource Development Centre
8.	Dr. Ranjeet Kumar Scientist					
9.	Dr. Mudila Dhanunjaya Rao Scientist					
10.	Dr. Satyajit Mukherjee Senior Scientist					
11.	Mr. Adeolu Adediran National Post Doctoral Fellowship	Hyderabad, Telangana	To Attend an International Conference on "Design and Manufacturing Aspects for Sustainable Energy"	19 May 2023	20 May 2023	Gokaraju Rangaraju Institute of Engineering and Technology, Hyderabad
12.	Dr. Abhilash Senior Principal Scientist	New Delhi, India	To Attend a National Conference on "9th India Energy Storage Week"	01 May 2023	06 May 2023	India Energy Storage Alliance
13.	Mr. Ajit Kumar Swain Principal Scientist	Online	To Attend a Training Program on "Metallurgical Accounting"	01 May 2023	01 Jun. 2023	Caspeo France
14.	Mr. Shivendra Sinha Senior Scientist	Kolkata, West Bengal	To Attend a Review Meeting on "Waste to Wealth"	13 Jun. 2023	14 Jun. 2023	Council of Scientific And Industrial Research–Innovation Management Directorate
15.	Mr. Nimai Haldar Senior Technical Officer (1)	Rourkela, Odisha	To Attend a Workshop on "Additive Manufacturing Knowledge and Skill Development Towards Industry 4.0 (AM KSD 2023)"	10 Jun. 2023	14 Jun. 2023	National Institute of Technology, Rourkela

#	Name	Place of Visit	Purpose/Role	Start Date	End Date	Organized By
16.	Mr. P. V. S. Chaithanya Senior Research Fellow	Jamshedpur, Jharkhand	To Attend a Seminar on "Behind The Teacher's Desk (BTTD 2023)"	08 Jun. 2023	09 Jun. 2023	Indian Institute of Metals (IIM), Jamshedpur Chapter, CSIR National Metallurgical Laboratory, National Institute of Technology Jamshedpur, Academy of Scientific and Innovative Research
17.	Mr. Manoranjan Jena Senior Research Fellow	Jamshedpur, Jharkhand	To Attend a Seminar on "Behind The Teacher's Desk (BTTD 2023)"	08 Jun. 2023	09 Jun. 2023	Indian Institute of Metals (IIM), Jamshedpur Chapter/ CSIR National Metallurgical Laboratory/ National Institute of Technology Jamshedpur/ Academy of Scientific and Innovative Research
18.	Mr. Abhinav Kumar Project Assistant					
19.	Mr. Vikash Kumar Sahu Senior Research Fellow					
20.	Mr. Vamsi Krishna Modalavalasa, Project Associate					
21.	Mr. Sukalpan Nandi Graduate Aptitude Test in Engineering Senior Research Fellow					
22.	Dr. Vinod Belwanshi, Scientist	Jamshedpur, Jharkhand	To Attend a Workshop on "Advance Nondestructive Testing & Application"	20 Jul. 2023	20 Jul. 2023	Indian Society for Non destructive Testing (ISNT), Jamshedpur Chapter
23.	Dr. Sarmishtha Sagar Chief Scientist					
24.	Dr. Suman Tewary Senior Scientist					
25.	Dr. Arpita Ghosh, Principal Scientist					
26.	Dr. Navneet Singh Randhawa Senior Technical Officer (2)	Ranchi, Jharkhand	To Attend an International Conference on "Non ferrous Metals 2023 (ICNFM 2023)"	07 Jul. 2023	08 Jul. 2023	Corporate Monitor, Kolkata
27.	Mr. Sambit Tripathy Project Assistant 1					
28.	Mr. Kumar Saurav Project Assistant 1					
29.	Mr. Akshay Kumar Project Assistant					
30.	Mr. Shibsundar Das Project Assistant					
31.	Dr. S. Sivaprasad Chief, Scientist	Tamil Nadu	To Attend an International Conference on "Structural Integrity"	23 Aug. 2023	25 Aug. 2023	Indira Gandhi Centre for Atomic Research (IGCAR) Kalpakkam
32.	Dr. Nikhil Kumar Scientist	Kolkata, West Bengal	To Attend a Conference on "National Science Exhibition 2023"	24 Aug. 2023	27 Aug. 2023	Council of Scientific & Industrial Research Headquarters
33.	Dr. S. K. Sahu Senior Principal Scientist	Goa	To Attend an International Conference on "Rare Earths for Energy Security (REES 2023)"	17 Aug. 2023	18 Aug. 2023	Rare Earth Association of India
34.	Dr. Asit Baran Panda, Senior Principal Scientist	West Bengal	To Attend a Seminar on "Sustainable Development in Chemical Science"	17 Aug. 2023	18 Aug. 2023	Science and Engineering Research Board & Mugberia Gangadhar Mahavidyalaya

#	Name	Place of Visit	Purpose/Role	Start Date	End Date	Organized By
35.	Mr. Mahesh Gulab Walunj Senior Scientist	Telengana	To Attend a National Symposium on "Electrochemical Science and Technology"	17 Aug. 2023	18 Aug. 2023	Electrochemical Society of India & International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI)
36.	Dr. Abhilash Senior Principal Scientist	Jamshedpur	To Judge an Interschool Fest Infinity 2K23	02 Aug. 2023	02 Aug. 2023	Vidya Bharati Chinmaya Vidyalaya, Jamshedpur
37.	Dr. Ranjan K Sahu Chief Scientist					
38.	Dr. Arvind Kumar Upadhyay Principal Technical Officer	West Bengal	To Attend a Seminar on "7th PTP/RMP Conclave"	16 Aug. 2023	17 Aug. 2023	National Accreditation Board for Testing and Calibration Laboratories (NABL), Gurugram
39.	Dr. Sanchita Chakravarty Chief Scientist					
40.	Ms. Rupa Das Biswas Senior Technical Officer					
41.	Dr. Ranjeet Kumar Singh Principal Scientist	Chennai, Tamil Nadu	To Attend a Workshop Program on "4th Annual Raw Material"	11 Sept. 2023	13 Sept. 2023	Saint Gobain India Pvt. Ltd.
42.	Mr. Pallab Bhattacharya Senior Scientist	West Bengal	To Attend a National Conference on "Current Trends and Future Extensions of Green Chemistry (CTFEGC)"	21 Sept. 2023	22 Sept. 2023	Midnapore City College, West Bengal, Sponsored by Council Of Scientific And Industrial Research
43.	Mr. Vinod Kumar Principal Technical Officer	Jamshedpur, Jharkhand	To Attend a National Workshop Program on "Advancement in Mineral Processing Techniques with Special Reference to Iron Ore and Coal (AMPTIC 2023)"	04 Sept. 2023	08 Sept. 2023	National Institute of Technology, Jamshedpur
44.	Mr. Mahesh G Walunj Senior Scientist	Mumbai, Maharashtra	To Attend a Workshop Program on "SEM, EBSD and EDS Technique: Theory and Hands on"	01 Sept. 2023	04 Sept. 2023	The Indian Institute of Metals & Indian Institute of Technology, Bombay
45.	Mr. Mahesh G Walunj Senior Scientist	Mumbai, Maharashtra	To Attend a International Conference on "Surface Protective Coatings and Paint Coatings cum Expo 2023"	15 Sept. 2023	16 Sept. 2023	The Society for Surface Protective Coating, Mumbai
46.	Dr. Ammasi A Senior Scientist	Ranchi, Jharkhand	To Attend a Seminar on "Biochar Greening of Steel through Agro Based products (BioS 2023)"	15 Sept. 2023	16 Sept. 2023	R & D Centre for Iron & Steel in Association with Steel Authority of India Limited, Ranchi
47.	Dr. Dayanand Paswan Principal Scientist					
48.	Dr. M. Malathi Principal Scientist					
49.	Dr. Jagannath Pal Chief Scientist	Varanasi, Uttar Pradesh	To Attend a Conference on 'Metallurgical Engineering and Centenary Celebration' (METCENT 2023)	26 Oct. 2023	28 Oct. 2023	Indian Institute of Technology (Banaras Hindu University), Varanasi
50.	Dr. Ankur Sharma Scientist					
51.	Dr. Rajen Kundu Scientist	Calicut, Kerala	To Attend a 'Two Week Online hands on training on MATLAB	02 Oct. 2023	13 Oct. 2023	Spark Institute of Advanced Science Research Forum
52.	Mr. Sivananda Acharya Project Associate					
53.	Dr. Sanchita Chakravarty Chief Scientist					

