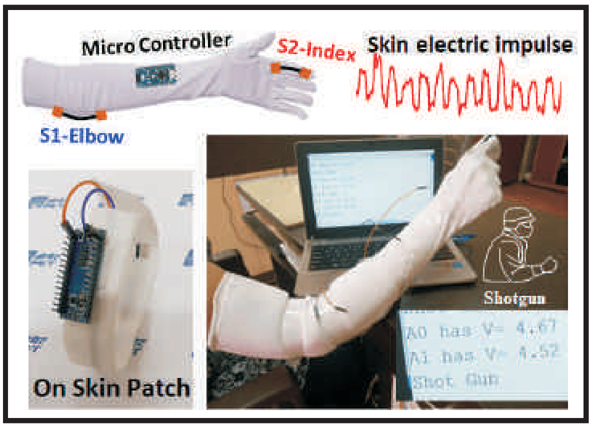
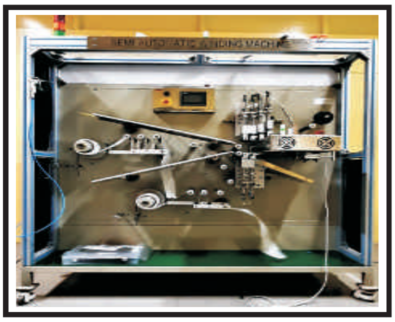
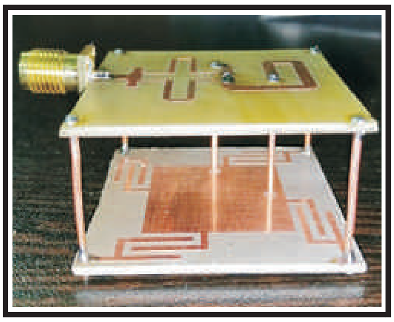


31st Year

ANNUAL REPORT 2020-21



Semiautomatic winding machine



Coupled shorting strip (CSS)

NavIC L5 antenna

CENTRE FOR MATERIALS FOR ELECTRONICS TECHNOLOGY (C-MET)
Scientific Society Under Ministry of Electronics and Information Technology (MeitY)
Government of India

Governing Council of C-MET (2020-2021)

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Hon'ble Minister
Ministry of Electronics & Information Technology
Electronics Niketan, 6, CGO Complex
New Delhi-110 003.

Shri. Sanjay Dhotre Deputy- Chairman
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Ministry of Electronics & Information Technology
Electronics Niketan, 6, CGO Complex
New Delhi-110 003.

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Electronic Corporation of India Ltd. (ECIL)
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Dr B.B. Kale Member Secretary
Director General (A)
Centre for Materials for Electronics Technology
Panchawati, Off Pashan Road
Pune-411 008, Maharashtra.

New Governing Council Committee approved in November 2019.

ANNUAL REPORT
2020-2021

CENTRE FOR MATERIALS FOR ELECTRONICS TECHNOLOGY (C-MET)

Scientific Society under
Ministry of Electronics and Information Technology (MeitY)
Government of India

Vision & Mission

Vision

C-MET will become a premier R&D organization known all over the world for its knowledge base, innovations and expertise in electronic materials.

Mission

To develop knowledge base in electronic materials and their processing technology for Indian industries and to become a source of critical electronic materials, know-how and technical services for the industry and other sectors of economy.

CONTENTS

Executive Summary

C-MET is a renowned prominent R&D institution focused on the development of requirement driven electronic materials in the country. C-MET targets to be the think tank leading to the progression of science and technology as well as the creation of innovation for the purpose of self-sufficiency of India in critical electronic materials. C-MET is working closely with industries as well as stake holders from strategic sector for specialized materials. C-MET has also put together and nurtured strong collaboration with national and international universities/institutions for the development of advanced materials and devices. C-MET has been working on LTCC based design and production of packages for integrated circuits, energy generation, energy storage materials & devices, nanomaterials, high purity materials, e-waste recycling processes, sensors, microwave materials/circuits, radio frequency switches and biomedical materials.

The Annual report 2020-21 of C-MET is prepared with an objective to publicize the achievements and other initiatives of C-MET among citizens of the country and also internationally. It highlights major success stories of technologies developed at C-MET and transferred to industries for production. The report also includes the brief on ongoing projects and their progress as well as new initiatives during the year 2020-21. Indigenous development and import substitution of critical materials will play a major role in achieving self-reliance and making the country ATMANIRBHAR.

Foreword

I am enormously overwhelmed to present the Annual Report of C-MET for the year 2020-21. This report offers amalgamated information on the events, accomplishments, output and global impact on C-MET during this period.

C-MET in accordance with its mission and vision has been concentrating on the development of sustainable technologies based on advanced electronic and related materials. C-MET has aligned its activities in the areas of nanotechnology, silicon carbide wafers, high purity materials, non-conventional energy generation and storage, materials for energy devices like batteries, supercapacitor etc. Also, energy generation materials and devices such as fuel cells, hydrogen, solar cells etc. E-waste recycling process technology has also been established to tackle the problem of electronic waste in the country. New futuristic areas like Quantum materials, advanced antenna materials, medical electronics with wearable and cancer detection devices are also been tapped by C-MET.

Unlike last few years, C-MET has been able to keep up its steadfast growth this year too. Three Centers of Excellence (CoE's), i.e., Center of Excellence in E-waste Management, Centre of Excellence in Rechargeable Battery Technology (Pre-cell) and Additive Manufacturing have been established. Further, this year, 10 sponsored projects have been completed; 8 new externally funded projects have been initiated, and 35 grant-in-aid projects are going on. C-MET has published 47 research articles in international journals and awarded 3 patents. C-MET scientist grabbed several awards via 52 presentations in conferences this year. I am glad to place on record that our extra budgetary resources have touched Rs. 40 Cr.

C-MET has also developed antiviral and antibacterial masks with metal/metal-semiconductor nanoparticles as a cost-effective alternative of N-95 masks for the Indian market. To address the acute shortage of Covid-19 testing kits in the country and reduce their price C-MET has successfully developed Polymer Swab for Covid-19 testing.

C-MET has signed MOU with M/s H2e Technologies Pune for Fuel Cells (μ-SOFC), IIT-BHU for R & D interactive program, School with Applied Sciences, KIIT for Academic Collaborations in the area of Nanomaterials, SPEL Technologies Pvt. Ltd. as industrial partner under CoE in Rechargeable Battery Technology (Pre-Cell), Research and Innovation Circle of Hyderabad (RICH) to promote and facilitate research in the areas of e-waste management, Space Applications Centre (SAC), ISRO, Ahmedabad and Ministry of Electronics and Information Technology (MeitY), New Delhi, for Technical Collaboration for Design & Development of Indigenous Antennas for NavIC.

C-MET's 30th Annual Foundation Day (AFD) 2021 was celebrated at Pune using virtual platform on 8th March 2021 alongwith an International Conference on Multifunctional Electronic Materials and Processing (MEMP-2021). Presidential address was delivered by Shri Sanjay Dhotreji, MOS, MeitY.

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Dr. V. K Saraswat (Member NITI Aayog), Dr. Vijay Bhatkar (Chancellor, Nalanda University), Shri Ajay Prakash Sawhney (Secretary, Ministry of Electronics & Information Technology), Mrs. Jyoti Arora

(Special Secretary & Financial Adviser MeitY), Shri. Arvind Kumar (GC-MeitY), Dr. Sandip Chatterjee (Director, MeitY) and other Meity as well as C-MET Scientists & officials attended the celebrations.

The preceding Conference (MEMP-2021) was inaugurated by Prof. Rodney Ruoff, an outstanding scientist in Graphene and Carbon Science. Prof. Yury Gogosti, the father of Mxene materials delivered plenary talk. Dr. R.A Mashelkar, Prof. Seeram Ramkrishna, Prof. Arindam Ghosh, Prof. Ajayan Vinu, Prof. Sanjay Mathur, Prof. Clare Grey, Prof. John Irvine, Prof. Pedro Gomez-Romero, Prof. A Sumant, Prof. Vinayak Dravid, Prof. Douglas Macfarlane, Prof. Adams, Prof. Animesh Jha, Dr. Mather, Prof. Sabine, Prof. Stretz, Prof. S. Agarwala and other 29 Eminentpersonalities from Industries and academia delivered their lectures.

Around 300 delegates attended and actively took part in the deliberations in the three-day virtual conference. Nearly 110 abstracts were received from students and R&D personnel from premier R&D institutions and industries in the field of Multifunctional Electronic Materials and Processing (MEMP 2021). The conference ended with a panel discussion on 'Materials Research a Pathway to Atmanirbhar Bharat'. The conclusion(s) inferred were thought to be useful in comprehending the Prime Minister's vision on "Make in India" campaign.

As envisioned by the Honorable Governing Council and Steering Committee members, C-MET continues to excel in its commitment to R&D for strategic, commercial and social sectors via working in multidisciplinary R&D areas. I have confidence that C-MET will continue to outshine even greater achievements under the visionary guidance of MeitY for realizing all its goals and objectives in the field of research and development on materials for electronics technology. Your valuable suggestions and feedback are always welcome!

Dr. B.B. KALE
Director General (A)
bbkale@cmet.gov.in

1. Overview: vision, mission, objectives, structure and functions of C-MET

1.1 Introduction

Centre for Materials for Electronics Technology (C-MET) has been set up as a registered scientific society in March 1990 under Ministry of Electronics and Information Technology (MeitY), (formerly known as Department of Electronics (DOE)) as a unique concept for development of viable technologies in the area of materials mainly for electronics. C-MET is operating with its three laboratories located at Pune, Hyderabad and Thrissur with specialized research mandate at each place.

1.2 Vision

C-MET will become a premier R&D organization known all over the world for its knowledge base, innovations and expertise in Electronic Materials.

1.3 Mission

To develop knowledge base in electronic materials and their processing technology for Indian industries and to become a source of critical electronic materials, know-how and services for the industry and other sectors of economy.

1.4 Objectives

The objectives of C-MET are:

- To establish the technology up to pilot-plant scale for a range of electronic materials and transfer the same to industry for commercialization.
- To establish relevant advanced analytical facilities.
- To undertake applied research activities in the area of its operation.

C-MET has set up its vision, mission and strategy to achieve its objectives.

1.5 Function of C-MET

To develop electronic materials and process technology in the allied area for social and strategic areas though sponsored projects, technical services and consultancies. To serve Indian industries and research organisations by providing characterization facilities on payment basis.

1.6 C-MET Organization Structure

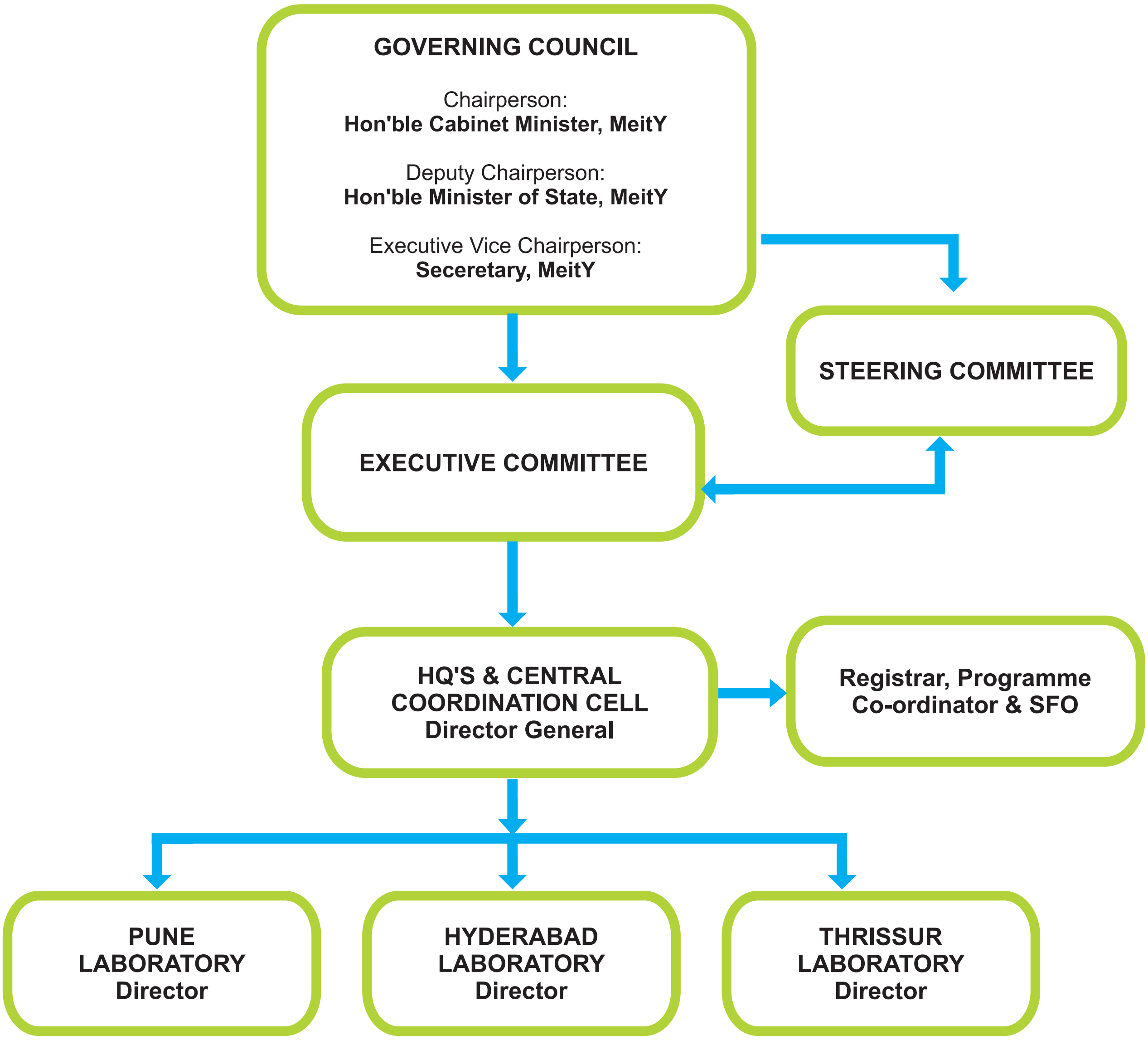


Figure 1: Organization chart of C-MET

1.7 Client's/Citizen Charter (CCC)

The detailed information about Client's/Citizen Charter is given in the website of Centre for Materials for Electronics Technology **website http://cmet.gov.in**

1.8 Human resource indicators (as on 31.03.2021)

C-MET team consists of 44 no. of S&T officers, 31nos. of S&T supporting staff and 38 nos. administrative staff. Among S&T officers and supporting staff, 44 nos. are having Ph.D. degrees. Additionally, there are 94 nos. project staff / Ph.D. students, DST Inspire / Young Scientists and Women Scientists working at three laboratories of C-MET and are depicted in Figure 2.

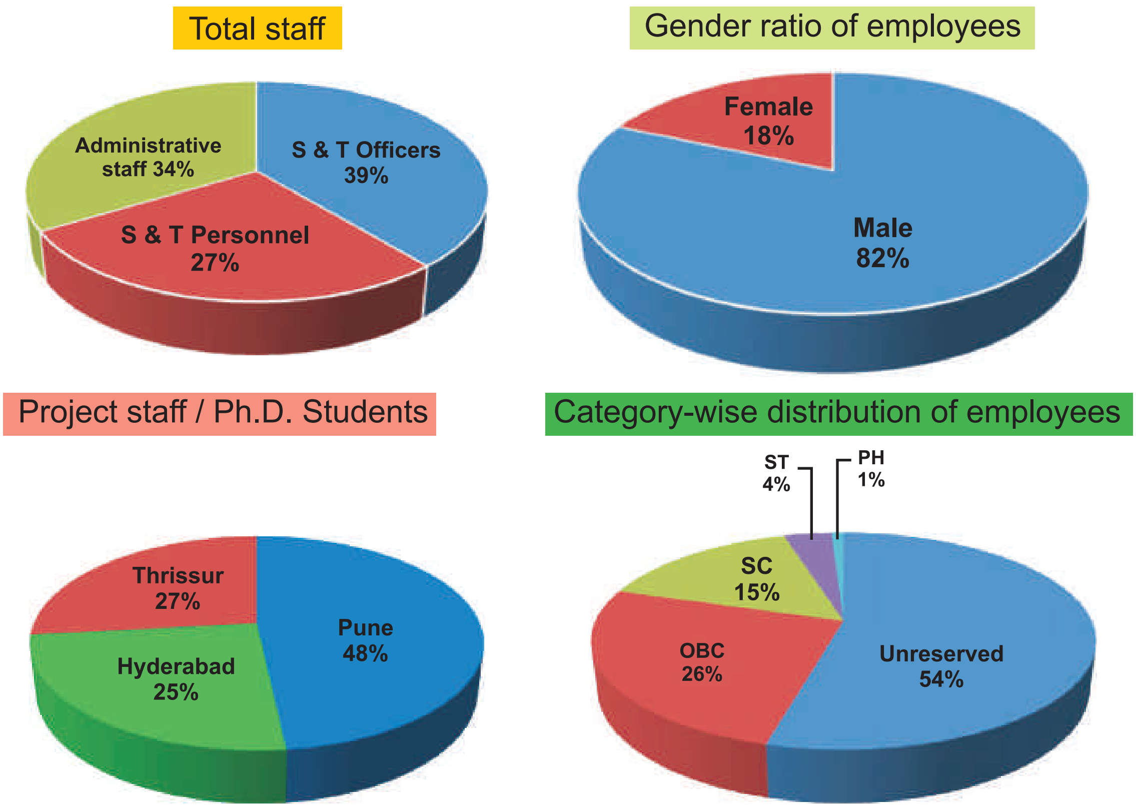


Figure 2: Human resource indicators of C-MET

2. C-MET's Core Competency in Electronic Materials

2.1 R & D in electronic materials & significance of C-MET

Electronic materials form a significant segment of advanced materials with important applications in the development of integrated circuits, substrates for circuit boards, electronic packaging, energy generation & storage systems, nanostructured materials, communication systems, displays & various sensors and actuators.

Electronics and Information Technology, which is a premier global technology comprises data (or information) generation, categorization, transmission, retrieval, processing and propagation to the benefit of society. Microelectronics is the keystone of IT. A strong IT network needs supporting system, which has roots in advanced electronic materials. Electronic materials are the key to many fast-emerging applications which help to improve the overall quality of life. Overall development of any nation has its roots in the advancement of defence, agriculture, education, medicine, space and other relevant fields. New device architectures and advanced materials become the base of the total technology strength of nation.

Research and development activities on the electronic materials domain have been pursued by various institutions in the country. However, focussed approach to undertake requirement driven R&D activities lies only with C-MET. This uniqueness of C-MET can be judged through its objectives laid down during its establishment and its achievements over these years. All the developmental programmes undertaken and carried out during previous years and currently are in accordance with these objectives. Various process and product technologies have been developed in the area of electronic materials over these years. A major stumbling block was the after effects of globalization and open market scenario immediately after the formation of
C-MET. Understanding this scenario, new knowledge-based methodologies have been evolved to enhance the partnership of end users like industries, services and strategic sectors in C-MET's technical program.

2.2 Core competence at C-MET laboratories

C-MET's R & D activities have been implemented in three laboratories i.e. Pune, Hyderabad and Thrissur. In the campus of Pune laboratory, C-MET headquarter is functioning which monitor the administrative activity and central technical coordination. Each of these laboratories has its own area of specialization with requisite infrastructure and expertise. This approach has proven to be successful in creating core competence at each laboratory.

2.2.1 Pune laboratory

Pune laboratory is mainly focusing on cutting edge R & D research on materials for electronic packaging, renewable energy, energy storage, sensors and nano-materials/composites. These key areas of research have been thrived out into various inter-disciplinary applications.

Figure 3: Two Wheeler with 48V Li-Ion Battery

2.2.2 Hyderabad laboratory

C-MET, Hyderabad has evolved as a unique facility for high pure materials in the country and is working independently in a focused manner to create excellent national facilities for ultra-pure materials, compound semiconductors, refractory metals, alloys, Restriction of Hazardous Substances (RoHS) and e-waste recycling.

Figure 4: Electron Beam Melted Hafnium metal (99.5% pure)

2.2.3 Thrissur laboratory

Major thrust area of C-MET Thrissur includes Microwave materials, Supercapacitors, Sensors & Actuators, Plasmonic materials and devices and Biosensors.

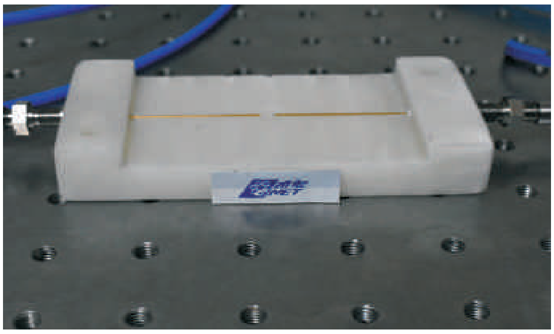


Figure 5: Fibre optic probe for liquid ammonia sensing

2.3 C-MET's approach and current strategy

2.3.1 Our approach

• Majority of Indian electronic industries do not have adequate in-house R&D facilities and are not in a position to set up new production line for new technologies. Additionally, after the globalization, it has become imperative for them to improve their production with respect to quality, quantity, price and delivery time to compete with their counterparts. To achieve this, they have to depend on either foreign collaborators or identify a suitable Indian partner. Indian industries had faced immense problems with absorption and up-gradation of imported technologies. Therefore, it has become essential for the industry to interact with R&D laboratory having a strong knowledge base and expertise in their desired field of interest. Realising this, C-MET has partnered with them, wherever possible, to meet their requirements. The paradigm shifts from research and development to technology development & transfer as well as providing timely services to industry are important in the changed scenario.

• Strategic sector has been routinely facing uphill task to procure the requisite materials, components and systems for their critical operations from various countries. Indian industries are lacking expertise in realising fully the cutting-edge technologies. Identification of a right agency in both these cases is very important and C-MET has a major role to play in terms of bridging the gaps. C-MET's expertise, infrastructure and long experience suit to take up this challenging responsibility. Hence, the total system has been mobilized and geared up to utilize the present situation in favour of C-MET. Accordingly, C-MET has signed MoUs with DRDO, ISRO and DAE institutes.

• Growing awareness towards a green and sustainable environment has prompted each C-MET centre to give adequate publicity through discussions on related subjects, secure wide participation and podcast these discussions in social media.

2.3.2 Current strategy

In order to accomplish the set objectives, C-MET has implemented the following strategies for project execution based on in-house expertise, competence and infrastructure to creative conducive ecosystem to support strategic and industrial sectors.

- To implement projects which are expected to generate technologies which have the potential to commercialize near future and the products/processes which are required for critical areas covering space, atomic energy, defence, industry, etc., that are essentially small volume but high value products.

- To develop leapfrogging technologies in the area of electronic materials to support critical strategic requirement

- Establishment of centre of excellences in line with make in India and digital India programmes to supply the critical materials and technologies for the Indian industries.

- To develop strong knowledge base in ensuing electronic materials technologies. The technology development and pilot plant activities can be sustained for longer periods with the backing of scientific skillset and proficiency of requisite standards. This could be engendered by numerous means, e.g. by undertaking research & development in the pertinent areas, hands on training to young scientists and providing services to the industry. Strong R&D knowledge base is essential in developing specialized electronic materials, especially for integrated electronic packaging, nanomaterials and devices, renewable energy storage and conversion, compound semiconductors, dielectrics for microwave applications, semiconductors for optical and energy applications, sensors and actuators, piezoceramics, medical imaging and energy harvesting applications, materials and methods for cost-effective early breast cancer detection as well as technologies to purify electronic materials, recycling of electronic waste etc. C-MET has strong expertise in multilayer packaging, e-waste recycling, nanostructured semiconductors, quantum dot semiconductor glasses, nanocomposites, plasmonic materials, ultra high purity materials and devices, etc.

3. R&D activities and S&T contribution

During the year 2020-21, the main technical activities of C-MET are the following:

- Implementation of supplementary grant-in-aid projects from MeitY as well as various government funding agencies like DST, ISRO, BRNS, DRDO, DAE, private industries and public sectors, etc.

- Technical and materials characterization services

3.1 Core program:

It was proposed to have more coordinated and focused approach to the R&D areas through inter-laboratory research interactions, where C-MET can deliver by exploiting its expertise gained hithertoin the development of traditional and advanced electronic materials.In this context, six major core programs listed as follows have been selected for implementation.

3.1.1 Electronic Packaging

C-MET has been working in the area of Low Temperature Co-Fired Ceramic (LTCC) since Year 2006. LTCC is a multilayer fabrication process in glass-ceramic regime that primarily creates high density circuit boards with integrated passive components. LTCC finds applications in various fields. The materials property of low dielectric constant and low dielectric loss and inherent high reliability make LTCC suitable for microwave circuits, allowing applications, in communications, military and aerospace. LTCC also finds applications in packaging of Integrated circuits, Micro Electro Mechanical Systems (MEMS) and Integrated Micro Systems. This capability opens up a host of additional applications in industry as well as healthcare. Recently, C-MET has developed indigenous LTCC tapes and pastes at pilot scale. C-MET, Pune has set-up state-of-the-art LTCC circuit and packages fabrication facility which is used to fabricate circuits, packages and materials.

Figure 6: LTCC based Biosensor with Integrated heaters and buried microfluidic channels for water quality monitoring

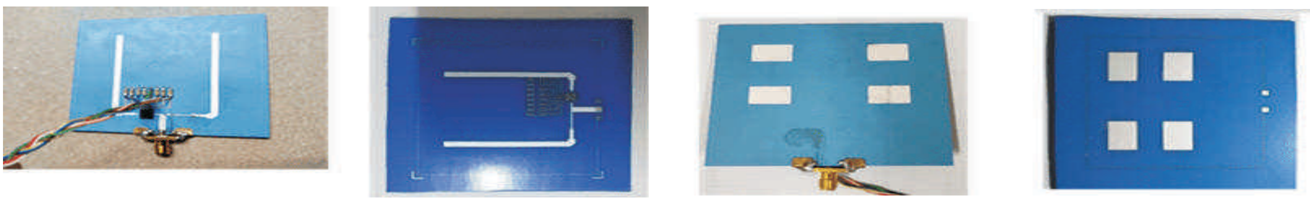


Figure 7: Microwave beam steering circuit (Top & bottom surfaces) made and assembled in LTCC using Dupont tape & CMET's Tape

The facility comprises of ~200 m^3 clean room of Class 10000 that houses the complete LTCC processing facility including tape casting and materials preparation.

3.1.2 Magneto-dielectric

C-MET Thrissur has been developed hexaferrite based flexible magneto-dielectric (MD) substate. The conformal antenna has been developed using flexible MD substrates for Radome application.

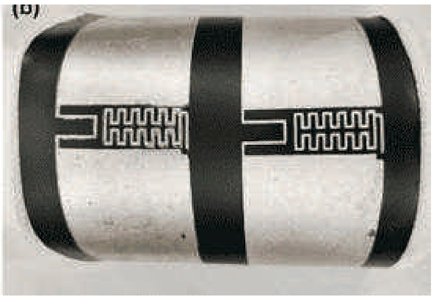


Figure 8: Screen printed conformal antenna on curved surface

The C-MET also aim to develop the cost-effective ceramic filler for PTFE and hydrocarbon-based substrates for microwave and millimetre-wave application. The phase pure ceramic filler without RE has been developed and PTFE and hydrocarbon polymer-based substrate will be developed using these fillers.

3.1.3 Sensors and Actuators

C-MET Pune is developing materials and prototypes for different chemical sensors such as hydrogen, NOx and VOCs based on semiconductor materials for operating at high temperature as well as room temperature. The physical sensors such as photosensor, piezoresistive pressure sensors, temperature and IR sensors. C-MET Pune has also recently transferred the ToT on photosensor to M/s. Ants Innovation Pvt. Ltd. Palghar, Mumbai and other ToTs on sensors and materials are in pipeline. C-MET, Pune is presently working on digitalization of indigenous NOx sensor for ISRO and the development of smart parking management system using sensors, IoT and GIS technologies. C-MET, Pune is developing conducting polymer composites based piezoresistive sensors for wearable biomedical applications. The sensors are potential in monitoring the physical actions, gesture, gait analysis, orthopaedical treatment and non-verbal communication applications etc.

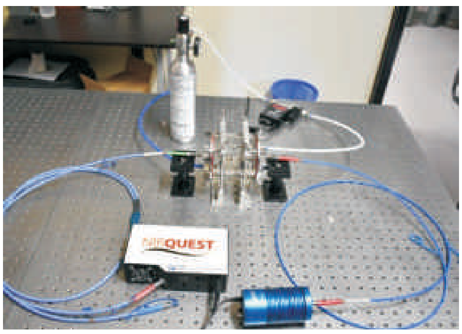


Figure 9: Demonstration of ammonia gas sensing at room temperature

During this period C-MET Thrissur mainly concentrated on NTC Thermal Sensors for weather balloon application of ISRO and also for understanding the key parameters that will help to locate the cancer lesion in breast cancer using 3D analysis. C-MET Thrissur has developed fibre optic sensors for ammonia and hydrogen sensing. The ammonia sensor exhibited limit of detection of 10 ppm for both liquid and gaseous ammonia at room temperature. The prototype hydrogen sensor had the limit of detection of 25 ppm for hydrogen gas. $Ti_3C_2T_x$ MXene was prepared through chemical route. Biopolymer (Chitosan) and Poly (vinyl alcohol) (PVA) based nanocomposite films were developed for EMI shielding applications. These flexible films are promising for EMI shielding with SE of 2.7 dB.