#	Name	Place of Visit	Purpose/Role	Start Date	End Date	Organized By
54.	Dr. Ganesh Chalavadi Senior Scientist	Varanasi, Uttar Pradesh	To Attend a Conference on 'Metallurgical Engineering and Centenary Celebration' (METCENT 2023)	26 Oct. 2023	28 Oct. 2023	Indian Institute of Technology (Banaras Hindu University), Varanasi
55.	Mr. Rajanikant Choudhari Technical Officer					
56.	Dr. Ammasi A Senior Scientist					
57.	Dr. Saurabh Shekhar Senior Scientist					
58.	Dr. Deepak Chandra Sau Principal Scientist					
59.	Mr. P. N. Mishra Senior Principal Scientist	Kalpakkam, Tamil Nadu	To Attend an International Conference on "Recent Advances in Information Technology (READIT) 2023"	22 Nov. 2023	23 Nov. 2023	Scientific Information Resource Division, Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam
60.	Mr. Ajeet Gangwar Project Assistant 1	Trivandrum, Kerela	To Attend an International Conference on "New Horizons in Biotechnology (NHBT 2023)"	26 Nov. 2023	29 Nov. 2023	CSIR National Institute for Interdisciplinary Science and Technology (NIIST) & The Biotech Research Society
61.	Dr. Lalit Kumar Meena Senior Scientist	Jamshedpur, Jharkhand	To Attend a Conference on "Advances in Laser & Arc Cladding Technologies"	03 Nov. 2023	04 Nov. 2023	The Indian Institute of Welding, Jamshedpur Branch
62.	Dr. Alok Kumar Meher Scientist	Jamshedpur, Jharkhand	To Attend a Meeting on "Industry Academia Conclave"	23 Nov. 2023	25 Nov. 2023	National Institute of Technology, Jamshedpur
63.	Dr. Asit Baran Panda Senior Principal Scientist	Bhubaneswar, Odisha	To Attend an International Conference on "Emerging Smart Materials in Applied Chemistry (ESMAC 2023) & Interdisciplinary Science for Sustainability"	18 Nov. 2023	20 Nov. 2023	CSIR Institute of Minerals and Materials Technology & Kalinga Institute of Industrial Technology
64.	Mr. Debasish Ghosh Senior Project Associate					
65.	Mr. Mahesh Gulab Walunj Senior Scientist	Bhubaneswar, Odisha	To Attend an Annual Technical Meeting of "The Indian Institute of Metals" and an International Conference on " Sustainable Transformations in Metal Industry"	22 Nov. 2023	24 Nov. 2023	The Indian Institute of Metals Sambalpur Chapter, Angul Chapter, Bhubaneswar, Hindalco Industries & Kalinga Institute of Industrial Technology
66.	Dr. Ganesh Chalavadi Senior Scientist					
67.	Dr. Sharma Paswan Principal Scientist					
68.	Dr. Ammasi A Senior Scientist					
69.	Mr. Sukalpan Nandi GATE Senior Research Fellow					
70.	Mr. Vikas Shivam National Post Doctoral Fellowship					
71.	Dr. Ashok Kumar Mohanty Senior Principal Scientist					
72.	Dr. Murtuja Husain Principal Scientist					
73.	Dr. Lalit Kumar Meena Senior Scientist					
74.	Mr. Gaurav Kumar Bansal Scientist					

#	Name	Place of Visit	Purpose/Role	Start Date	End Date	Organized By
75.	Dr. Biraj Kumar Sahoo Senior Scientist					
76.	Dr. Saurabh Shekhar Senior Scientist	Bhubaneswar, Odisha	To Attend an Annual Technical Meeting of "The Indian Institute of Metals" and an International Conference on " Sustainable Transformations in Metal Industry"	22 Nov. 2023	24 Nov. 2023	The Indian Institute of Metals Sambalpur Chapter, Angul Chapter, Bhubaneswar Chapter, Hindalco Industries & Kalinga Institute of Industrial Technology
77.	Dr. Sanjay Agarwal Senior Principal Scientist	Bhubaneswar, Odisha	To Attend an Annual Technical Meeting of "The Indian Institute of Metals" and an International Conference on " Sustainable Transformations in Metal Industry"	22 Nov. 2023	24 Nov. 2023	The Indian Institute of Metals Sambalpur Chapter, Angul Chapter, Bhubaneswar Chapter, Hindalco Industries & Kalinga Institute of Industrial Technology
78.	Mr. Shivendra Sinha Senior Scientist					
79.	Mr. Avanish Kumar Chandan Senior Scientist					
80.	Dr. V C Srivastava Chief Scientist	Jodhpur, Rajasthan	To Attend an International Conference on "Solidification Science and Processing (ICSSP8)"	11 Dec. 2023	14 Dec. 2023	Indian Institute of Technology, Jodhpur & Indian Institute of Technology, Hyderabad
81.	Mrs. Y Usha Senior Scientist	Patna, Bihar	To Attend a National cum International Conference on "Indian Society for Heat and Mass Transfer American Society of Thermal and Fluids Engineers (ISHMT ASTFE) Heat and Mass Transfer (IHMTC 2023)"	14 Dec. 2023	17 Dec. 2023	Indian Institute of Technology, Patna & Birla Institute of Technology, Patna
82.	Dr. Manoj Kumar Mohanta Chief Scientist	Barbil, Odisha	To Attend a Workshop on "Geometallurgical approach for raw material preparation suited to pellet and sinter making towards sustainable Mining and Development"	15 Dec. 2023	16 Dec. 2023	Pellet Manufacturers Association of India, AISCO & Ardent Steel Limited
83.	Mr. Minati Kumari Sahu Council of Scientific & Industrial Research Senior Research Associate	Erode, Tamil Nadu	To Attend an International Conference on "Recent Advances in Materials and Manufacturing (ICRAMM 2023)"	29 Dec. 2023	30 Dec. 2023	Velalar College of Engineering and Technology, Erode, Tamil Nadu
84.	Mr. Kundan Kumar Project Assistant 1	Dhanbad, Jharkhand	To Attend an International Conference on " Net Zero Emission Technologies for Sustainable Development: Challenges & Opportunities. (N0ET 2023)"	16 Dec. 2023	17 Dec. 2023	Indian Institute of Technology (Indian School of Mines), Dhanbad
85.	Mr. Mahesh G Walunj Senior Scientist	Chandigarh	To Attend a Function on "CII National Corrosion Management Practices Competition and Awards 2023"	18 Dec. 2023	19 Dec. 2023	CII Corrosion Management Division, Confederation of Indian Industry, Block 3, Sector 31 A, Chandigarh
86.	Mr. Vikas Shivam National Post Doctoral Fellowship	Ropar, Punjab	To Attend an International Conference on "Fundamental and Industrial Research in Materials (iConFIRM 2023)"	12 Dec. 2023	14 Dec. 2023	Department of Metallurgical and Materials Engineering, Indian Institute of Technology–Ropar
87.	Dr. Navneet Singh Randhawa Senior Technical Officer(2)					
88.	Dr. Susanta Kumar Nath Principal Scientist	Kolkata, West Bengal	To Attend an International Conference on " Exploring The Emerging World of Ceramics and Glass (ICEECG 2023)"	19 Dec. 2023	21 Dec. 2023	The Indian Ceramic Society Kolkata Chapter

#	Name	Place of Visit	Purpose/Role	Start Date	End Date	Organized By
89.	Mr. Raju Das Project Assistant 1					
90.	Dr. Satyajit Mukherjee Senior Scientist	Kolkata, West Bengal	To Attend an International Conference on "Energy Transition: Challenges and Opportunities"	27 Dec. 2023	30 Dec. 2023	Indian Institute of Chemical Engineers
91.	Mr. Rohit B. Meshram Senior Scientist					
92.	Dr. Rajen Kundu Scientist					
93.	Mr. Arindam Sen Project Associate					
94.	Dr. Animesh Jana Senior Scientist					
95.	Dr. Ashis Kumar Panda Senior Principal Scientist	Hyderabad, Telangana	To Attend an International Conference on "Magnetic Materials and Applications"	04 Dec. 2023	06 Dec. 2023	Magnetics Society of India, Defence Metallurgical Research Laboratory (DMRL) & Mishra Dhatu Nigam Limited (MIDHANI)
96.	Dr. Rajat Kumar Roy Senior Principal Scientist					
97.	Dr. Premkumar M Senior Scientist					
98.	Mr. Kalicharan Hembrom Senior Scientist	Margao, Goa	To Attend an International Conference on "Safe Smart and Sustainable Mining"	16 Dec. 2023	18 Dec. 2023	Indian Institute of Technology (Indian School of Mines), Dhanbad
99.	Dr. Ranjeet Kumar Singh Principal Scientist					
100.	Dr. Shobhana Dey Chief Scientist					
101.	Mr. Abhishek Kumar Senior Scientist					
102.	Mr. Mohan Rao Andavarapu Technical Officer					
103.	Dr. Vinod Belwanshi Scientist	Pune, Maharashtra	To Attend a Conference on "Non Destructive Evaluation and Enabling Technologies"	07 Dec. 2023	09 Dec. 2023	Indian Society for Non destructive Testing (ISNT)
104.	Dr. Sarmishtha Sagar Chief Scientist					
105.	Dr. Sanjay Agarwal Senior Principal Scientist	Visakhapatnam, Andhra Pradesh	To Attend a Summit on "Manganese/Chrome Ores, EMD, EMM and Ferro Alloys"	18 Dec. 2023	19 Dec. 2023	Federation of Indian Mineral Industries & Manganese Ore (India) Limited
106.	Dr. Navneet Singh Randhawa Senior Technical Officer(2)					
107.	Mr. Shivendra Sinha Senior Scientist					
108.	Dr. Abhilash Senior Principal Scientist	Chennai, Tamil Nadu	To Attend a Conference on "EnVision,' India's First Energy Festival 2023"	04 Dec. 2023	05 Dec. 2023	Indian Institute of Technology, Madras
109.	Dr. Pratima Meshram Principal Scientist					
110.	Dr. Beena Kumari Principal Scientist	Sidhgora, Jamshedpur	Science Fest at Hindustan Mitra Mandal High School	10 Jan. 2024	10 Jan. 2024	Beharagora Polytechnic
111.	Ms. Rukshana Parween Project Senior Research Fellow	Bangalore, Karnataka	AITP 2024, Three days All India Training Program on Industrial Metal Finishing and Allied Technologies for Aerospace & Automotive Industries.	16 Jan. 2024	18 Jan. 2024	The Electrochemical Society Of India, IISc