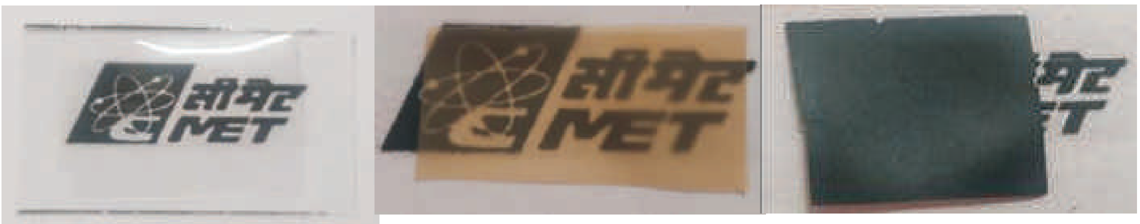


Figure 10: Films of PVA, PVA-Chitosan and MXene/PVA-Chitosan for EMI Shielding application

All these programs are supplemented/complimented by grant-in-aid sponsored projects.

3.1.4 Nano materials

- C-MET, Pune engages in development of hierarchal Nanostructure such as Sn_3O_4, Sn_3O_4 Graphene and N-doped Sn_3O_4. The Q-dots of Bismuth and Sm@CdS (2-5 nm) have been grown in glass matrix for water purification. The SnO_2, Silicon nano particles were synthesised and used as anode materials for LIBs.
- By suitably engineering plasma frequency, C-MET Thrissur has developed films on glass exhibiting surface plasmon resonance upto wavelengths as low as 1300 nm in NIR, crossing telecommunication window. The centre also developed transparent heater films on 5”by 3” substrate size using large spray coating machine.

Figure 11: Round shaped transparent heater

3.1.5 Materials for Renewable Energy

(a) Solar cells: C-MET Pune has established the hybrid solar cell (inorganic-organic materials based) fabrication facility and developed conceptual solar cell. Also, DSSC and Perovskite solar cell materials are being developed under this activity.

(b) Hydrogen generation and storage: C-MET, Pune is working on the hydrogen generation using renewable energy source i.e., sunlight, from water, hydrogen sulphide and biomass. The stable and economical photocatalysts (Nano Semiconductors) have been developed for hydrogen production under natural sunlight from water and H_2S. C-MET has established photoreceptor system which can produce hydrogen from H_2S using natural sunlight. The hydrogen storage materials such as Hollow glass microspheres and other hydride materials have been developed.

(c) Fuel cells: Fuel cell is one of the efficient energy generation devices where hydrogen is a fuel and air is an oxidant. C-MET, Pune is working on PEM fuel cells where bimetallic economical nanophase catalysts have been developed. Proton conducting membranes are also developed for SOFC. Development of SOFC fuel cells using LTCC packaging is also in progress.

(d) Thermoelectric cells: C-MET, Pune is working on development of thermoelectric materials for energy generation from waste heat. Facilities for making thin films of materials have also been established.

3.1.6 Energy Storage Materials and Devices

The state-of-the-art facility for Li-ion and other rechargeable batteries fabrication has been established. The cathode and anode materials for Li-ion batteries and Sodium ion batteries have been developed. The solid-state Li-ion battery has also been demonstrated. Considering the demand of flexible electronics, flexible batteries have also been developed. Nanomaterials and their nanostructures play a critical role in the recent advancement of some key technologies associated with energy conversion and storage. Nanomaterials differ from micron sized and bulk materials not only in the scale of their characteristic dimensions, but also in the fact that they may possess new physical properties and offer new possibilities for various technical applications. For example, the reduction of electrode particle size to nano regime (few nm) in batteries leads to tremendously improved intercalation kinetics and ultimately enhances the overall degree of intercalation. This will also help to miniaturize the size of batteries. Rechargeable batteries are increasingly viewed as an important means of alleviating problems associated with an overdependence on fossil fuels, as they can serve as storage devices for renewable energy, such as wind and solar power, and as power sources in environmentally friendly vehicles (fully electric and hybrid cars) as well as in a host of consumer electronics, such as mobile phones and laptops. However, the low abundance and uneven distribution of lithium resources show the potential difficulties of the long-term and large-scale applications of lithium-ion batteries in terms of their availability and cost. Hence, the development of new types of batteries, such as sodium-ion and magnesium-ion batteries, are necessary. Among them, sodium-ion batteries (NIBs) possess electrochemical working principles that are similar to LIBs. In addition, sodium is inexpensive and abundant in nature. Sodium is the sixth richest element on earth. Therefore, NIBs could substitute LIBs in applications such as smart grids and large-scale energy storage for renewable solar power and wind power.

Figure 12: Li-ion battery pouch cell developed at C-MET

The major activities being carried out at C-MET Thrissur under materials for renewable energy are both Aerogel based and graphene-based supercapacitors for potential applications in various sectors such as strategic, automobile, power electronics etc.

- C-MET is working on the development of Aerogel supercapacitors for various applications starting from raw material production at pilot plant level to fabrication of aerogel super capacitors up to 50F using in house indigenously established supercapacitor fabrication facility. Currently aerogel super capacitor is being tested as a power source for VVPAT of Electronic Voting Machine.

- C-MET has established a process for the production of continuous graphene electrodes suitable for supercapacitors. C-MET has developed graphene-based supercapacitors having capacitance of 0.1 F to 100 F and achieved an ESR of 10 milliohm.

3.1.7 High purity materials & compound semiconductors

C-MET, Hyderabad has evolved as a unique facility for highly pure materials in the country for ultra-pure materials for Cadmium (Cd), Tellurium (Te), Zinc (Zn) and Germanium (Ge). Necessary process technologies and processing equipment have been developed for the preparation of 7N pure (99.99999 %) Cd, Te, Zn and Ge starting from 4N (99.99 %) purity. To process highly pure Te, Cd, Zn and Ge, C-MET has established a clean room of class 10,000 with a class 100 environment in vertical laminar air flow benches in the area of nearly 200 sqm.

The highly pure (7N grade) Te and Cd are the major constitutes in cadmium telluride (CdTe), cadmium zinc telluride (CdZnTe), mercury cadmium telluride (HgCdTe), etc., which are used in various opto-electronic applications such as solar cells, IR detectors, imaging devices, electro-optic modulators, fluorescence, etc due to their sensitivity to X-rays, gamma-rays and photonic (UV-visible-IR) radiation. CdTe and CdZnTe substrates are used for growing epi-layers for Focal Plane Arrays (FPAs), whose major applications are in night vision cameras and thermal imaging devices in the kilometers range, predominantly used by army during night time operations.

C-MET has also developed process technology for the purification of Ge from scrap Ge through induction zone refining up to 7N purity. The design of induction zone refining furnace was done indigenously and two patent applications were filed to protect the intellectual property rights. C-MET has also been engaged in the growth of 2” SiC single crystal boules using physical vapor transport technique and grown 6H SiC single crystals first time in the country. C-MET has established infrastructure and process technology for growth of 2” diameter SiC (6H polytype) single crystal boule for electronic device application. The 6H SiC single crystal boules are grown by Physical Vapour Transport (PVT) technique using polycrystalline SiC powder as starting material on SiC seed crystal under Ar atmosphere inside the graphite assembly in the temperature range of 2200-2400 oC. This project is addressing the need for the technologically important wide band gap semiconductor for advance electronics application (high power, high frequency and high temperature). In house grown and further processed device grade SiC single crystal wafers will be used for RF device fabrication, high temperature (> 650 ˚C) gas sensors, solid-state transducers such as pressure sensors & accelerometers for automotive and space industry using micro-electromechanical systems (MEMS) in collaboration with user agencies viz. SSPL and DMRL.

3.1.8 Electronic waste and RoHS

E-Waste management is one of the major problems being faced by the world. With the non-monotonous increase in end of life electronic and electrical products, India is the third largest producers of e-waste. In order to address the e-waste related issues, a Centre of Excellence (CoE) on E-waste Management is being established at C-MET Hyderabad to tackle efficient management of e-waste such as proper collection, handling and processing of E-Waste and also to develop scientific methods to recover valuable materials. It is a single point solution provider for various aspects of e-waste management. Grand challenge programme for swift solutions to various associated technologies, incubation center for startups, skill development programme by providing training to interested recyclers, outsourcing of dismantling activities are various aspects of CoE. Environmentally benign technological solutions for recovery of valuable secondary raw materials from spent printed circuit boards, Li ion batteries, permanent magnets, solar cells, CFLS are also being developed under CoE.

A pilot plant facility established with a capacity of 300kg PCB recycling per day at C-MET Hyderabad. Processing facilities such as dismantling, depopulation, shredding, smelting, re-melting, electro refining, leaching systems etc. have been established. Characterization systems such as cupellation furnace, fire assay system, microwave digestion system and metal sorter are also in place for analyzing the metal contents in spent PCBs. The facilities established are utilized for processing of materials from various e-waste dismantlers, training informal sector and also demonstrate the PCB recycling technology to industrial partners.

C-MET, Hyderabad laboratory has established a self-sustainable world class chemical testing facility for the evaluation of electronic and related products to help the Electrical Electronics Equipment (EEE) industries on PAN India basis and developed a mechanism to identify and quantify the substances restricted under RoHS, Directive. This is the only RoHS testing facility in India established with the aegis of Ministry of Electronics & IT (MeitY), Government of India.

The RoHS facility at C-MET follows Standard Operating Procedures (SOPs) as per IEC 62321:2020 standard. RoHS analysis of variety of products are being carried out using these advanced characterization facilities. The test facility is accredited as per ISO 17025:2017 standard by National Accreditation Board for Testing & Calibration Laboratories (NABL), Department of Science & Technology, Government of India, with certificate No: T-1224 in the field of chemical analysis of electronic materials (polymers, metals, etc.).

Figure 14: Smelting of shredded PCB as a part of technical service to e-waste dismantlers

3.2 Products developed for strategic sectors

3.2.1 Carbide derived carbon for strategic applications

Nano structured carbon has received much attention during the last decades because of their importance in various applications and energy storage devices such as batteries, fuel cells and supercapacitors. Carbide derived carbon (CDC) is a high surface area material with large pore volume. The tunable pore size makes it an ideal material as the carbon source in supercapacitor applications. CDC is prepared by chlorination of metal carbides. CMET Hyderabad has got decade long experience in the chlorination process for the preparation of transition metal chlorides. CMET is engaged in the preparation of CDC for super capacitor application for VSSC.

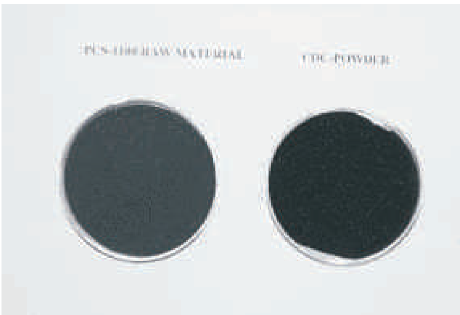


Figure 15: CDC Powder

3.2.2 Hafnium sponge for strategic applications

The first indigenous Hafnium Plant in India with a production capacity of 320 kg /annum of hafnium metal sponge to meet the total annual requirement of Vikram Sarabhai Space Centre (VSSC) for their applications in rocket nozzles and thrusters has been established at C-MET, Hyderabad laboratory. Hf metal sponge is preferred for the aforementioned applications due to its superior mechanical stability at high temperature range of 1500 °C. Hafnium is a costly rare metal with a world production of only 70 metric tonnes per annum. Hafnium oxide is also a future high dielectric gate oxide material for silicon based MOSFETs due to combination of high dielectric constant (k), thermal stability, large heat of formation and large band gap. Input material for hafnium production is zirconium raffinate, which is an effluent generated during the production of zirconium.

Figure 16: Passivated Hf sponge before unloading

3.2.3. 7N pure Germanium for detector applications

Induction zone refining system designed, fabricated for the purification of scrap Germanium converted to 7N pure Germanium for detector applications. Zone refined samples analyzed by GDMS at NRC Canada and confirms 7N Ge with respect to metallic impurities. 5 kg of 7N pure Germanium prepared by induction zone refining was supplied to SSPL, DRDO.

Figure 17: 7N pure Germanium to SSPL, DRDO

3.2.4 FT Actuators developed for DEBEL (DRDO)

For DEBEL (DRDO), C-MET developed fully mechanically amplified Indigenous linear Piezo actuators for use in breathing regulators for aircrew. Identified suitable piezo ceramic material for FT manufacturing by confirming the properties, optimized slurry composition and converted the Piezo composition to thin sheets by tape casting process. Multilayer processing conditions were optimized, designed and developed multilayer actuators and stacks. Delivered one bench model and three sets of FT actuators to DEBEL and properties of FT actuators were measured and confirmed by DEBEL.

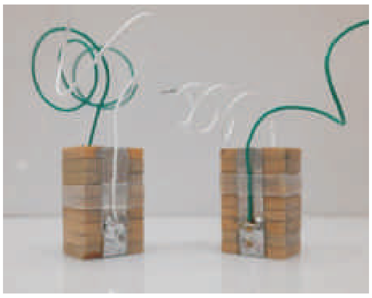


Figure 18: ML stack delivered to DEBEL

3.2.5 Graphene supercapacitor bank for electronic time fuse application.

The Graphene supercapacitor bank of desired voltage and capacitors successfully fabricated. The module was tested and validated by ARDE (DRDO), Pune for electronic time fuse application.

3.3 Technologies transferred

One technology has been transferred to the Indian industries during the year 2020-21. Technology for the “3D analysis system for wearable device for the prediction of tumor parameters” has been transferred to M/s. Murata Business Engineering (India) Pvt. Ltd., Hyderabad on 6.12.2021.

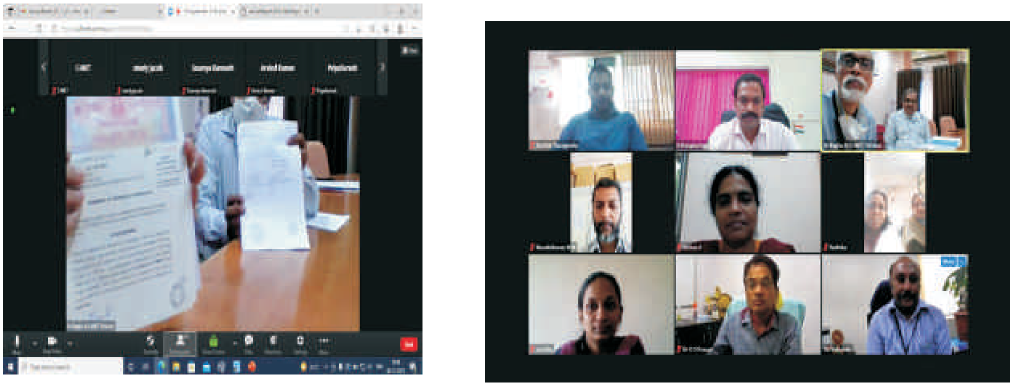


Figure 19: Signing of ToT agreement with Murata Business (I) Pvt. Ltd., Hyderabad

3.3 Technologies ready for transfer

The following technologies are ready for transfer. The glimpses of these technologies are given below

3.3.1 Nanomaterial based antimicrobial coatings for masks/fabrics

Antiviral and antibacterial mask developed by C-MET

C-MET, Pune has developed nanomaterial-based coatings for the mask and other healthcare fabrics. The mask having size of 4x8 inch requires around 40 to 45 mg of nanomaterial coatings. The process for nanomaterial synthesis and its coatings have been optimized for 10 g batch scale and can be scale up easily. In 10 gm nanomaterials almost 200-250 mask can be coated. The coatings remained on the masks/fabrics even after several wash. The nanomaterials are in the form of powder and need to be mix with polymer solution for performing the coating. This technology is specific for making the antimicrobial coated mask and other fabrics useful in health care industries.TRL level of technology is 3.

3.3.2. Aluminium-air batteries using activated carbon derived from bamboo for low power applications

Battery for 12V

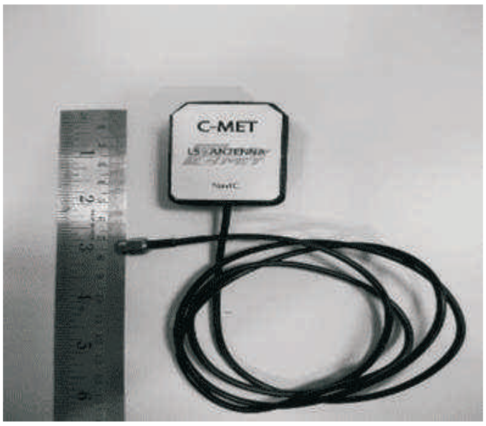
LED glowing with battery

C-MET, Pune has developed 100 % indigenous Al-air primary, 12 V battery for emergency and for the low power applications. Battery is developed using activated carbon derived from Bamboo grown in Maharashtra Forest.

These batteries can be used for energy applications as follows:
- No need of recharge
- It can give power continuously upto 24 hour
- Ideal for rural and hilly regions in India, where there is no regular power supply
- The battery is very handy, light weight and can be developed at low price
- Battery can be used after 5 years without activating as it has low self-discharge

TRL level of technology is 3.

3.3.3 L5 NavIC Antenna



Ceramic NavIC antenna (L5 band)

Navigation with Indian Constellation (NavIC) is an independent regional navigation satellite system developed in the country. The indigenous navigation system is expected to provide information on more accurate location performance, faster Time-To-First-Fix (TTFF) position acquisition and improved robustness of location-based services at all weather conditions. C-MET, Hyderabad has developed indigenous ceramic NavIC antenna for use in L5 band (1176.45 MHz). The salient features of the technology are miniaturized size, high gain and high radiation efficiency.

TRL level of technology is 4.

3.3.4 7N Tellurium & Cadmium

7N pure Cd &Te

Highly pure Te & Cd are required for synthesis of a range of materials including cadmium telluride (CdTe), cadmium zinc telluride (CdZnTe), mercury cadmium telluride (HgCdTe), etc. which are used in various opto-electronic applications such night vision cameras, tera hertz devices, etc.

C-MET, Hyderabad has developed indigenous technology for ultra-high pure (7N grade) tellurium and cadmium @4 kg per batch. Necessary augmentation has been done to improve the quality and quantity of throughput.

TRL level of technology is 4.

3.3.5 7N Zinc for detector applications

7N Zinc granules

C-MET Hyderabad has developed process technology for the purification of 3N Zinc to ultrahigh pure 7N Zinc by zone refining at 1 Kg batch size. Also developed the process technology for conversion of zone refined ingot to granules of <3 mm diameter for detector applications. Zone refined samples analyzed by HR-ICPOES at CSIR-NGRI confirms 7N purity w.r.t. metallic impurities.

TRL level of technology is 4.

3.3.6 Purification of scrap Germanium to 7N Germanium

7N Germanium ingots

C-MET Hyderabad has developed process technology for the purification of scrap Germanium to ultrahigh pure 7N Germanium by induction zone refining at 1 Kg batch size. Indigenous induction zone refining system has been designed and fabricated. Zone refined samples analyzed by GDMS at NRC Canada confirms 7N purity w.r.t. metallic impurities.

TRL level of technology is 4.

Other technologies available at C-MET

S.No.	Name of the technology
1	Thermistor based digital thermometers
2	Graphene through Chemical route technology
3	3YSZ ceramic Tapes for oxygen sensor applications
4	Graphene supercapacitors
5	Lead free X-ray absorbing materials
6	3D analysis system for wearable device for the prediction of tumour parameters
7	Wearable Device and Analysis System for Early Detection and Screening of Breast Cancer
8	(a) Environmental friendly treatment of PCBs and production of black copper enriched with precious metals (b) Recovery of valuable and precious metal from spent printed circuit boards (c) Recovery of valuable and precious metals from
	black copper obtained from spent printed circuit boards
9	Aerogel Supercapacitors for Electronics & Energy Storage Applications
10	Transparent thin film heater
11	Process for Nano-ZnO powder
12	Piezoceramic Compositions and Components
13	Lead Free X-Ray Absorbing Materials & Medical Apron
14	Microwave substrates with dielectric constant 6.15 and 3.0
15	Microwave Substrates of Dielectric constant 10.2, 13 & 14.8
16	Modified Silica filler for space applications
17	Quickly Rechargeable Emergency Lamp
18	Photopatternable Silver and Photoconductor thick film pastes for Photo Sensors

Details of the above technologies

@ https://www.cmet.gov.in/technologies-developed-c-met

3.4 Externally funded projects

During the year 2020-21, C-MET has initiated 8 new grant-in-aid and technical services projects, in addition to 36 ongoing grant-in-aid projects from previous year. Also, 10 projects have been successfully completed during the year. C-MET has earned Internal and Extra Budgetary Resources (IEBR) to the tune of Rs. 2643.51 lakhs during the year 2020-21. The laboratory wise sponsored projects funding pattern is depicted in Figure 20.

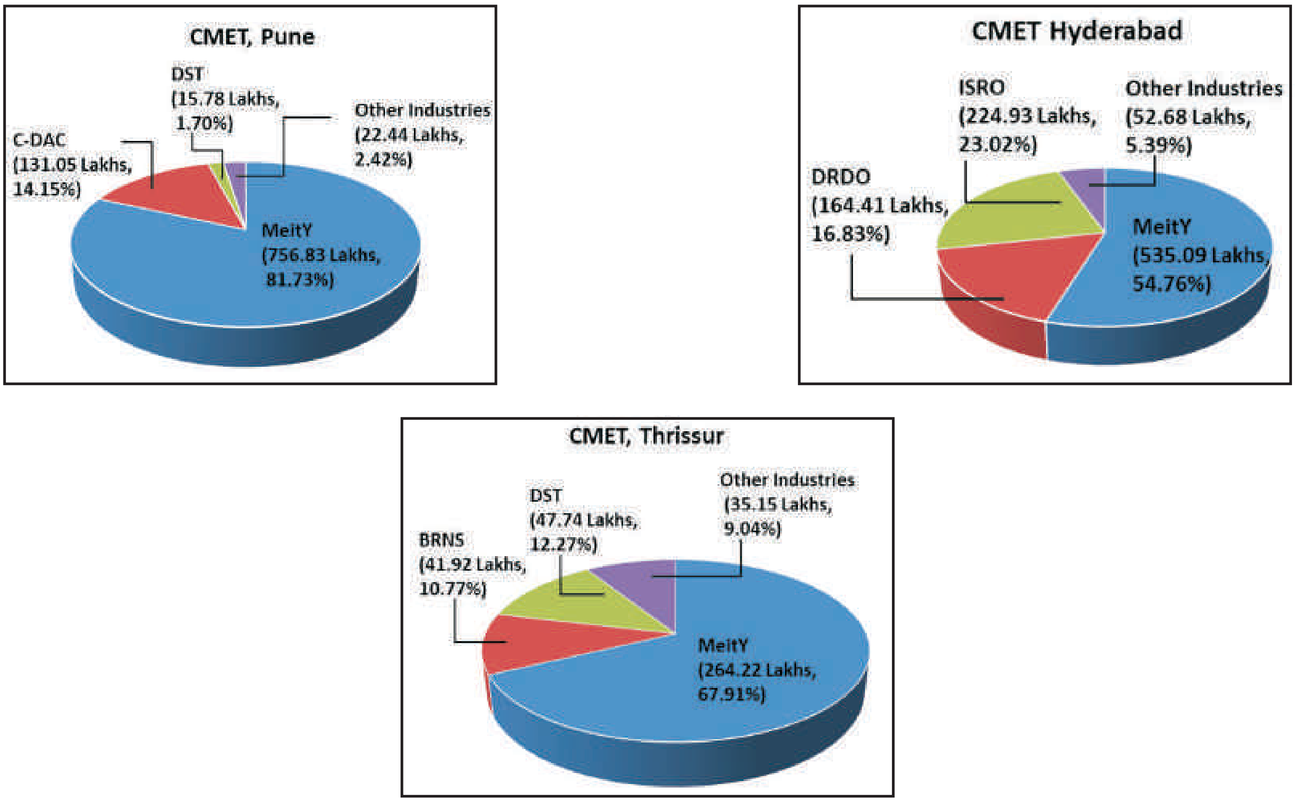


Figure 20: Sponsored projects funded by various agencies at C-MET Pune, Hyderabad and Thrissur

The growth in IEBR is graphically shown in Figure 21.

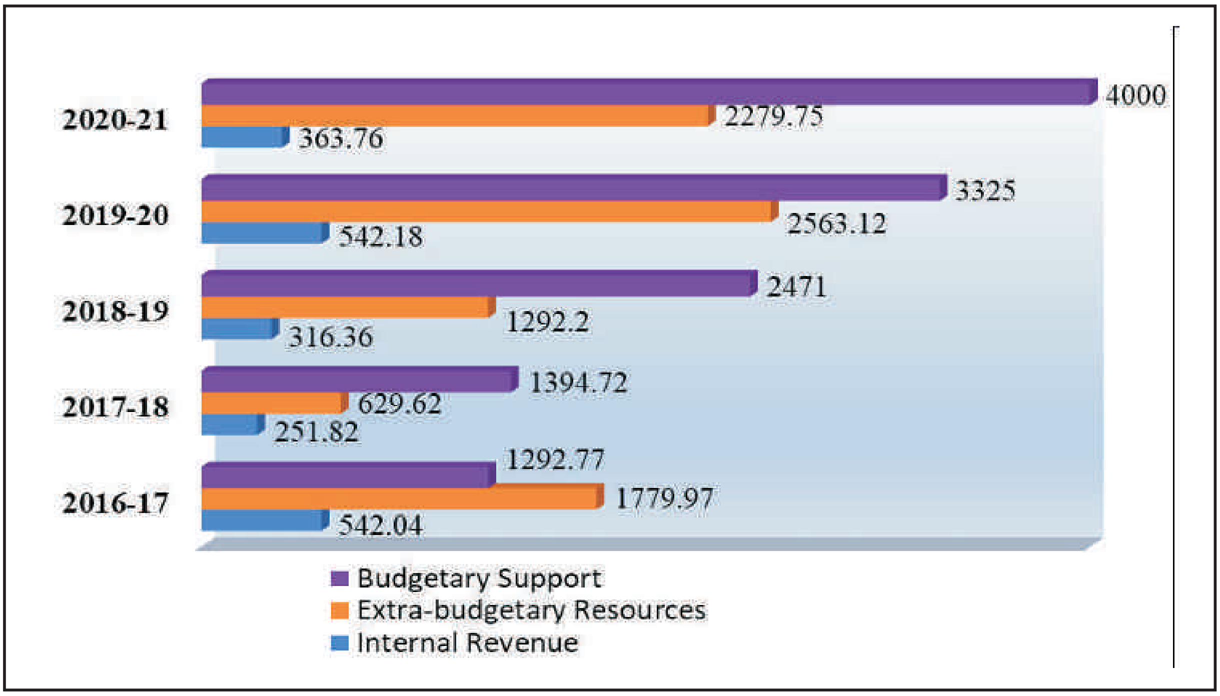


Figure 21: Budgetary support (BS), Internal Revenue (IR) and Extra-Budgetary Resources (EBR) of C-MET since 2016-21

C-MET has also been enhancing its intellectual outputs in terms of journal publications, conference papers, Indian and foreign patents and invited talks as seen in Figure 22. The trend clearly evidences better scientific recognition of the R&D capability of C-MET.

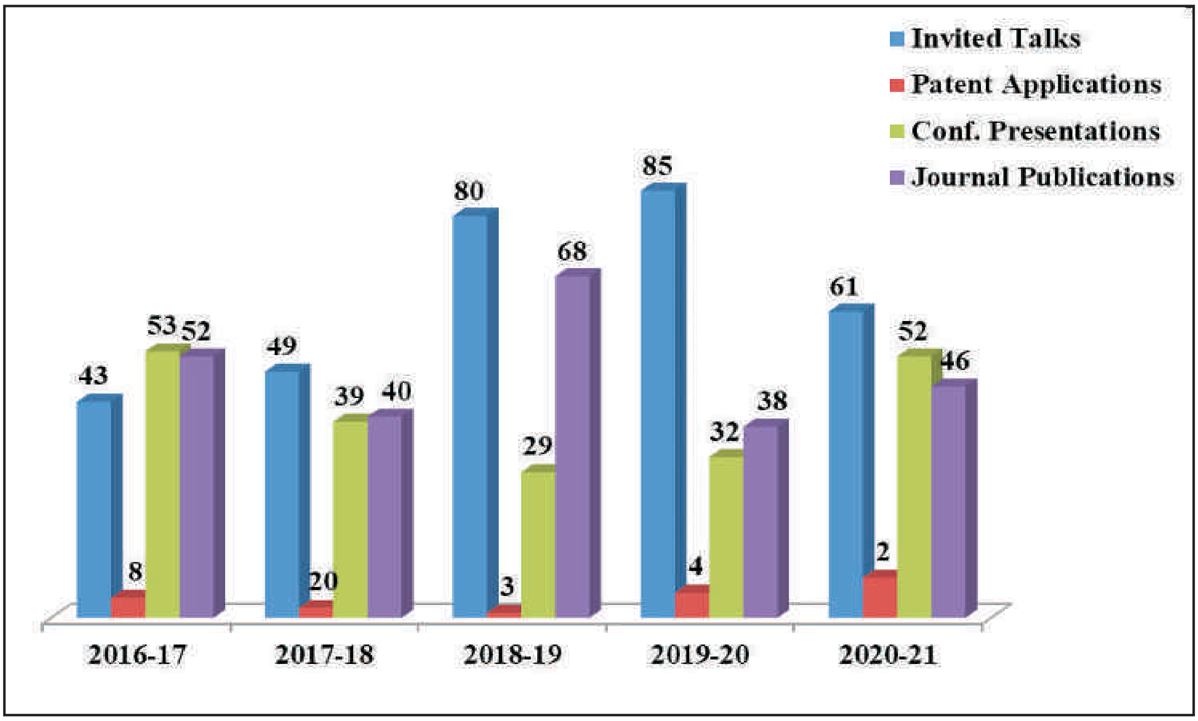


Figure 22: Intellectual output of C-MET since 2016-17

3.4.1 Completed grant-in-aid projects

The major achievements in respect of completed grant-in-aid projects are furnished below:

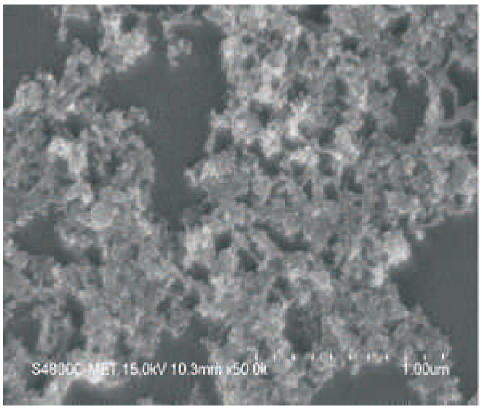
C-MET, Pune

1. Flexible solid-state supercapacitor device
(Sponsored by DST, Outlay: Rs. 60.64 lakhs DoS: 01.07.2017; DoC: 29.07.2020)

The proto-type solid-state supercapacitor has been fabricated and demonstrated to funding agency. Project completion report has been prepared and submitted to funding agency i. e. DST.