#	Name	Place of Visit	Purpose/Role	Start Date	End Date	Organized By
112.	Ms. Karina Rani Project Assisstant					
113.	Ms. Ruchi Verma Project Associate					
114.	Ms. Dhole Sneha Somnath Project Associate					
115.	Dr. Pallab Bhattacharya Senior Scientist	Kharagpur, West Bengal	International Conference on Functional Materials (ICFM) 2024	09 Jan. 2024	11 Jan. 2024	Materials Science Centre, IIT Kharagpur
116.	Dr. Sharma Paswan Principal Scientist	Mumbai, Maharashtra	To Attend an International Summit on "Corrosion Technology & Management 2024 (CORTEM 2024)"	28 Feb. 2024		Confederation of Indian Industry(CII), with support of Ministry of Steel, Govt. of India
117.	Mr. P. V. S. Chaithanya GATE Senior Research Fellow	Online	To Attend a Conference on "Industrial Corrosion and its Control"		29 Feb. 2024	The Electrochemical Society of India & Dept. of Metallurgical & Material Engineering, NIT Surathkal
118.	Mr. Kutcherlapati Pritam Raj Project Associate					
119.	Mr. Abhishek Kumar Senior Scientist	Jamshedpur, Jharkhand	To Attend an International Conference on "Mining and Beneficiation Technology"	12 Feb. 2024	14 Feb. 2024	TATA Steel Ltd.
120.	Dr. A. Vidyadhar Senior Principal Scientist					
121.	Dr. Ammasi A Senior Scientist	Rourkela, Odisha	To Attend a National Conference on "Sustainability in Metal Industries(NCSMI 2024)"	01 Feb. 2024	02 Feb. 2024	SAIL RSP and IIM Rourkela Chapter
122.	Dr. Sanjay Prasad Principal Scientist	Varanasi, Uttar Pradesh	To Attend an International Conference on "Management and Recycling of Metallurgical wastes"	02 Feb. 2024	03 Feb. 2024	Dept. of Metallurgical Engineering, IIT(BHU), Varanasi
123.	Dr. Deepak Chandra Sau Principal Scientist					
124.	Mr. Rajanikant Choudhari Technical Officer					
125.	Dr. Saurabh Shekha Senior Scientist					
126.	Dr. Sanjay Agarwal Senior Principal Scientist					
127.	Ms. Pushpa Kumari Project Associate I					
128.	Mr. Niranjan Dutta Project Assistant					
129.	Dr. Ammasi A Senior Scientist					
130.	Dr. Sanjay Prasad Principal Scientist	Pune, Maharashtra	To attend an International Conference on "Powder Metallurgy & Particulate Materials"	11 Feb. 2024	12 Feb. 2024	Powder Metallurgy Association of India
131.	Dr. Saurabh Shekhar Senior Scientist	Kolkata, West Bengal	To attend an International Conference on "Processing of Minerals, Metals and Materials"	25 Feb. 2024	28 Feb. 2024	KNU IIM & NIT Durgapur
132.	Dr. M. Malathi Principal Scientist	Chennai, Tamil Nadu	To Attend a Conference on "Recent Trends in Metallurgy & Materials Science (AMALGAM 2024)"	21 Feb. 2024	23 Feb. 2024	Indian Institute of Technology Madras

#	Name	Place of Visit	Purpose/Role	Start Date	End Date	Organized By
133.	Mr. MD Arif Technical Officer	Mumbai, Maharashtra	To Attend a Conference on "Current Trends In Analytical Chemistry (CTAC–2023) "	01 Mar. 2024	03 Mar. 2024	Analytical Chemistry Division, Bhabha Atomic Research Centre (BARC)
134.	Dr. Alok Kumar Meher Scientist					
135.	Dr. Sanchita Chakravarty Chief Scientist					
136.	Dr. Rajen Kundu Scientist					
137.	Mr. Chinamy Bewa Project Associate	Mamallapuram, Tamil Nadu	To Attend an International Workshop on "Electromagnetic Nondestructive Evaluation"	06 Mar. 2024	09 Mar. 2024	Indira Gandhi Centre for Atomic Research (IGCAR) & Indian Society for Non destructive Testing (ISNT) KALPAKKAM Chapter
138.	Dr. Vinod Belwanshi Scientist					
139.	Mr. Akshay Kumar, Project Assistant	Kolkata, West Bengal	To Attend an International Conference on " Processing of Minerals, Metals & Materials"	04 Mar. 2024	06 Mar. 2024	Department Of Metallurgical Engineering, Kazi Nazrul University, Asansol
140.	Mr. Shibsundar Das Project Assistant					
141.	Ms. Pushpa Kumari Project Associate 1	Kanpur, Uttar Pradesh	To Attend a Conference on "National Symposium of Research Scholars on Metallurgy and Materials (NSRS 2024) "	28 Mar. 2024	29 Mar. 2024	Indian Institute of Technology Kanpur
142.	Mr. Niranjan Dutta Project Assistant					
143.	Mr. Sunil Kumar Project Associate 1					
144.	Ms. Nikita Agarwal Project Associate 1					
145.	Mr. Rajanikant Choudhari Technical Officer					
146.	Mr. Durga Prashanna Sahoo Senior Technical Officer 1	Jamshedpur, Jharkhand	To Attend an International Conference on "The International Conference on Refractory Jamshedpur (ICRJ)"	09 Mar. 2024	10 Mar. 2024	Indian Ceramic Society, Jamshedpur Chapter in association with Tata Steel
147.	Dr. Susanta Kumar Nath Principal Scientist					
148.	Dr. Ammasi A Senior Scientist					

Distinguished Visitors

#	Visitor	Date of Visit	Topic of Lecture
1.	Dr. Rajiv Maharshi MBBS, Consultant-Neuro & Spine Surgery	13 April 2023	"Back Pain and Spondylitis"
2.	Prof. Sunil Kumar Singh Director, CSIR-NIO	12 May 2023	"Back Pain and Spondylitis"
3.	Dr. Poulami Chakraborty Postdoctoral Research Fellow, Basque Centre for Applied Mathematics (BCAM), Bilbao, Spain	05 June 2023	"Hydrogen interplay with defects in Al alloys"
4.	Dr. Niranjan K Verma, Advanced Ayurveda Therapist	19 June 2023	"Treatment of disease by Panchagavya method"
5.	Dr. Ritika Mishra, R.O (Ay), Nodal Officer	11 July 2023	"Role of Ayurveda in Diabetes Mellitus"
6.	Dr. T. Bhaskar, Chief Technology Officer, Tata Steel Long Products Limited	18 September 2023	“My Engineering journey!”
7.	Ms. Varsha M., DVP & Regional Head, Wealth, Tata Capital	27 September 2023	“Financial Management Session and Activity”
8.	Prof Hanumantha Rao, Emeritus Professor, Norwegian University of Science and Technology	15 November 2023	"Green extraction of rare earth elements (REE) using froth and foam flotations"
9.	Mr. Sudhir Toppo, Assistant Public Prosecutor, Jamshedpur Civil Court	08 December 2023	"Elimination of all forms of violance and discrimination against women and on sensitization for employees to make them aware about the provisions of the sexual Harassment of Women at Workplace (Prevention, Prohibition and Redressal) Act, 2013 and towards the need for upholding the dignity of women and end gender stereotype so as to encourage more and more women"
10.	Dr. D. K. Singh, Scientific Officer H, Rare Earth Extraction Unit, Material Research Group, BARC	13 December 2023	"A Step towards Resource Sustainability and Value Supply Chain of Rare Earths"
11.	Dr. A. K. Arya, Former Medical Officer, CSIR-NML	15 December 2023	" Diabetic Management"
12.	Mr. Alok Sharma, Controller of Administration, CSIR-CIMFR, Dhanbad	15 December 2023	"Central Civil Services (Conduct) Rules, 1964, Immovable property - acquisition & disposed of and O-APAR (Performance Appraisal report)"
13.	Dr. Srutarshi Banerjee, Postdoctoral Associate at the Advanced Photon Source Synchrotron in Argonne National Laboratory, IL, USA	03 February 2024	"Physics based Machine Learning for Radiation Sensor Material Characterization"

One Week One Lab

CSIR-NML One Week One Lab Campaign (24th -28th April 2024)

The One Week One Lab (OWOL) countrywide Campaign of CSIR and each of its 37 Laboratories was launched by Hon'ble Union Minister for Science & Technology and Earth Sciences, Dr. Jitendra Singh. As a compliance, during the week-long programme of CSIR-NML, various events were organized at CSIR-NML. While connecting to the government, industries, academia, students, MSMEs and entrepreneurs, CSIR-NML also intended to identify the needs of the regions, and industries and providing suitable scientific solutions. The campaign provided to be an opportunity for the laboratory for showcasing its legacy and achievements and strengthening the connectivity between the pillars of research and innovation ecosystem of CSIR-NML.

Inauguration of CSIR-NML One Week One Lab Campaign (24th April 2024)

CSIR-National Metallurgical Laboratory, Jamshedpur started its One Week One Lab (OWOL) Programme through Curtain Raiser Ceremony at Hotel Radisson Blu, Ranchi. The participation of key government officials in the meeting was ensured this way. We were fortunate to have His Excellency, Shri C.P. Radhakrishnan, Hon'ble Governor, Jharkhand as well as head of our CSIR family Dr. N. Kalaiselvi, DG-CSIR & Secretary, DSIR in the Curtain Raiser event. Honourable Governor had kindly appreciated CSIR-NML's involvement in various government missions like "Skill India", "Make-in-India", "Swachh Bharat", Self-Reliant India" and others. He emphasized upon the significant role of CSIR-NML in developing mineral rich state of Jharkhand and in this regard Honourable Governor had kindly shown his interest to visit CSIR-NML, Jamshedpur.



H.E. Shri C.P. Radhakrishnan, Hon'ble Governor of Jharkhand gracing the Inaugural Ceremony and addressing the gatheirng



Address by Dr. N. Kalaiselvi, DG-CSIR Release of OWOL@CSIR-NML Souvenir

Workshop on "Rare Earths for Self-Reliant India" (24th April 2024)

In order to connect with the industries, a workshop on Rare Earths for the Self-Reliant India was organized as a part of the inaugural function. Eminent speakers like Dr. R.N. Patra, Former CMD, IREL Ltd., Member REE, Task Force Committee, Niti Aayog, Mr. Yamuna Singh, Former Head, Mineralogy, Atomic Minerals Directorate for Exploration and Research, Hyderabad and Mr. Tumuluri Sreenivas, Outstanding Scientist & Head, Mineral Processing Division, BARC talked about the relevance of the rare earths for industries. The speakers along with Dr. P.K. Banerjee, Outstanding Scientist, CSIR-CIMFR also participated in a panel discussion on the theme of workshop.



An exhibition "NML at a Glance" (25th April 2024)

On the second day of the program at CSIR-NML, Jamshedpur, the exhibition for showcasing its technological innovations & inventions was inaugurated by Dr. Debashish Bhattacharjee, Vice President, Technology & New Materials Business, Tata Steel, Jamshedpur. The aim of the exhibition was to connect with students, industries, MSMEs and general public. The exhibition housed about 80 Nos of technical posters covering various domains of its contributions like: NML Technologies commercialized, NML Technologies ready for commercialization, Sophisticated instruments/ high end equipments, R&D solutions to solve societal challenges, R&D for strategic sectors (Defence/ Aerospace / Space etc.), Breakthrough industrial R&D / solutions, Other impactful activities / outcomes. In addition to technical posters, live demonstration of some of the

inventions and few portable models of the processing equipment, like polymer 3D printing etc. were the part of the show. A set of futuristic ideas by the young scientists of CSIR-NML was also presented in the show. A selfie-point was also set up to provide the visitors with a long-lasting memory of the event.



Jigyasa: School Students-Scientists interaction (25th April 2024)

The event was organized to connect with the students. Prof. Gangadhar Panda, the Vice Chancellor of Kolhan University and Dr. Indranil Chattoraj, Former Director, CSIR-NML was the chief guest and guest of honor, respectively. Under the Jigyasa program, approximately 300 Students from standard IX to XII and 16 teachers from seven different schools, named, Vidya Bharati Chinmaya Vidyalaya, NML-Kerala Public School, Sister Nivedita Girls High School (Hindi Medium), Sister Nivedita English School, Kendriya Vidyalaya, Jamshedpur, BPM+2 High School and Khalsha High School, Burmamines, and 120 students from Netaji Subhas University visited CSIR-NML R&D facilities, Exhibition and interacted with the researchers, during the day.



Technology challenge Hackathon (25th April 2024)

The event was organized with a vision to reach out a large number of school students. The school students of class VIII-XII from in and around Jamshedpur, Jharkhand participated in the event. Scientific Ideas based presentations were made by participants on theme of “Quest of Smart and Sustainable Society”. A panel of scientists judged the presentation and interacted with the students. Ms. Nandani and Mr. Abhishek from B.P.M +2 High School, Burmamines were awarded First Prize, where Mr. Arindam Patra and Mr. Sahil Kumar Saha from Kerala Samajam Model School Golmuri and Mr. Aditya Karmakar and Mr. Prerit Singh from Little Flower School, Telco were awarded Second and Third prizes in the event. The event was graced by the presence and motivational speech by Dr. Indranil Chattoraj, Former Director, CSIR-NML on “CSIR-NML Technologies and Technologists”.



An Industrial Problem Solving (IPS) contest was organized for the problem statements received from Tata Steel, Jindal Steel, Saint Gobain and CSIR NML R&D projects related to Ferroalloys, Steel making, Industrial and E-Waste management and Mineral processing. Panel of senior scientists interacted with the teams and judged the presentations of students. Mr. Sovan Kumar Patra and Mr. Yashraj Kanaskar from Tata Steel stood as First Award Winners for their presentation on solution for the problem “Reduction of Carbon Footprint in Ferroalloys”, and Mr. Adhiraj Kanrar and Mr. Sambit Tripathy, Project Assistants from CSIR-NML received Second Award in the competition for their solution for the problem “Utilizing AI Based Nozzles in Continuous Casting Operations to Minimize Water Consumption”. Mr. Sambit Tripathy and Mr. Shubendu Chatterjee, Project Staff, CSIR-NML were awarded the Third Award in the event for their idea on using microwave in “Reduction of Mn Ores to Reduce Energy Consumption in Ferroalloy Processing”. Participation was received from NIT Jamshedpur, IIT Hyderabad, Govt. Polytechnic Adityapur, KIIT Bhubaneshwar, Shavak Nanavati Technical Institute, Tata Steel Limited and CSIR NML.

Workshop on “Materials Challenges in Unlocking the Hydrogen Era" (26th April 2024)

The workshop aimed to focus only on the materials for the storage and transportation of gaseous hydrogen. Technical

lectures were presented by the eminent industry experts in the field like Dr. Indranil Chattoraj, Former Director, CSIR-NML; Mr. Arvind K, from IOCL; Mr. Paramjeet Singh, Ministry of Steel; Mr. Ashendra Singh, Petroleum & Explosives Safety Organization (IPESS); Dr. Manish Prasad, GAIL; Dr. Subrata Mukherjee, Tata Steel; Dr. S.K. Chowdhury, WELSPUN; Dr. Ramgopal Thodla, DNV. Towards the end the dignitaries also participated in the Panel Discussion on the topic of the workshop to find new and upcoming R&D opportunities in the area. Representatives of various steel manufacturers, pipe manufacturing companies as well as organizations associated with certification and inspection of those materials.



Technopreneurship Meet and Shilpakar Mela (Artisans Meet) (27th April 2024)

The purpose of Technopreneurship meet was to provide a platform where entrepreneurs, start-ups and industries could meet and could explore the technologies ready for commercialisation at CSIR-NML. The lecture of the chief guest of the event Mr Rajesh Kumar Pathak, Secretary, TDB explained the need for the transitioning research into technology and reaping economic benefits from the intellectual property (IP). Dr. Ujjal Chakraborti, Managing Director JCPACL and Chairman, CII Jharkhand Chapter and Guest of Honour for the day, reminded the audience of the great history of the city of Jamshedpur. Dr Ravindra Sharma, General Manager, Metal Handicrafts Service Centre, Moradabad emphasized on the importance of Artisans for the economic development of the country. Dr. Smitha Puthucheri, Project Co-coordinator, Technology Development Board (TDB) explained that the objective of TDB is to help and the entrepreneurs, start-ups and industries with market ready technology by giving financial as well as management assistance to gain market access. The participants of the workshop included representatives of MSMEs, industries as well as research students.



In order to connect with grassroot level entrepreneurs/ innovators, the Laboratory organised a unique Shilpakar Mela (Artisans' Meet) for the Brass artisans from West Bengal, Orissa and Jharkhand to interact with the researchers and exhibits their products. The objective of the meet was to strengthen MSME ecosystem where artisans, technology providers, government, e-marketing officials, export promotion council officials joined hand with each other on a single platform. One hand the Artisans can upgrade the technology with the intervention of CSIR-NML knowledgebase on the other hand they have the opportunity to get guidance how to get better price for their product in the marketplace. An interactive session with brass artisans was held as a part of Shilpakar Mela. Dr. Ravindra Kumar Sharma, GM of Metal Handicrafts Service Centre under Govt of India, graced the occasion. He shared about the practical challenges faced by artisans especially in the remote areas and extended his help to all those who were present in the meeting.



Academia Meet and Industry Meet (28th April 2024)

On the last day of the OWOL Campaign, an "Academia Meet" was held at CSIR-NML for an interaction amongst the academic institutions of the Jharkhand State with researchers and experts in the field of Metallurgy. Prof. Indranil Manna, Vice Chancellor of BIT Mesra and former Director of IIT, Kanpur graced the occasion as Chief Guest and delivered the keynote lecture on "Major challenges in Metallurgical and Materials Engineering for Future Development of India". Dr. Sayan Bhattacharyya, IISER Kolkatta, delivered a lecture on "Energy Solutions in the 21st Century". Prof. Prita Pant, IIT Mumbai delivered a lecture on "Wootz Steel- Science Technology and Travels". Later the experts also participated in a panel discussion on the "Role of CSIR-NML in scientific pursuit for development of society". Prof. Rajesh Kumar Tiwari, Principal, RVS college of

Engineering & Technology Jamshedpur participated in the panel discussion. Around 100 students and 30 faculty members from colleges and universities of Jharkhand participated in the meet. A poster presentation session on the theme "Metals and Materials for the growth of the nation was held.