2. Synthesis of nanosized AIN ceramic powder by transferred arc plasma reactor for electronic packaging applications
(Sponsored by ISRO, Outlay: Rs. 28.64 lakhs DoS: 24.01.2018; DoC: 31.03.2021)

- Optimization of evaporation of aluminum metal precursor has been done for the synthesis of Aluminum Nitride (AIN) by varying reactor parameters such as plasma power, plasma gas composition, flow rates of plasma gases and quenching gases in order to generate nano particles of AIN, particle size < 100 nm
- Detailed characterization of synthesized nano aluminium nitride powders was carried out by using different physico-chemical FE-SEM, TEM, XRD, BET, etc.
- Under the optimized reaction condition AIN nano powder having particle size <100 nm was synthesized
- 200 gms AIN nano powder were submitted to the funding agency, VSSC, Thiruvananthapuram for their applications



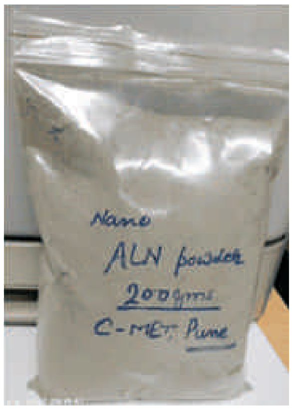


Figure 23: FE-SEM of Optimised AIN nano powder   Submitted AIN to VSSC

C-MET, Hyderabad

3. Recycling of scrap germanium to ultra-high pure germanium
(Sponsored by DRDO, Outlay: Rs. 122.072 lakhs, DoS:17.10. 2016; DoC:31.8.2020)
5 Kg 7N Germanium is ready for delivery to SSPL, DRDO along with GDMS analysis reports from NRC Canada. Final Project Completion Report prepared.

4.Processing and supply of Hafnium sponge
(Sponsored by VSSC ISRO, Outlay: Rs. 633.08, DOS:01.07.2016: DoC:31.03.2021)

212 Kg of space grade Hafnium sponge prepared and supplied to VSSC against three MoUs of 20 Kg each, 12 Kg against six months monthly maintenance payment, and two order of 70 Kg supply.

C-MET, Thrissur

5. Development of transparent conducting oxide and metal nitrides as low loss plasmonic materials in near IR and visible frequencies
(Sponsored by BRNS + C-MET, Outlay: Rs. 31.83 lakhs, DoS: 28.08.2017; DoC: 27.08.2020)

Developed ZnO based doped metal oxide films and demonstrated surface plasmon resonance applications in NIR frequencies for the wavelength >1600nm. Developed and demonstrated nitride films for plasmonic applications in visible region. The films can thus perform as low loss alternative cost effective plasmonic materials in near IR and visible regions. Metal oxide/dielectric multilayer hyperbolic metamaterial has been developed using the plasmonic films and demonstrated negative refraction in NIR. Properties are validated through near filed measurements by the collaborating institute.

6. Development of transparent conducting oxide-based fibre optic plasmonic hydrogen and ammonia sensors
(Sponsored by SERB + C-MET, Outlay: Rs. 44.85 lakhs, DoS: 20.10.2017; DoC: 19.03.2021)

Fibre optic probes with 12 cm length and 1 cm sensing region exhibiting surface plasmon resonance in near infrared has been developed using cost effective metal oxide films. Using these probes, successfully demonstrated ammonia and hydrogen sensors. Thermally evaporated polyaniline films with required protonation/deprotonation properties were used as a sensing layer for ammonia sensors, while palladium has been used for fabricating hydrogen sensors. The fibre optic sensor developed for ammonia exhibited limit of detection of 10 ppm for liquid and gaseous ammonia. The prototype hydrogen sensor had the limit of detection of 25 ppm for hydrogen gas.

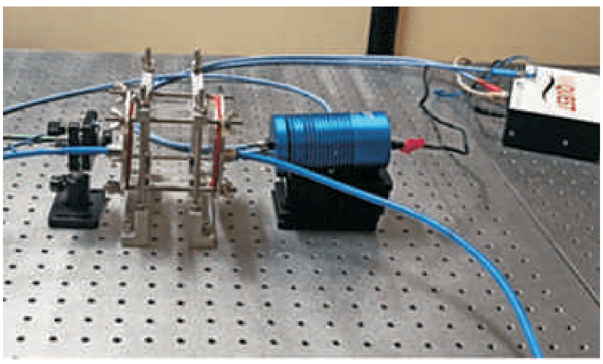


Figure 24: Sensor demonstration set up

7. Development of thermal tomography for the detection of breast cancer and to predict the size and location of the cancerous tissue
(Sponsored by MeitY, Outlay: Rs. 55.67 lakhs, DoS: 12.06.2018 DoC: 11.12.2020)

2D & 3D imaging software for accurate prediction of human breast abnormality was developed in python for the estimation of position of cancerous tissue, depth of cancerous tissue, metabolic heat rate (Q), blood perfusion rate and size (diameter). The 3D imaging of human breast was developed using the MAYAVI Visualization toolkit in Python. It was designed in such a way that the user can interactively slide through the 3D domain and slice it both horizontally and vertically to locate a potential tumor. The validation of the analysis system was done using the clinical data obtained in the earlier clinical trials. 248 clinical data were used for the validation and results were validated with Mammogram. This standalone software includes GUI and automatic reporting system. In addition, we have also analyzed 100 volunteer data from Murata Business Engineering India Pvt. Ltd.

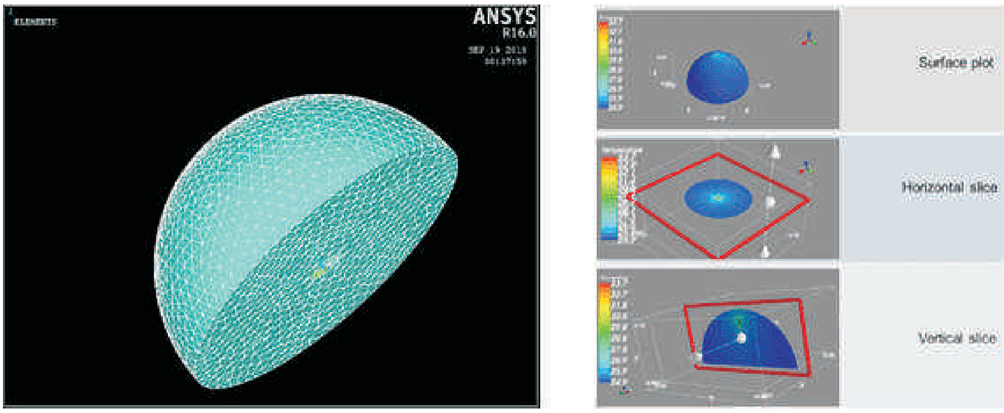


Figure 25: 3D analysis system

8. High capacitance (50F to 200F) graphene supercapacitors for storage of power from renewable energy sources
(Sponsored by CPRI (MoP), Outlay: Rs. 64.80 lakhs, DoS: 20.11.2018, DoC: 28.02.2021)

C-MET has already established a process for the production of graphene from natural graphite flakes through chemical route. In this project, we have developed various types of graphene supercapacitors. Lead type graphene supercapacitors were developed for capacitance in the range 50 F to 100 F and the process conditions were optimized for this technology. Snap in type 110 F to 200 F supercapacitors were developed and the process for this technology is also optimized. These capacitors were found to be at par with commercial imported supercapacitors. Hence, in this project a totally indigenous technology was developed for graphene supercapacitors up to 300 F. Graphene supercapacitor modules were also prepared.

Figure 26: Commercial supercapacitors and graphene supercapacitor developed at C-MET

9. Development of mechanically amplified linear piezo actuator for use in breathing regulators for aircrew"
(Sponsored by DEBEL, DRDO, Outlay: 43.47 lakhs, DoS: 4.07.2018, DoC: 31.08.2020)

The design of Flex Tensional (FT) actuator for breathing regulators for aircrew using commercially available soft piezoelectric PZT-5 compositions were developed and supplied to DEBEL. The images of FT actuator stacks supplied to DEBEL are shown below.

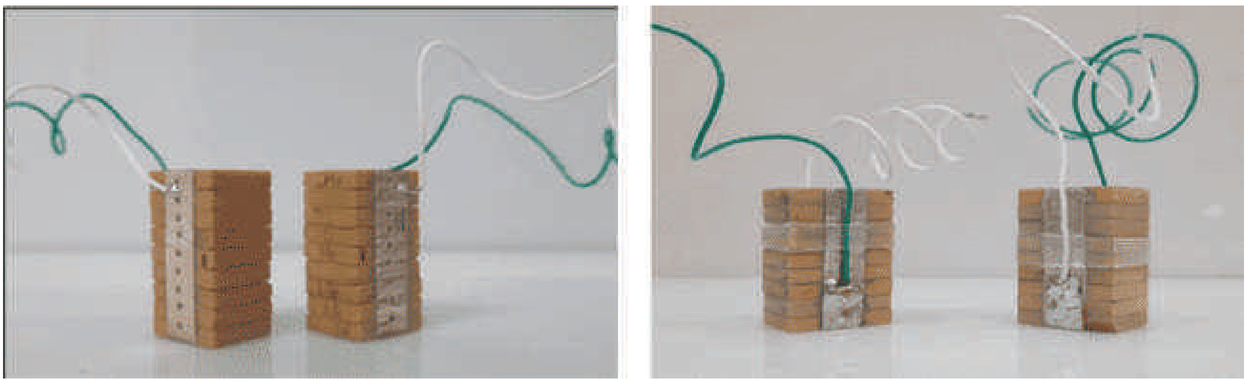


Figure 27: Mechanically amplified linear piezo actuator

10. Magneto-dielectric substrates for miniaturized antenna application
(Sponsored by MeitY, Outlay: Rs. 80.51 lakhs, DoS: 23.08.2016; DoC: 07.02.2021)

This project aims to develop MD substrate material and fabrication of miniaturized antennas on the MD substrate. Phase pure fillers of substituted analogues of Z-type hexaferrite and Y-type hexaferrite was prepared and laminated to obtain MD substrate. Antenna fabricated showed miniaturization of 30% and bandwidth enhancement of 4%.

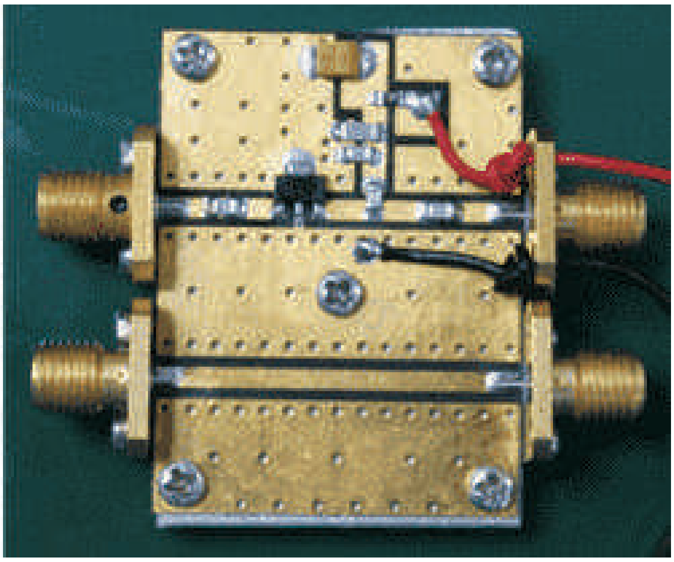


Figure 28: Conformal antenna on MD substrate and amplifier circuit on MD substrate (Astra Microwave, Hyderabad)

3.4.2 On-going grant-in-aid Projects

The consolidated progress in respect of on-going grant-in-aid projects is furnished below:

C-MET, Pune

1. Novel nanostructured high-performance anode materials for high energy Na-ion batteries
(Sponsored by DST, Outlay: Rs. 68.27 lakhs DoS: 30.11.2017; DoC: 29.11.2021)

- Sn metal nanoparticles (Sn MNP) were synthesized by thermal plasma process.
- The synthesized Sn MNPs were characterized by using XRD, Raman spectroscopy and TEM analysis
- Fabricated coin (2032) type of cell and performed its electrochemical testing at C/20 current rate up to 20 cycles.
- Initiated the synthesis of Sn@C and SnO_2 nanomaterials as an anode material for Na-ion batteries

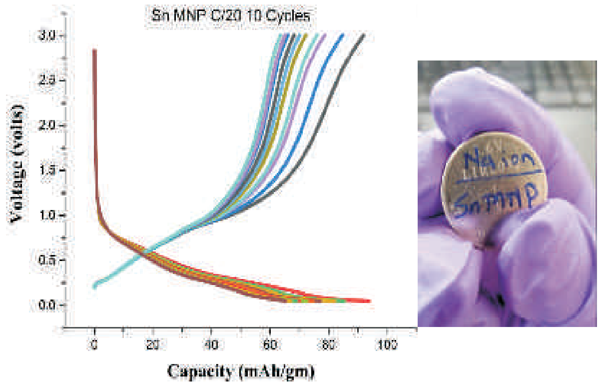


Figure 29: Charging-discharging cycles for Sn MNP cell (C/20, 10 cycles) and photograph of coin type (2032 type) Na-ion cell

2. Development of LTCC based sensors for real time water quality monitoring (Sponsored by IUSSTF, Outlay: Rs. 36.966 lakhs DoS: 07.06.2018; DoC: 06.06.2021)

- The first PCR chip design showed issues of sample evaporation during temperature cycling. The design was modified to make a flow type sensor with three different temperature zones
- Flow type sensor device tested at IIT Delhi showed smooth flow of liquid sample at the desired flow rate but had temperature equalization problem
- Targeted cooling was planned and incorporated in the new design to maintain the desired temperature profile. However, the design could not be implemented since IUSSTF decided to short close the project possibly due to financial issues.