An Industry Meet was organized by CSIR-NML Madras Centre with an objective to bring the representatives of the industries in and around Chennai and showcasing available technologies of CSIR-NML to them. Dr. N. Anandavalli, Director, CSIR-SERC and the Coordinating Director, CSIR-Madras Complex in her inaugural address emphasized the exemplary role played by CSIR-NML in the industrial development of India, post-independence. The Chief Guest, Mr. M. Srinivasan, Executive Director - Operations, Ramco Cements Limited emphasized the need for collaborative R&D by industry and R&D laboratories for resolving the industrial problems. Mr. Tim Sheehan, Managing Director of Eriez Magnetics India Limited spoke on the need to conserve the non-renewable resources while practicing environmentally safe operations. Professionals from the different industries participated in the event.





Valedictory session of One Week One Lab (28th April 2024)

Valedictory session of the CSIR-NML One Week One Lab Program was held in the presence of Prof. Indranil Manna. According to him, such campaigns are really instrumental in spreading awareness in various groups of stakeholders. He also praised that such initiative of CSIR and constituent laboratory spread within the country can bring the science closer to society. He concluded that showcasing the available S&T solutions and Technologies is a must.





One Week One Lab campaign by CSIR was successful in showcasing its technological innovations and achievements by organizing various week-long events like Workshops, Industry Meet, Students Connect, Society Connects and showcasing of Technologies. The entire programme was designed to connect Academic Institutes, Government, Industries, Starutups/MSMEs/Entrepreneurs/ innovators and students. The proceedings and the outcomes of CSIR-NML One Week One Lab campaign have highlighted a number of take-aways and shown the way forward from this juncture. A need for developing a dedicated and time-efficient communication system was also felt for quick identification of existing & futuristic industrial problems as well as formulation of related new projects.

Special Days & Events

Celebration of Technology Day (11th May 2023)

The occasion was celebrated at CSIR-NML. The main function was graced by Mr. Ujjal Chakraborty, Managing Director, Jamshedpur Continuous Annealing & Processing Co. Private Limited (JCAPCL) as chief guest.



Celebration of Swachchhata Pakhwada 2023 (1st-15th May 2023)

In alignment to the "Swachh Bharat" mission of Government of India, a cleanliness drive of 15 days formally named as the "Swachhata Pakhwada -2023" was celebrated. A number or events were organized on the occasion having the theme of "Swachhata" and "Plastic Curbing" to spread awareness viz. Swachhata-Pledge taking ceremony by staff, Cleanliness drive, Sit and Draw Competition for school children, Essay Competition for youth, Extempore competition, Slogan Writing Competition and Tree Plantation Program. Under the program, a total of 36 trees were planted in and around the main laboratory, residential colonies and all campuses. Water Purifier and dustbins were also installed at different places. Efforts for weeding out of old files were also put in. The valedictory session of the "Swacchata Pakhwada" was graced by Shri Ritu Raj Sinha, Managing Director, Tata Steel Utilities and Infrastructure Services Limited (Formerly known as JUSCO), as the chief guest.



Memorandum of Agreement(MoA) Signing with Aquatic Industries Private Limited, Bhuwaneshwar and IMMT, Bhuwaneshwar for Licensing of Knowhow Brass Melting Furnace (Licensing) (June 2023)



Hindi Workshop for CSIR-NML Staff (14th June 2023)

The workshop was organized for the CSIR-NML Staff to reemphasize the importance of using Hindi as the official language for official work.



A national level student seminar, "Behind the Teachers Desk (BTTD 2023)" (08th-09th June 2023)

The Indian Institute of Metals, Jamshedpur Chapter in association with Tata Steel Limited (TSL), CSIR-National Metallurgical Laboratory (CSIR-NML), National Institute of Technology (NIT), Jamshedpur and Academy of Scientific and Innovative Research (AcSIR) jointly organized the students' seminar. More than 100 students of 40 colleges across the country have participated in the seminar.



International Day of Yoga celebrations (21st June 2023)

Yoga Session at residential complexes under the guidance of Mrs. Vineeta Sharma, Yoga Trainer.



Blood Donation Camp (26th May 2023)

More than 80 units of blood was donated by CSIR-NML staff



Memorandum of Agreement (MoA) signing with M/s. Novasensa Pvt. Ltd., New Delhi for the Licensing of technological KNOW-HOW a) to recycle spent Lithium-Ion Batteries (LIBs) to produce value added products of Li, Co, Mn, Cu, Ni, as metals/ salts and b) for the extraction of Cu, Al and Au as Metals/ salts from waste PCBs (May 2023)



Visit of CMD, MOIL (Manganese Ore India Ltd.) at CSIR-NML (13th April 2013)

A high-level team from MOIL Ltd., Nagpur, comprising Mr. Ajit Kumar Saxena (CMD), Mr. P V V Patnaik (Director Commercial), Mr. Rajesh Kumar Verma (GM, Mining), and Mr. D V V Giri (Jt. GM Process), visited CSIR-NML to witness the pilot-scale production of electrolytic manganese metal (EMM). The project on large scale production of EMM is being sponsored by MOIL Ltd., Nagpur.



"Rashtriya Boudhik Sampada" Mahotsava Celebration (May 2023)



As a part of Azadi ka Amrit Mahotsava to mark the 75th year of India's Independence., CSIR organized the "Rashtriya Boudhik Sampada Mahotsav (RBSM)" (National Intellectual Property Festival) with a focus on creating awareness on Intellectual Property Rights (IPR). This initiative was aligned with the thematic objectives of enabling ATMANIRBHARTA to grow roots in the society. CSIR-National Metallurgical Laboratory conducted three events in this connection wherein 400 students took part along with their teachers. The event consisted lectures on "Basics of Intellectual Property Rights" , " Make IP India" followed by interactive sessions for students. As a part of the events, the students also visited the laboratory facilities. Another event, National Workshop (Hybrid Mode) on IP life Cycle conducted on Hybrid mode, was designed for a wider audience, including college students, research fraternity, S&T staff at CSIR-NML, Industry and Start-ups. The event featured lectures by Dr. H Purushotham, DPIIT-IPR Chair Professor & Director, Center for Intellectual Property Rights, Andhra University, Mr. Kundan Kumar, Assistant Controller of Patents & Designs, Patent Office, Kolkata and Dr. Sital Kumar Pal, Head RPBD, CSIR-NML. The event was well received with around 99 online participants and 45-50 offline participants.

79th Research Council Meeting of CSIR-National Metallurgical Laboratory (09th August 2023)

The 79th Research Council Meeting was chaired by Prof. Indranil Manna, Vice Chancellor, BIT Meshra, and other members present were Prof. Jyotsana Majumdar, IIT Kharagpur and Dr. Debahish Bhattacharjee, Vice President, Tata Steel. The major ongoing R&D projects and other achievements of the laboratory were deliberated upon in the meeting. A comprehensive report on CSIR-NML One Week One Lab (24th-28th April 2023) program was also released during the event, by the RC members. Dr. AK Srivastava, Director, CSIR-NML felicitated the current RC members.



Independence Day Celebrations 2023

CSIR-NML celebrated Independence Day with a number of events and activities. National Flag was hoisted by the Senior Most Chief Scientist of CSIR-NML, Dr. Sandip Ghosh Chowdhury at the main Laboratory premises. Flag hoisting ceremonies were also organized in the residential premises of the laboratory. The independence celebrations also a number of competitions for the staff and staff families viz. Poetry Recitation, Singing, Sit & Draw, Rangoli Making, Quiz and a Football Match. Various colourful programs like singing and dancing were performed by the staff children and the staff, on the occasion.



11th Prof. S. N. Sinha Memorial Materials and Metallurgy Quiz (SNSM3Q-2023)



The SNSM3Q-2023 was was open to all standard XI and XII students of Jharkhand State. A total of 36 teams, representing 18 schools, participated in the quiz. The Indian Institute of Metals (IIM), Jamshedpur Chapter, organized the quiz in association with CSIR-NML. The quiz has been named after Prof. S. N. Sinha, an eminent educationist and former president of the IIM Jamshedpur Chapter.

Celebration of Indian Organ Donation Day at CSIR-NML (3rd August 2023)

The event proved to be successful in increasing awareness about the significance of organ donation, with a total of 100 individuals signing up as organ donors during the event.



Special Campaign 3.0 for Swachhata (2nd October, 2023)

CSIR-NML organized a Cleanliness drive. Employees and their family members participated in the event and did “Shramdaan” for the Swachhata program.



Certificate distribution program under Women Technology Park Project



Dr. Naresh Chandra Murmu, Director, CMERI, Durgapur took over as Director, CSIR-NML (Additional Charge) (06th September 2023)



82nd Foundation Day (26th September 2023)

The 82nd Foundation Day of Council of Scientific and Industrial Research (CSIR) was celebrated in the laboratory on 4th October 2023. Shri Nirbhik Banerjee, Executive Director, RDCIS, SAIL, Chief Guest of the function, delivered the CSIR Foundation Day Lecture. An agreement was also signed by CSIR-NML and RDCIS on the occasion for enabling future R&D collaboration in future. C



Fit India Swachhata Freedom Run 4.0 (31st October 2023)





Ayurvedic Medical camp and Lecture (7th October 2023)

The speaker for the event was Dr. Ritika Mishra, R.O(Ay), Nodal Officer. The topic of her lecture was "Role of Ayurveda in Diabetes Mellitus".





3rd Janjatiya Gaurav Divas (30th November, 2023)

3rd Janjatiya Gaurav Divas was celebrated at CSIR-NML. Dr. Naresh Chandra Murmu, Director, CSIR-NML delivered a talk on the occasion.





National Sports Day Events: Throw Ball Volleyball (26th August 2023) for Women and Football Match for Men (27th August 2023)





Hindi Week Celebration (1st – 8th September, 2023)

The inauguration of the event happened on 1st September in the gracious presence of Mr. P. Paleewal, Former Senior Most Official Language Officer, CGCRI & Creative Writer and Prof. Sanjay Kumar, Head, Computer Science Department, NIT, Jamshedpur. A skit entitled "Boodha Baccha" was also played on the last day of the weeklong celebration. The Valedictory session was celebrated in the gracious presence of Dr. Pushpa Kumari, Head, Hindi Department, Jamshedpur Women's University, Jamshedpur. The chief guest awarded all the winners of the various competitions.









Vigilance Awareness Program 2023

Vigilance Awareness Program was celebrated at the laboratory and a number of programs were organized on the occasion. CSIR-NML staff visited Rautara gram panchayat for raising awareness about vigilance and the adverse impact of corruption. Events were also organized for the staff members of CSIR-NML like Essay competition and Poster making competition. The programs aimed to encourage individuals for adopting ethical practices and upholding high standards of honesty and integrity.





Vigilance Awareness Program 2023; Theme: "Say no to Corruption; commit to the Nation" (30th October to 5th November 2023)

Vigilance Awareness Week was celebrated at CSIR-NML, by organizing a number of events like Essay Competition, Poster making competition, Quiz Competition and Slogan Writing Competition. Mr. Shishir Dhamija, Principal Commissioner of Income Tax, Jamshedpur delivered a general awareness lecture on "Preventive Vigilance" on 03-11-2023. A skit (Nukkad Natak) entitled "Public Interest Disclosure and Protection Informers (PIDPI)" was also performed at the residential campus of the laboratory for spreading awareness.



Poster Presentation and Exhibition as a Part of the Outreach Program on "Maritime Corrosion Monitoring and Management (MCMM)" by CSIR-National Metallurgical Laboratory (CSIR-NML), Jamshedpur (18th December, 2023)

The contributions of CSIR-NML, Jamshedpur in the field of Corrosion research and its prevention have been displayed during the poster and model presentation for school children's and local people at the Marine Corrosion Research Station (MCRS), Digha, West Bengal. Mr. A M Rizvi, Executive Director, RDSO, Lucknow formally inaugurated the exhibition. Approximately 40 students of classes IX, X, XI, XII belonging to schools: Digha Debendralal Jagabandhu Sikshasadna and Didgha Vidyabhawan and science related teachers visited the exhibition and participated in the IISF program.



An Outreach Program on "Maritime Corrosion Monitoring and Management (MCMM)" by CSIR-National Metallurgical Laboratory (CSIR-NML), Jamshedpur (18th December, 2023)

CSIR-National Metallurgical Laboratory (CSIR-NML), Jamshedpur organized an outreach program on the theme of "Maritime Corrosion Monitoring and Management (MCMM)" at Hotel Le ROI, Digha, West Bengal and its Marine Corrosion Research Station (MCRS) located at Digha, West Bengal on 18th December 2023 to commemorate 9th edition of India International Science Festival (IISF-2023). Chief Guest of the event, Mr. Sanjay Chowdhury, Vice President & Business Head-Protection, Berger Paints India Ltd. emphasized on Collaboration, Communication and Commitment (3C's) and suggested to develop preventive strategies for corrosion including coatings. Prof. Ranjit Prasad, NIT Jamshedpur & Member Vijnana Bharati (VIBHA) introduced the activities of IISF and Vijnana Bharti to the house and talked about their roles in inculcating the scientific thought process in the people of India. Around 80 speakers and delegates from industries, academia and research institutions participated in the program. Mr. S. Ravichandran, Chief Manager, Berger paints; Mr. D S Rao, Chief General Manager, IOCL Bhubaneswar; Mr. S. Srikanth, General Manager, RDCIS SAIL Ranchi; Mr. A M Rizvi, Executive Director, RDSO, Lucknow; Mr. Utpal Shah, Chief Engineer of Ministry of Rails and Dr. T K Rout, Tata Steel Ltd. India, delivered talks in the technical sessions. The program was also attended by the local administration Mr. Saikat Hazra of Digha Shankarpur Development Authority (DSDA), WB.



Steering Committee Meeting of Neeti Aayog on Mission Mode Project: "Red Mud Recycling" hosted at CSIR-NML (12th December, 2023)

CSIR-National Metallurgical Laboratory, Jamshedpur, hosted the 6th Monitoring and Steering Committee Meeting of Niti Aayog on Red Mud Recycling on 12th December 2023, to discuss the scale-up validation progress for the processing of red mud. The meeting was attended by Dr. R. Saravanabhavan, Adviser, Niti Aayog, along with Dr. N.C.Murmu (Director, CSIR-NML), Dr. Ramanuj Narayan (Director, CSIR-IMMT), Dr. D.K.Singh (BARC) and Dr. Sanjay Kumar (NML), along with industrial partners viz., NALCO (Dr. Partha Bandhyopadhyay, Mr. Vinod Verma); HINDALCO (Dr. Sagar Pandit); Vedanta (Dr. B. Kiran Kumar). Dr. Abhilash and Dr. Pratima Meshram were the members of CSIR-NML in the Steering Committee..



CSIR-NML Annual Sports (16th December 2023)

Annual Sports Day 2023 was organized by CSIR-NML Staff Club at NML Sports Ground, Agrico. The day started with an opening ceremony, featuring the lighting of the ceremonial torch. The events that followed included a variety of competitions such as Pick & run, Toffee race, Math race, Sprint, Skipping and Hopping race, Musical Chair, Shot put etc. Staff members along with their families participated in the sports event enthusiastically.



New Year Get-together (3rd January, 2024)

A New Year get-together was organized at CSIR-NML with the staff members to recollect achievements of the past year and to mark the areas of development in the new year.



Visit of Titan, Hosur, Precious Alloys, Mumbai and Blue Power, Germany ()

Teams from Titan, Hosur, Precious Alloys, Mumbai and Blue Power, Germany visited the Inert Gas Atomizer facility at CSIR-NML and witnessed the trial run of gold alloy atomization.



22K & 19K gold alloy powder in receiver after atomization

74th CSIR-NML Foundation Day Celebrations (11th December, 2023)

The event was graced by Dr. C.K. Asnani, CMD of Uranium Corporation of India Ltd as the Chief Guest; Dr. Ramanuj Narayan, Director of CSIR-IMMT, Bhubaneswar, as the Guest of Honor and Dr. Indranil Chattoraj, Former Director of CSIR-NML as the guest of Honor. On the occasion, the Annual Report 2022-23 was also released by the dignitaries. The function was formally concluded with the national anthem.



Republic Day Celebrations- 2024

75th Republic Day was celebrated in CSIR-NML and CSIR-NML Residential Complexs on 26th January, 2024. The national flag was hoisted by Dr. Sandip Ghosh Chowdhury, Senior Most- Chief Scientist. Staff members and their families participated in the celebration.



Tennis Ball Cricket Tournament was organized by CSIR-NML Staff Club at NML Sports Ground, Agrico (17th February, 2024).




International Women's Day (12th March, 2024)

The theme of International Women s Day 2024 was "#InspireInclusions". As the part of the International Women's Day celebration, multiple programs were organized at the laboratory and residential premises like Women's cricket tournament, food fest, cultural programs and a SKIT. Mrs. Rupa Mahanty, a Management Consultant, an Educator, a Philanthropist and Reiki Grand Master was the chief guest of the main function. In her address she mentioned that we women always "choose to challenge" the status quo. She talked about the special strength that women possess and can utilise to fight the odds. This year, two of female janitorial staff Mrs. Chaya Devi and Mrs. Mayno Mardi were felicitated by the chief guest in appreciation of their enduring and dedicated services to the laboratory. The main program concluded with the National anthem.





80th Research Council Meeting (7th March, 2024)

The eightieth Meeting of the CSIR-NML Research Council (RC) was held on March 07, 2024 through hybrid mode. The following members attended the meeting Shri Amarendu Prakash, Chairman-RC, MD SAIL; Dr. R. Balamuralikrishnan, Member, Director-DMRL; Shri Chaitanya Bhanu, Member, Tata Steel; Prof. Karabi Das, Member, IIT Kharagpur; Dr. Prakash Kumar, Member, Director-CSIR-NGRI; Dr. R.M. Mohanty, Member, CSIR-HQRS; Dr. N. C. Murmu, Director CSIR-NML & CSIR-CMERI and Member.

Women Cricket Tournament was organized by the CSIR-NML Staff Club at NML Flats, Agrico (9th March 2024)



Dr. V. K. Saraswat, Member, Niti Aayog visited CSIR-NML to inaugurate battery recycling plant at CSIR-NML, Jamshedpur.




Phenom India: CSIR Health Cohort Knowledge Base (PI-CHK) Study Programme (12th to 18th March, 2024)

The aim of this seven-day program is to capture longitudinal molecular, biochemical and organ scanning data of employees and their spouse.