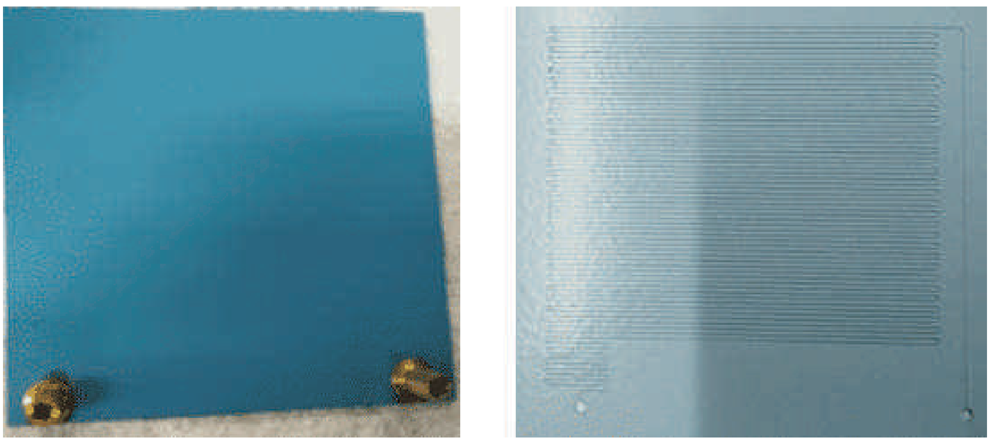


Figure 30: Fired and tube-soldered PCR sample and LASER cut serpentine channels

3. Three dimensional nanostructured based miniaturized and flexible rechargeable lithium batteries for flexible electronics
(Sponsored by MeitY, Outlay: Rs. 454.10 lakhs DoS: 15.05.2018; DoC: 14.05.2023)

- Performed experiments for the optimization of active materials, separator and Metal Organic Framework (MOF) via electrospinning for the preparation of flexible electrodes
- Synthesized films of CTA, Lithium Titanium Oxide (LTO) via electrospinning using PVP and MOF on the collector plate and subjected for surface morphological characterization using FE-SEM analysis
- Fabricated the flexible pouch type cells using commercial active materials (cathode and anode) as well as in house developed active materials and performed electrochemical (battery testing) testing at different current rates of C/10, C/5, C/2 and 1C for each 3 cycles for 0, 45, 90-, and 180-degree bending angles
- The deformation study of fabricated devices was carried out in terms of bending and twisting. Wide range of bending angles were used (15°, 30°, 45°, 90° and 180°) for stability test

Temperature dependant performance of fabricated devices was carried out with temperature variation from 0 to 60 °C.

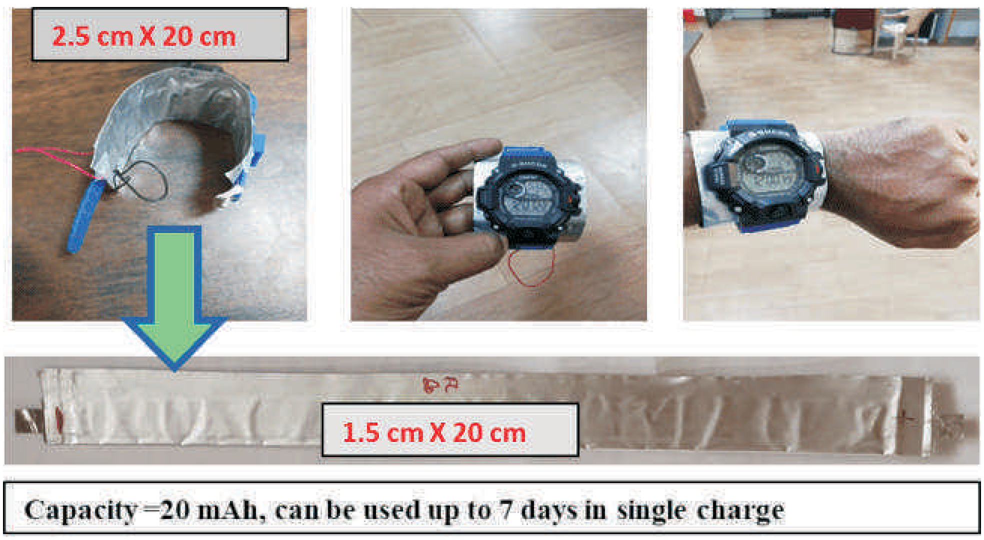


Figure 31: Flexible Battery for smart watch.

4. Engineering of a Q-dot based solar radiation harvester for enhanced water evaporation and nano filtration
(Sponsored by Royal Society of Chemistry, Outlay: Rs. 25.85 lakhs DoS: 06.08.2018; DoC: 05.08.2021)

The Q-dot glass was optimized at 100 gm scale. Bismuth (Bi) QD's are grown in the glass of size 2-3 nm. The glass powder containing QD is supplied to University of Leeds UK. PI has visited to University of Leeds for the design of evaporator.

5. Development of robust metal supported micro proton conducting solid oxide fuel cells for portable power applications
(Sponsored by DST, Outlay: Rs. 35.00 lakhs DoS: 13.09.2018; DoC: 12.09.2023)

The proton conducting solid oxide $BaCe_{0.3}Zr_{0.55}Y_{0.15}O_{3-\delta}$ electrolyte has been successfully synthesized by combsution method. The dense electrolyte membrane was achieved with the addition of small amounts of NiO, CuO and ZnO and the optimal sintering temperature was found to be 1400°C. The stability of electrolyte material was examined by thermogravimetric analysis (TGA) as a function of temperature under CO_2 atmosphere and found excellent chemical stability. The conductivity of electrolyte is found to be ~10^{-3} S/cm at 500°C in humid gas conditions. The deposition of thin electrolyte films on glass substrate and electrode was also attempted by pulsed laser deposition (PLD).

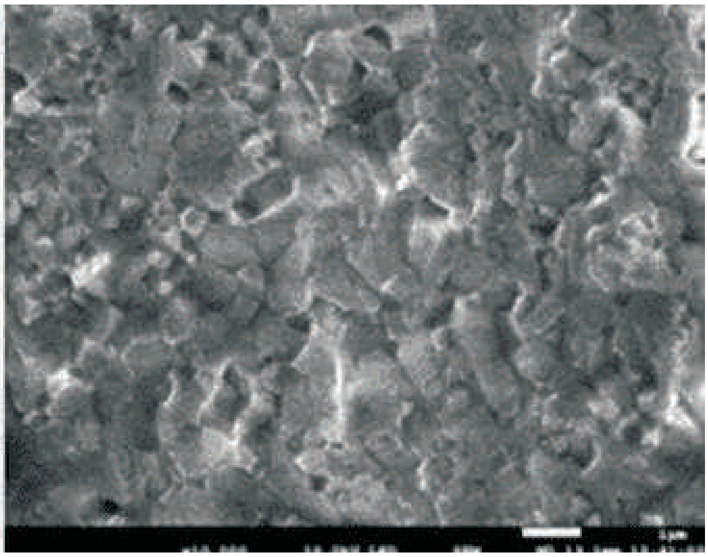


Figure 32: Proton conducting dense electrolyte membrane

6. Nanostructure NMC as a cathode material for rechargeable lithium-ion batteries (Sponsored by ISRO, Outlay: Rs. 25.54 lakhs DoS: 08.11.2018; DoC: 8.05.2021)

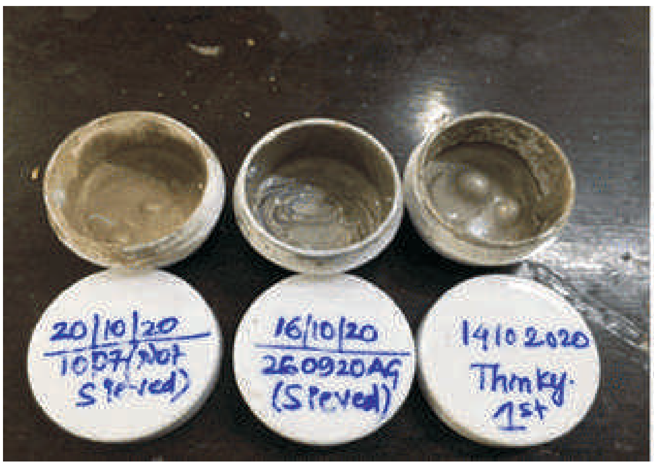
100 gm batch of NMC material was performed on spray pyrolizer and characterized. Electrochemical performance was tested and optimized with respect to calcination temperature. The spray pyrolizer has heating problems and hence re-designed the heaters and given for fabrication.

7. Development of printable silver thick film ink for Radio Frequency Identification (RFID) Tags on environment friendly, flexible substrate for smart applications (Sponsored by MeitY, Outlay: Rs. 108.84 lakhs DoS: 13.11.2018; DoC: 12.11.2021)

Up-scaled 50g batch of Silver flakes at 10gm batch each and repeatable results were obtained. Formulated Silver paste with in-house synthesized silver flakes showed good results in terms of resistivity and printing ability which is compatible to commercial sample

Various parameters like drying time, layer thickness were optimized in order to get the desired electrical properties of thick films.

Fabricated passive RFID antennas were attached to SMA connectors using conductive adhesive and customized the set-up for RFID tags measurements (for 13.56 MHz frequency). Tested S parameters of fabricated passive RFID antenna with respect to reference antenna and the results were comparable to reference antenna results. The Hyperlog 7060 (Active) antenna having the frequency range of 700 MHz to 6 GHz were installed for testing and measurement of antenna properties.



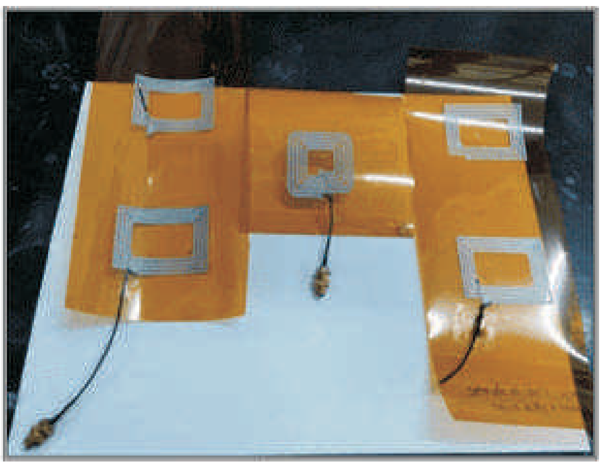


Figure 33: (a) Silver paste and (b) antenna printed on PET substrate with connectors

8. Development of hybrid battery power module with indigenously developed super capacitor and Li-ion Cell
(Sponsored by MeitY- CSIR NEIST, Outlay: Rs. 76.68 lakhs (Revised) DoS: 11.02.2019; DoC: 10.07.2021(Revised)

The process for synthesis of LCO at 400 gm /batch has been optimized. Around 3000 gm LCO (3 Kg) has been accumulated for fabrication of 18650 type cells. Optimization of process for LCO synthesis at 500 gm batch scale has been achieved.

Figure 34: Photographs of 18650 type cells fabricated using Lithium Cobalt Oxide (LCO) synthesized at C-MET

The synthesized LCO has been characterized using XRD technique. The prepared LCO has also been used for fabrication of Li ion cells (Pouch cells). The battery pack prepared using these pouch cells is tested for two wheeler application which shows good performance. The equipments such as semiautomatic winding machine, cylindrical cell grooving machine and deep welding machine are procured and installation is in progress. Purchase order for the semiautomatic coating and slitting machine has been placed.

9. Centre of Excellence in Rechargeable Battery Technology (COE-RBT) (Pre-Cell) (Sponsored by MeitY, Outlay: Rs. 2087.67 lakhs DoS: 13.09.2019; DoC: 12.09.2024)

1. Specifications of Spray Pyrolizer at 200 gm/hr scale are finalized. The specification for continuous slurry mixer is being finalized based on inputs given to M/s. Clarion, Engineers, Nashik.

Synthesis and optimization of cathode active materials for Li ion Battery:
- LCO by Solid state route (500 g scale)
- NMC (at 100 g scale) using spray pyrolysis technique
- LFP at 15 g scale optimized

2. Synthesis of anode material, $Li_4Ti_5O_{12}$ (LTO) by solid state method (100 g scale)

- Active materials for Li ion Battery: Spherical Hard carbon derived from Biomass (Potato & Banana) (100 g scale)
- Active material for Na-ion Battery: Nitrogen-doped carbon nanofibers (using electrospinning) as an anode material

- UV curable binder for electrode manufacturing process (patent draft is ready for submission)
- Fabricated Li-ion pouch cells of dimensions (3" x 4" as well as 5" x 4") using standard Graphite material and in house developed LCO. Li-ion battery for mobile and module prototype is demonstrated for two-wheeler

3. Phase pure $NaCoO_2$ is prepared and fabricated coin type of half-cell delivered capacity of 30 mAh g-1. The stabilization and optimization of $NaCoO_2$ is in progress. Initiated synthesis of $Na_3V_2(PO_4)_3$ as cathode material, which is commonly used for Na-ion batteries at R&D level

4. Procurement of server, computer and VASP with GUI is underway

5. The collection of inputs for techno-commercial road mapping

6. Two Industries responded against the advertisement. Committee evaluated the EoI

7. Trademarked the LOGO for CoE RBT

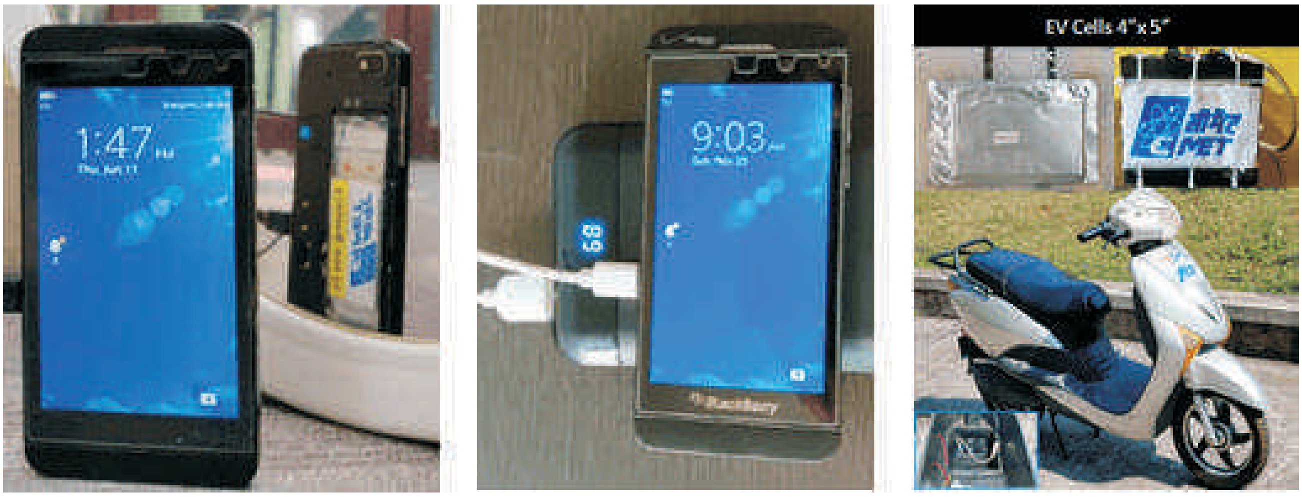


Figure 35: Developed Battery for Mobile and Battery Pack for EV's

10. Digitalization and quantification studies of highly sensitive indigenous NOx sensor and its optical calibration.
(Sponsored by ISRO, Outlay: Rs. 32.83 lakhs DoS: 31.10.2019; DoC: 30.10.2022)

This project involved development of highly sensitive indigenous digitized NOx sensor and its quantification studies. Electrical and optical NOx sensor will be developed to detect NOx gas and will be used in Indian Space program. This developed NOx sensor will be calibrated using optical devices.