National Science Day (14th March, 2024)

On this occasion, AcSIR PhD students delivered talks on interesting achievements from their PhD work to commemorate National Science Day. This year theme was "Indigenous Technologies for Viksit Bharat" in order to emphasize our own innovations.



Dr. Sandip Ghosh Chowdhury, Chief Scientist, took over the position of Director at CSIR-NML (15th March 2024).



Contract Bridge Paris Championship (24th March 2024)



Staff Club Cultural Activities: Sawan Mahotsava Program held at CSIR-NML Residential Campuses, Agrico and Golmuri (3rd-6th August 2023)

Sawan Mahotsav was organized at the residential premises of CSIR-NML (National Metallurgical Laboratory) at Agrico, Jamshedpur. As part of the event, a food fest was also organized. As many as 12 stalls of home-cooked food items were set up by the women. The main Sawan Festival was celebrated on August 5, 2023 at the stall club on the campus. A colorful program of Sawan Festival was also organized by women under the banner of "Rimjhim Barse Sawan". Dr. Mita Tarafdar, Chief Scientist, CSIR-NML was the Chief Guest of the event. Sawan Queen was selected and awarded by the chief guest.

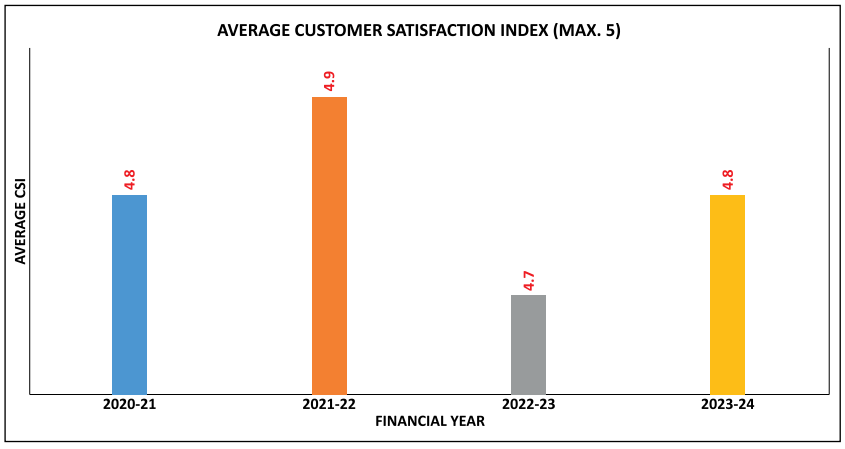


CSIR- NML Outreach Event and Staff Get Together (28th January, 2024)

An outreach program and staff get-together were organized at the Eco Hut, Dalma Wildlife Sanctuary, Makulakocha, Jamshedpur. An exhibition on the CSIR-NML products & technologies that can contribute to the development of the society was organized, in this connection. This activity was planned in the Dalma wildlife area of Jamshedpur with a motif to spread awareness about beautiful wildlife around the Dalma forest region, the tribal culture and the lifestyle of people around and to showcase the CSIR-NML activities for the benefit of society. The Mukhiya, Gram Pradhan along with members of village interacted with Scientists.



Customer Satisfaction Index (CSI) & Feedbacks



"Good support from PL"

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

– Tata Steel Limited --SSP 1244, SSP 1325

"R&D facility of NML, Jamshedpur is good."

"The R&D facility at NML proves commendable, and the assistance from the staff during experimentation deserves appreciation. However, it is noteworthy that the completion of merely six trials took a more extended period than initially anticipated, stretching to 2 to 3 months. I look forward to have future engagements with the NML lab."

– Jamipol Limited--SSP 1327, SSP 1343

"Good lab having solution to all products. Need more scientists for on time delivery of projects."

– Euro Pratik Ispat Pvt. Ltd.--SSP 1371

"Hydrometallurgical Know-how for the recycling of metals from waste provided by CSIR-NML will be commercially viable. In future also we would like to be in contact with CSIR-NML to get new recycling technology."

– Jai Mata Di Plastics--SSP 1314

"The testing live pictures and other videos shall be shared with report for better understanding of procedures and equipment availability very supportive team."

– Arcelor Mittal Design and Engineering Centre Private Ltd.--SSP 1295

"Working Experience with NML is very satisfactory. NML has wide range of testing and characterization facilities and talent pool for research activity. We would be happy to collaborate with NML in future as well for various studies and testing activities."

– Arcelor Mittal Nippon Steel Inc.--SSP 1311

"Thank you for the completion of the work in time. You did an amazing job; your lab test work findings have given new opportunity to improve our silver recovery. I personal learnt a lot in this journey. Hopefully, we will continue to work with this team and mutually explore the new opportunity to improve the grade and recovery in our mill operations."

– Hindustan Zinc Ltd--SSP 1307

"Project completed to the expectation."

– HPCL, Visakh Refinery--SSP 1168

"Excellent."

– SUNFLAG--SSP 1213

"Excellent; NML stands to its mark."

– Godawari Power And Ispat Ltd. --SSP 1331

"The R&D results reported have met expectations of the Company."

– Sandur Manganese & Iron Ore--SSP 1330

"Very Good."

– Uttam Value Steels Ltd--SSP 1324

Star Clients

Fortune 500 & ET 500 Companies



Intellectual Property Rights

Patent Applications Filed in India

#	Title	Application No.	NFNO
1	Process for extraction of lithium as high pure lithium carbonate from lepidolite ore	202311036117	0100NF2022/IN
2	Preparation of non-fused flux for dephosphorization and desulphurisation of steel in induction furnace	202311051893	0166NF2022/IN
3	A sensing device for in-situ health monitoring of engineering components exposed to high-temperature and stress	202311053163	0179NF2022/IN
4	Durable anti-icing and hydrophilic copper-based alloy coating and a method thereof	202311082992	0096NF2023/IN
5	Advanced zinc alloy coating and a process there of	202411025006	0241NF2023/IN

Patents Granted in Foreign Countries

#	Title	Country	NFNO	Patent No.
1	Electrospun collagen-graphene-polymer composite nanofibres for supercapicitors	U.S.A.	0263NF2016/US	11697734

Patents Granted in India

#	Title	NFNO	Patent No.
1	A process for production of directly reduced iron in tunnel kiln	0318NF2014/IN	430461
2	An apparatus and method for dry separation of materials based upon their density difference	0133NF2019/IN	435608
3	A process for the preparation of graphene oxide and functionalized graphene oxide from aeschynomene aspera plant	0092NF2014/IN	437220
4	Hot-dip al-si-mg-cu-sc coating on steel sheet with excellent in corrosion resistance as well as hot forming application and process for the production thereof	0069NF2018/IN	440682
5	A process for recovering zinc as zinc phosphate and other valuable products from zinc dross	0003NF2019/IN	443379
6	A process for the production of ferric sulphate and silica powder from copper slag	0045NF2018/IN	443944
7	A process for production of gadolinium metal from gadolinium chloride by electrolysis	0095NF2018/IN	444684
8	A rolling process for the preparation of grain oriented electrical steel sheet using low temperature reheating method	0270NF2015/IN	446860
9	An energy efficient leaching of metals from complex metal sulfides using oxygen enriching materials	0161NF2016/IN	448012
10	A process for producing goss texture in fe-3.2si electrical steel sheets	0233NF2015/IN	452984
11	A new hot- rolling method in fully ferritic region for preparing hb to produce crgo steel	0014NF2016/IN	453225
12	A novel multi-stage multi-product processing scheme for dry beneficiation of -1.0 mm coal fines by gravity separation using air fluidization on an inclined deck	0270NF2014/IN	454447
13	A process for preparation of blended cement using overburden shale as pozzolanic material	0145NF2019/IN	459972
14	Electrospun collagen-graphene-polymer composite nanofibres for supercapicitors	0263NF2016/IN	461568
15	A process for the preparation of grain oriented electrical steels using strip cast ingots	0271NF2015/IN	462327

#	Title	NFNO	Patent No.
16	Cu-based ductile bulk metallic glass and a process for the preparation of the same	0243NF2014/IN	462365
17	A process for the preparation of air cooled carbide free bainitic steel for abrasion resistance applications	0034NF2016/IN	463771
18	Ni-mb-cu-ga based magnetocaloric materials and process for preparation thereof	0034NF2018/IN	463905
19	An inoculation method for generating cube-on-face texture in as-cast strips of fe-si steels	0079NF2016/IN	464491
20	Electrodeposited ceramic coating for hardware submerged in hot dip galvanizing bath and process of electrodeposition	0081NF2018/IN	467087
21	A closed loop system for simulating and monitoring corrosion properties in continuous flow condition	0071NF2017/IN	473719
22	A process for the pyrolysis of depopulated printed circuit boards of e-waste	0094NF2014/IN	473801
23	A high strength as-cast mg-y alloy and process for the preparation thereof	0035NF2018/IN	474503
24	A process to produce blocks/bricks using high iron ash generated in sponge iron plants through geopolymerization	0204NF2014/IN	477140
25	An improved process for refining of crude/sponge magnesium using a modified flux	0033NF2018/IN	478069
26	A process to produce refractory bricks using fly ash	0047NF2013/IN	480271
27	A connector-condenser for the electrothermic production of magnesium	0315NF2014/IN	486839
28	A process for the preparation of cold bonded carbon composite pellets using wastes generated from steel plants	0302NF2014/IN	488634
29	A process for direct production of low and medium carbon ferromanganese in electric arc furnace	0119NF2018/IN	495872
30	Improved process for manganese recovery from reduced manganese ore and production of high pure electrolytic manganese dioxide	0195NF2019/IN	497329
31	An improved process for producing acquired aluminium nitride inhibitor precipitation in cold rolled grain oriented steel	0008NF2016/IN	497296
32	A process for preparation of cu-based brazing alloys for joining steel components	0084NF2012/IN	498028
33	A process for the preparation of grain oriented electrical steel through ingot metallurgy route by solidification under the effect of fast cooling rate & directional inoculation	0269NF2015/IN	499111
34	Iron-cobalt based high induction soft magnetic amorphous alloys	0242NF2014/IN	499663
35	White cast iron alloy composition for improved toughness and wear resistance in as-cast condition	0180NF2017/IN	500528
36	A process for enhancing oxygen mass transfer in stirred tank reactors using novel additives	0162NF2016/IN	510663
37	A novel electrochemical method for the recovery of metal values from spent ndfeb magnet	0160NF2019/IN	510829
38	A process of preparation of medium carbon and high hardness nanobainitic steel	0094NF2019/IN	510984
39	An improved hot dip coating process	0147NF2018/IN	514053
40	A process for production of highly metallised directly reduced iron cylinders(dri-c) from lead grade raw materials	0019NF2017/IN	525648
41	Process for production of low phosphorus steel	0036NF2018/IN	526619

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Trendsetters in Aviation Industry:

Indian Airlines have transformed the equations of gender parity. Now these airlines are hiring most number of women pilots & crew members as well as operating with all women crew for fostering a women inclusive society with their professional abilities. India has the highest rate of female air captains in the world. In India, 12.4 per cent of pilots are women.

All women Crew- Indigo Airlines





"They see women, we see pilots"-IndiGo. With over 44% of women in its workforce, IndiGo is championing Girl Power not just up in the air, but every step of the way through women-led development. The airline has one of the highest percentages of women pilots in the world and is the only airline in India with an all-female cabin crew. Also awarded by the Indian Women Pilot Association for employing nearly 700 women pilots, the highest in any airline in the world.



All women Crew- Air-India Airlines



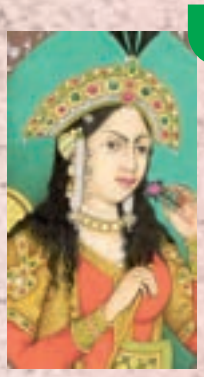
Air India operated 90 all-women crew flights on the Women's Day 2023 and has continued to do so.

Women Challengers in Indian History:

Indian Queens who fought for changing the prevailing rules for fostering a women inclusive society with their perseverance and courage.

Leading Women of India...





Razia Sultana (1205-1240)

Razia Sultan was the only female ruler that ruled the Delhi sultanate. Despite of strong rebellion of family, nobles and general public who could not accept a woman ruler, Razia could be ascended to the thrown. Although her reign was short-lived, Razia Sultan proved herself as a strong and capable leader.



Ahilyabai Holkar (1725-1795)

Ahilyabai Holkar refused to follow the "Sati" pratha after the death of her husband. Despite of many conspiracies and attacks, she became the queen of Indore, after the death of her father-in-law. She was trained in military warfare, and used to lead her army in battle herself. This Indian queen defended the state of Malwa against intruders. She is well known for construction of multiple Hindu temples and Dharmashalas across the country. Kashi Vishwanath Temple, Varanasi is the most famous out of all such temples that she crafted.

Lakshmi Bai Newalkar (1828-1858)

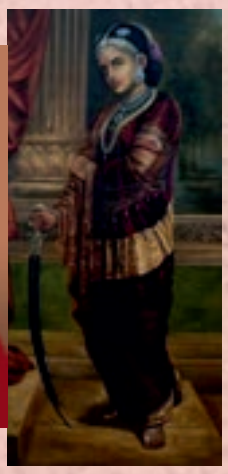
The queen of Jhansi is one the most well-known women rulers of India for her inclusive approach for women in her kingdom. This Indian queen ascended the throne after the death of her husband. She was highly educated and was against the discrimination prevailing in the society on the basis of caste, religion and gender. She raised the all-women cavalry to fight against the British. She was trained in warfare from a young age and was a proficient military leader. She played a crucial role in the Revolt of 1857 against British rule in India and died fighting bravely with the British army to protect Jhansi.







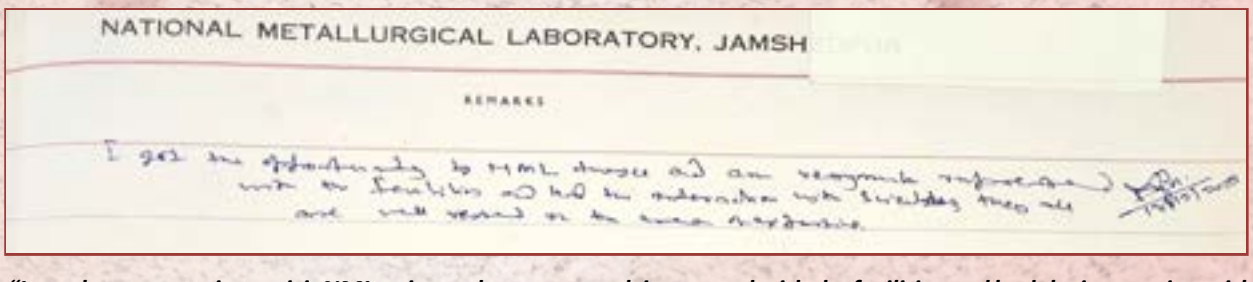




Kittur Chennamma (1778-1829)

The queen of Kittur in Karnataka(present) was trained in sword fighting, archery and horseback riding. She had to be ascended to the thrown after her sons and her husband died. This Indian queen was also one of the first women rulers who fought against the British and led her army into battle. She won the first battle but got imprisoned in another attack by British. She died during imprisonment. She is celebrated in Karnataka folklore as a hero. As a tribute, statue of Kittur Chennamma has been installed in the Parliamentary Building premises at New Delhi.

impressions

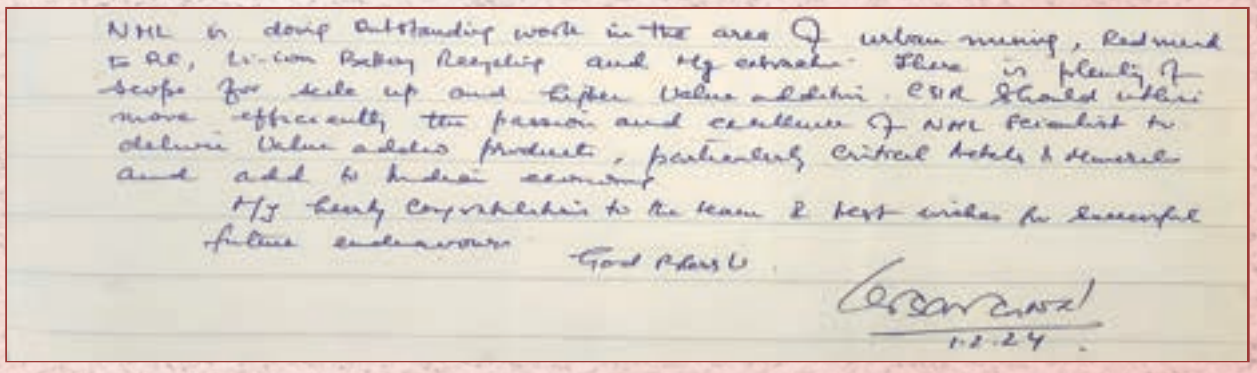

NATIONAL METALLURGICAL LABORATORY, JAMSH

REMARKS

I got the opportunity to NML twice and am very much impressed with the facilities and had the interaction with scientists, they all are well versed in the area of expertise.

"I got the opportunity to visit NML twice and am very much impressed with the facilities and had the interaction with scientists, they all are well versed in the area of expertise."

Dr. D. K Singh, BARC, 13.12.2023


NML is doing outstanding work in the area of urban mining, Red mud to RE, Li-ion Battery Recycling and Mg extraction. There is plenty of scope for scale up and higher value addition. CSIR should utilize more efficiently the passion and excellence of NML Scientist to deliver value added products, particularly critical Metals & Minerals and add to Indian economy. My Hearty congratulation to the team & best wishes for successful future endeavours. God Bless U

1.2.24

"NML is doing outstanding work in the area of urban mining, Red mud to RE, Li-ion Battery Recycling and Mg extraction. There is plenty of scope for scale up and higher value addition. CSIR should utilize more efficiently the passion and excellence of NML Scientist to deliver value added products, particularly critical Metals & Minerals and add to Indian Economy. My Hearty congratulation to the team and best wishes for successful future endeavors. God Bless You!"

Dr. V. K Saraswat, Niti Aayog, 01.02.2024

"The process flowsheet for the recycling of red mud developed by NML very well suits red mud of NALCO. The process is capable to recover alumina as well as extract metallic iron, with enrichment of Ti and REEs in slag. We look forward to its scale-up data."

Ms. Binuta Patra, GGM-R&D-NALCO, 21.02.23

Acknowledgment

We sincerely thank all who have extended their generous support, advice and help, in the preparation of the Annual Report 2023-2024 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. Kohinoor Printers for the timely publishing of this good quality Report.

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