- Hydrothermal synthesis of adipic acid assisted WO_3 has been carried out
- Prepared WO_3/Pd composite material with varied Pd loading (1-10 %)
- Sensing experiments for detection of NOx have been completed
- Optical gas sensing assembly was set-up

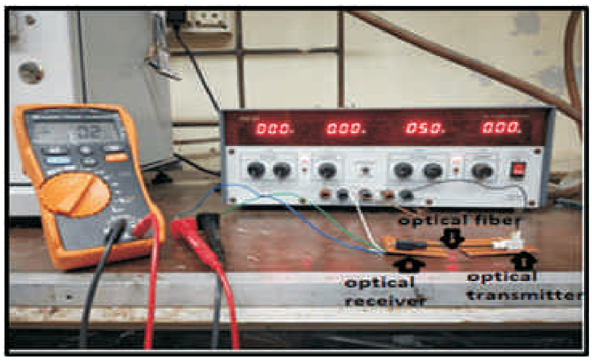


Figure 36: Optical sensing set-up for gas detection

11. Development of smart parking management system using Sensors, IoT and GIS.
(Sponsored by DST, Outlay: Rs. 11.92 lakhs (39.78 (C-MET + CDAC Hyd) DoS: 08.11.2019; DoC: 07.11.2021)

This project involved smart parking management system using gas senosr, IoT and GIS technology. There are four types of gas sensor viz. SO_2, NO_2, CO_2 and CNG used to detect gas level in parking area and information will be avilable to person through IoT and GIS technology

- The gas sensing and calibration system was set-up
- The real time data collection for gas sensors viz. SO_2, NO_2, CO_2 and CNG have been completed and sensors were calibrated

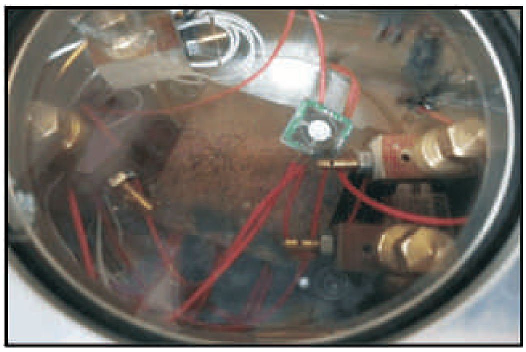


Figure 37: Developed gas sensing set-up

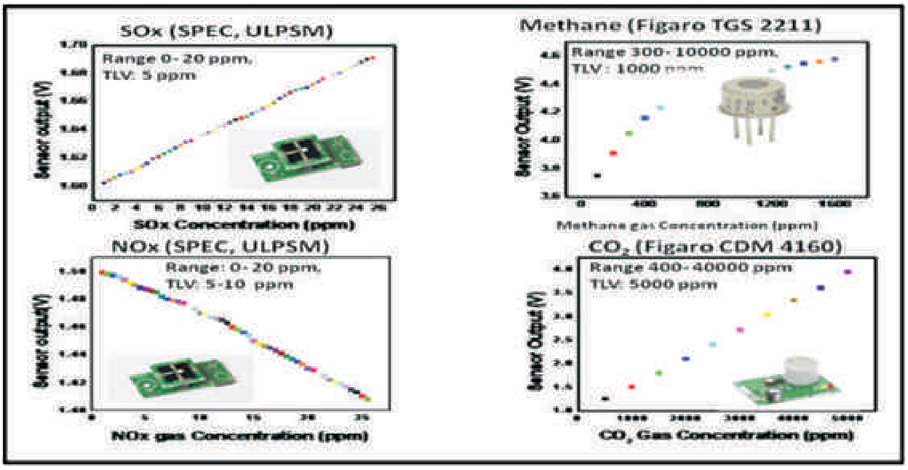


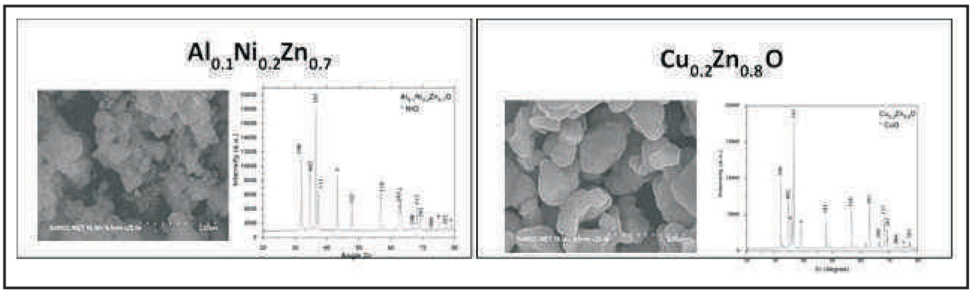
Figure 38: The real time data collection for gas sensors

12. Development of micro solid oxide fuel cells (μ-SOFC) in low temperature co-fired ceramic (LTCC) technology.
(Sponsored by DST, Outlay: Rs 212.168 Lakhs, DoS: 13.11.2019; DoC: 12.11.2022)

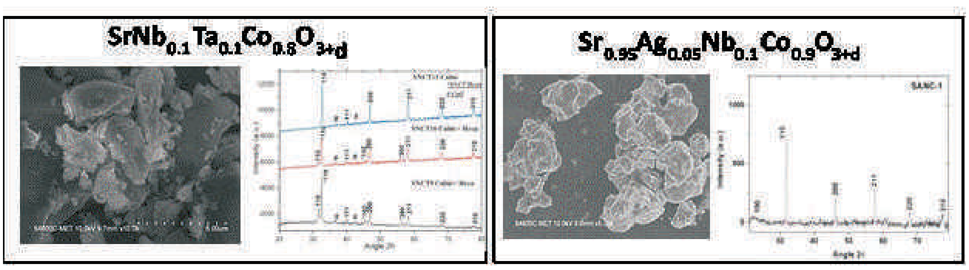
This project involves Development of LTCC integrated micro-SOFC with integrated heaters and temperature sensors. The device will have microfluidic channels to handle fuel and the by-product together with external fuel supply system or fuel cartridge. Preparation of electrodes and electrolytes and their integration with LTCC is the responsibility of CMET. The following were the activities carried out during the year:

- Completed review and shortlisted Anode and Cathode materials
- Completed preparation of Anode and Cathode Materials by chemical and solid-state route

Anode Material



Cathode Material



Electrolyte

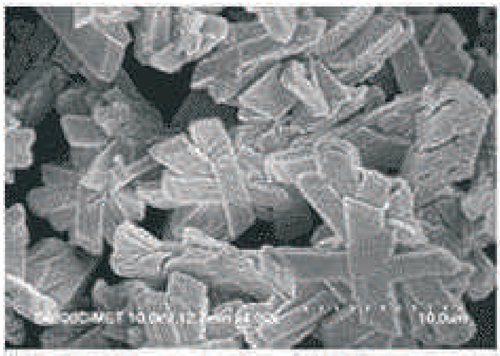


Figure 39: Prepared Gadolinium doped Ceria (GDC) electrolyte by chemical route

13. Design of new anodes for biogas fueled protonic ceramic fuel cells (Sponsored by DST-SERB, Outlay: Rs. 30.03 lakhs DoS: 26.12.2019; DoC: 25.12.2021)

The proton conducting oxide $BaCe_{0.4}Zr_{0.4}Y_{0.16}Ni_{0.04}O_3$-δ and $BaCe_{0.4}Zr_{0.4}Y_{0.16}Zn_{0.04}O_3$-δ powders have been successfully synthesized by citrate-nitrate combsution method. The dense membranes were prepared. Anode powder NiO-$BaCe_{0.4}Zr_{0.4}Y_{0.2}O_3$-δ (50 vol% Ni and remaining BCZY44) composition was prepared and charecterized.

14. Studies on annealing on magnetic performance of NiFe laminations for pulsed magnets used in accelerators.
(Sponsored by BRNS, Outlay: Rs. 34.00 lakhs DoS: 10.01.2020; DoC: 09.01.2022)

- Studies on effect of anneling conditions on micro-structural and morphological properties of Ni-Fe laminates has been initiated.

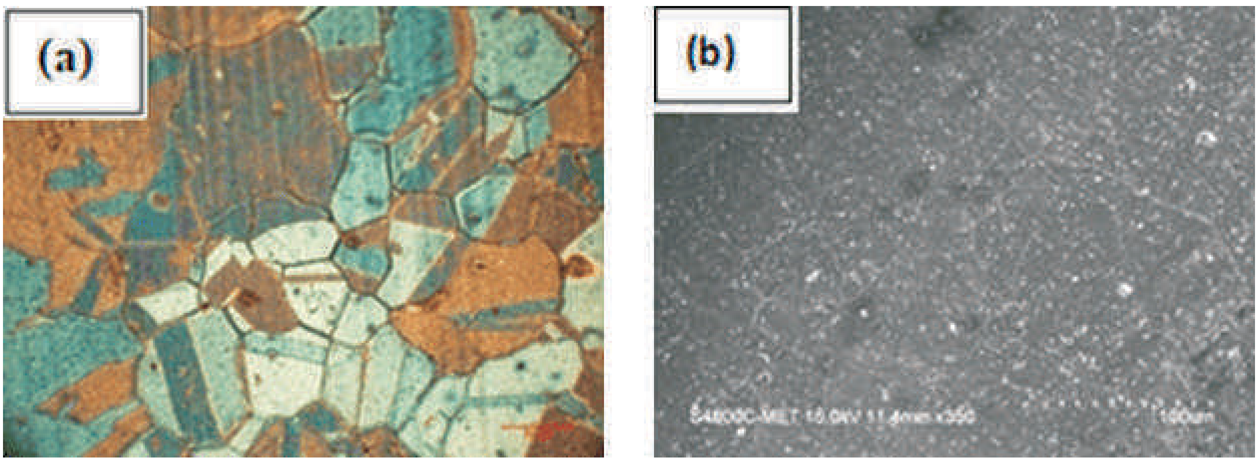


Figure 40: (a) Optical and (b) Scanning Electron Microscopy images of 36 Ni-64Fe laminate annealed at 1150 °C and Oxidized at 400 °C.

15. Creation of R&D culture in SC, ST and Woman candidates in colleges of Maharashtra.
(Sponsored by MeitY, Outlay: Rs. 131.00 lakhs DoS: 07.03.2020; DoC: 06.03.2023)

- Six colleges from remote and tribal areas of Maharashtra have been shortlisted for participation in the training program
- Total 239 students belonging to SC/ST and Women category as well as 50 faculties from remote and tribal areas of Maharashtra have enrolled to participate in this program
- More than 40 training sessions were conducted so far

C-MET, Hyderabad

16. Processing and supply of hafnium sponge
(Sponsored by VSSC/ISRO, Outlay: Rs. 633.08 lakhs, DoS: 01.07. 2016 to 30.03.2021)

Processed 70 KL feed in cycle-1, 11.8 KL in cycle-2 and 6.2 Kl in cycle-3 of solvent extraction. 198 KL solvent regenerated. 2.12 KL pure solution converted to Hf hydroxide. 111 Kg dry Hf hydroxide calcined to get 50 Kg Hf oxide. 135.35 Kg coked Hf oxide briquette prepared (including from 31 Kg recycled oxide). 116 Kg Briquette loaded in chlorinator and prepared 116.25 Kg Hf chloride. Three Kroll reduction and three Vacuum distillation experiments conducted and prepared 43.7 Kg Hf sponge. Total 70 Kg Hf sponge (including previous batches 40 kg) handed over to VSSC/ MIDHANI for EB melting experiments. Another order for supply of 70 Kg Hf sponge received from VSSC and 40% advance (Rs.79.47 lakhs also received under new project HD/TS/003).

17. Environmentally sound methods for recovery of metals from PCB's: phase – II
(Sponsored by MeitY, KBITS, Outlay: Rs. 1229.80 lakhs, DoS: 22.08.14; DoC: 23.06.2021 in collaboration with E-Parisaraa, Bangalore)

Front firing rotary tilting furnace (FFRTF) indigenously designed and fabricated for the smelting of calcined PCBs. Necessary modifications have been incorporated in the door design, chute design and gas inlet to use shredded PCBs directly as the raw material. The modified system is tested and its efficacy demonstrated. The process methodology was demonstrated to M/s Namo E-waste as a part of technology transfer. Training given to M/s Namo E-waste staff by processing 300 kg PCBs supplied by the them. Similarly, 400 kg PCBs were smelted for recyclers/dismantlers on payment basis. Electro-refining facility is scaled up to 3kL electrolyte holding capacity, which can cater to the requirement of 100kg PCB/day demonstration capacity. A state-of-the-art gas cleaning system comprising of vent line, secondary burning chamber, quenching system and scrubbing system is designed and fabricated which is adequate for 300kg PCB/day capacity using TBRF. Experiments were conducted on the recycling of aluminium capacitor for the recovery of aluminium metal.

Figure 41: Front firing rotary tilting furnace

18. To develop process for the growth of 6H SiC (undoped/ doped) single crystal boule (Sponsored by DRDO, Outlay: Rs. 1045. 19 lakhs, DoS: 27.07.2016; DoC: 26.01.2022)

In the present MoU with DRDO, C-MET has to deliver high resistive 2” SiC boule with targeted specifications for 6H SiC Polytypes, Bandgap, Crystallinity (FWHM), Micropipe density and Resistivity to be used as a substrate for GaN devices. Single crystal growth process parameters were optimized using Design of Experiments (DoE) and simulation through Virtual reactor (VR) software. 20 SiC single crystal growth experiments were conducted for optimization of process parameter to accomplish targeted deliverables. Results revealed that 100% 6H SiC Polytype was achieved for 2” diameter. Micropipe density (MPD), Full Width Half Maxima (FWHM) are found to be <20 cm^{-2} and <30 arc-sec respectively. Preliminary result shows that electrical resistivity is found to be 1 Ohm-cm for crystal grown with UHP source materials and further impurity doping experiments are under progress. 14 Nos of SiC boules were delivered to DRDO till date.

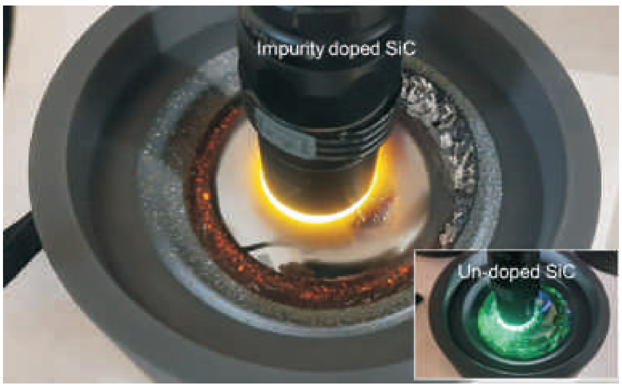


Figure 42: Impurity doped SiC boule grown at C-MET using PVT process

19. Development of indigenous antennas for navigation with Indian constellation (NavIC)

(Sponsored by MeitY, Outlay: Rs. 267.02 lakhs, DoS: 29.09.2018; DoC: 28.09.2021)

Developed ceramic filled polymer composite laminates having effective dielectric constant of 14.5 and loss tangent of 0.0018 at S-Band. Fabrication and testing of L1 and L5 dual band antennas were successfully completed. Simulation, fabrication and testing of miniaturized S-Band antenna on 14.5 flexible substrate successfully completed. System level evaluation of dual band antenna completed.

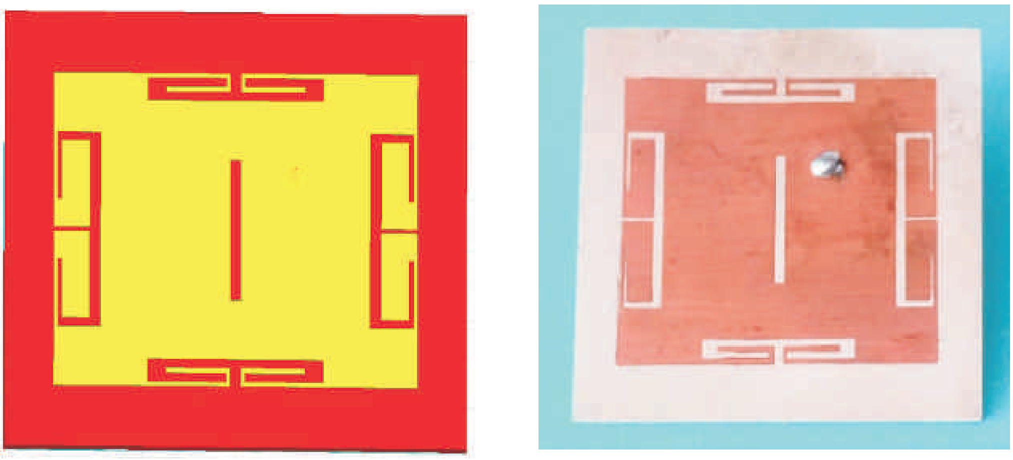


Figure 43: Simulated and fabricated dual band antenna using 14.5 substrate

20. Design and fabrication of MEMS bionics sensors for autonomous underwater vehicles

(Sponsored by SERB-DST, Outlay: Rs. 43.19 lakhs, DoS: 22.03.2019; DoC: 21.03.2022)

The microstructure dimensions optimized by Eigen frequency analysis and static structural analysis using FEM (finite element method) Multiphysics simulation software tools i.e., COMSOL and Ansys. The stress concentrated regions on the suspended beams have been identified for piezo resistors placement. The final design of MEMS bionic sensor for structural, mechanical and electrical properties are investigated. The optimized design of MEMS sensor submitted for MASK fabrication. Fabrication process steps are validated by facility technologist of National Nanofabrication Centre (NNFC), Centre for Nano Science and Engineering (CeNSE) IISc, Bangalore.

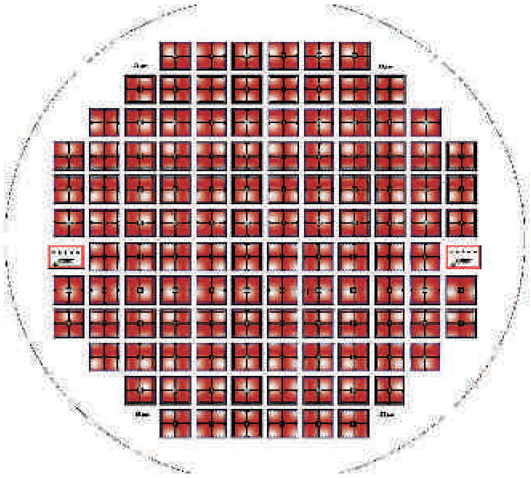
	Typical Dimension: **Total number of mask set:** 5nos **Die size:** 3000 µm x 3000 µm **Space between each die:** 500 µm **Piezo resistor length:** 100 µm **Piezo resistor width:** 25 µm **Metal line width:** 5 µm **Bond pad:** 100µm x100 µm **Expected diaphragm thicknesses:** 10, 15, 20, 25 µm

Figure 44: Designed mask layout for complete 4" wafer with typical dimensions

21. Establishment of Centre of Excellence (CoE) on e-waste management (Sponsored by MietY & Govt. of Telangana, Outlay: Rs. 3580.00 lakhs, DoS: 30.09.2019; DoC: 29.09.2024)

Centre of Excellence (CoE) on E-waste Management has been established at C-MET Hyderabad to develop technology for the recovery of valuable metals from End-of-Life Li ion battery, rare earth oxides from spent NdFeB permanent magnets and recovery of valuable metals from end-of-life Silicon Solar cells. CoE is working closely with Research and Innovation Circle of Hyderabad (RICH), Government of Telangana for Technology Transfer and Hand holding. Interacted online with industries viz. M/s. Greenko, M/s. Ramki Recycling, M/s. Recykal, M/s. Waste Ventures India for e-waste technology transfer. Non-disclosure agreement (NDA) has been signed with these industries for further interactions. Working closely with Telangana Academy for Skill and Knowledge (TASK), Government of Telangana for E-waste Awareness and Skill development programmes. Initiated Grand Challenge Programme and received overwhelming response from various national institutions and universities. EoI received from 7 industries for rolling out of spent PCB recycling technology as channel partners. EoI received from 7 industries for joining with E-waste CoE as industrial collaborator for Li-Ion recycling technology. Design & development of Automated PCB depopulation system and indigenous rotary smelting system from interested entrepreneurs through EoI mode is initiated and non-disclosure agreement signed for close interaction. Steps initiated to source E-waste from various Government agencies through MeitY. Received E-waste materials from UIDAI, NSDL, SAMEER etc. E-waste awareness programme conducted for 100 students. E-waste dismantling training conducted for informal sector. Trade marking rights filed for newly created CoE on E-waste management emblem and its specialized activities. Awareness lectures on ROHS and E-waste management were delivered to informal recyclers. Regular MTech course classes were conducted jointly with IIT, Hyderabad through online mode. First semister course has been successfully completed.

Figure 45: Training on dismantling to informal sector under CoE

Figure 46: Interaction with academic institute (JNTU Hyderabad) officials and demonstration of facilities under CoE

22. Development of carbide derived carbon for storage applications (Sponsored by VSSC, Outlay: Rs. 38.00 lakhs, DoS: 24.12.2019; DoC: 23.12.2021)

Carbide derived carbon (CDC) is an exotic material which finds applications in variety of fields varying from energy storage to hydrogen storage due its distinct properties such as narrow pore distribution, high surface area etc. Because of the high surface area, large pore volume and low density, this material is an ideal candidate for energy storage applications. CDC is prepared by chlorine etching (chlorination) of metal carbides. The characteristics of CDC largely depend on the precursor, chlorine treatment conditions and mainly on the soaking temperature. Process facilities for dry chlorine etching of carbides were established and conducted trial runs for the optimization of process parameters such as chlorine flow rate, carrier gas flow rate, soaking temperature, and time. Process parameters optimized for 800°C temperature for two types of input materials and delivered five samples to VSSC for further electrochemical evaluation.

23. Purification of hafnium metal sponge using electron beam melting and preparation of hafnium metal targets for electronic applications (Sponsored by DST-SERB, Outlay: Rs. 11.20 lakhs, DoS: 11.02.2020; DoC: 10.02.2022)

4 Kg Hafnium metal sponge of 95% purity prepared and consolidated by Electron Beam (EB) melting. The Institute of Electronics - Bulgarian Academy of Sciences (IE-BAS), Bulgaria has carried out simulation studies of EBM process to achieve optimum parameters. The 2.7 Kg Hafnium consolidated mass was sent to IE-BAS. EB refining of the Hf has been performed and achieved more than 99% purity.

Figure 47: Electron Beam consolidated Hafnium Pellets

C-MET, Thrissur

24.Development of Ceramic dielectric thin film capacitors for hybrid electric vehicle applications
(Sponsored by SERB, Outlay: Rs. 35.32 lakhs, DoS: 18.03.2020, DoC: 17.09.2022)

The design of novel ceramic materials for developing dielectric thin film capacitors as DC-link capacitors in DC-AC inverter of hybrid electric vehicles is being carried out.

25.Development of a new and cost-effective biosensor based on transparent conducting oxide thin films working in near IR frequency
(Sponsored by DST + C-MET, Outlay: Rs. 48.20 lakhs, DoS: 31.10.2018; DoC: 31.03.2021, extension requested)

Cost effective metal oxide films were developed on BK7 glass exhibiting surface plasmon resonance up to wavelengths as low as 1300 nm in NIR, crossing telecommunication window. The same is used to develop portable biosensor for detecting food borne pathogens with Rajiv Gandhi Centre for Biotechnology (RGCB). The collaborating group has identified and immobilized bioreceptors on the surface of TCO film developed by C-MET. Detection of E -Coli bacteria using the portable biosensor has been successfully carried out at RGCB. Excellent shift in the SPR resonance has been attained on binding with bacteria using the cost effective plasmonic films. Validation studies are continuing with other food borne bacteria including salmonella.

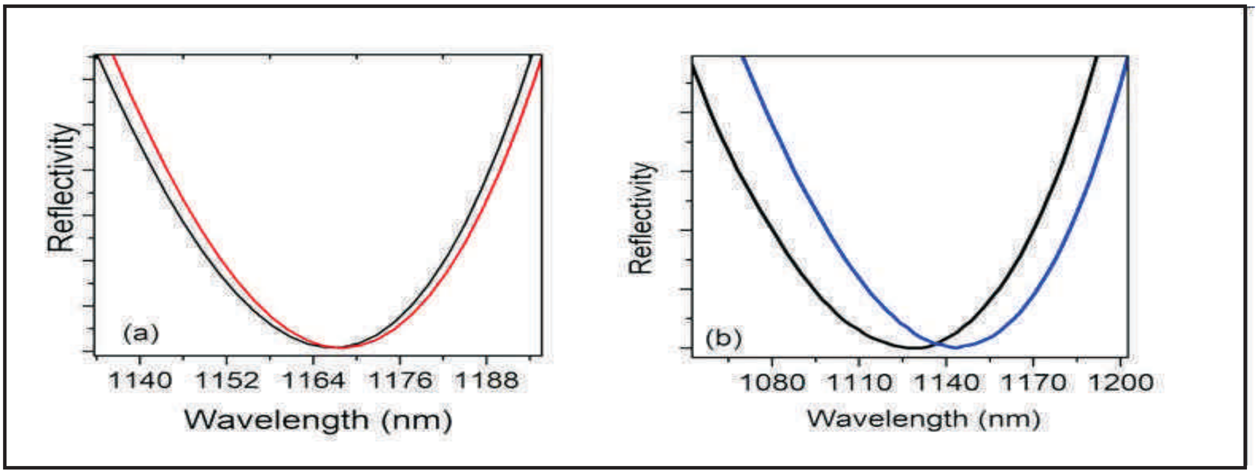


Figure 48: SPR reflectivity curves obtained using the portable biosensor before and after binding with (a) S aures and (b) E Coli bacteria in water medium

26. Development of nano NTC composition-based sub millimeter sized thermal sensors for low temperature applications
(Sponsored by SERB, Outlay: Rs. 47.37 lakhs, DoS: 15.03.2018; DoC: 14.09.2021)

The nano NTC thermistor compositions and sub millimeter sized chip thermal sensors for low temperature applications (-100 °C to +50 °C) have been developed for monitoring weather in space applications.

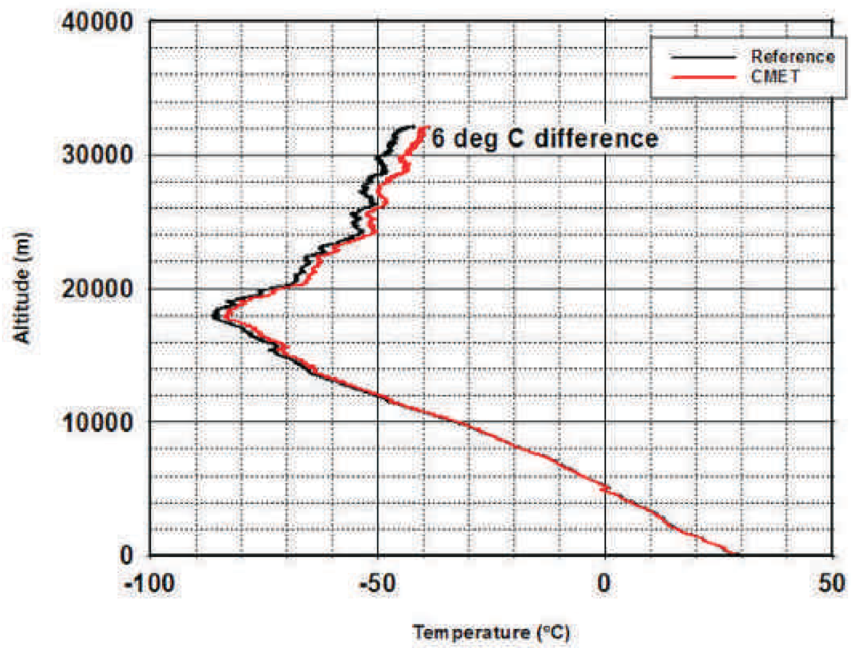


Figure 49: Evaluation of thermistor developed at C-MET vs reference material

27. Development of supercapacitor bank for electronic time fuse application (Sponsored by ARMREB, Outlay: Rs. 53.12 lakhs, DoS: 10.05.2018, DoC: 09.05.2021)

6 numbers of graphene supercapacitor bank having 12V working voltage and 10,000μF capacitance were supplied to ARDE, Pune (DRDO).

Figure 50: Graphene coin cell supercapacitor modules

28. Entrepreneurial Training Programme for Scheduled Caste Communities to produce Digital Thermometers
(Sponsored by MeitY Outlay: Rs. 253.47 lakhs, DoS: 25.09.2019, DoC: 24.09.2022)

Design and development of digital thermometer for medical application, industrial and food service was achieved. The clinical digital thermometer developed by C-MET has qualified all tests as per IS 15113:2002

(Medical Laboratory Instruments, Clinical Electrical Thermometers with Maximum Device). We have used thermal sensors developed in house using an indigenous sensor technology developed at C-MET. The test was conducted at a NABL accredited Laboratory. C-MET has also got design registration from Indian patent office for the design of the clinical digital thermometer.

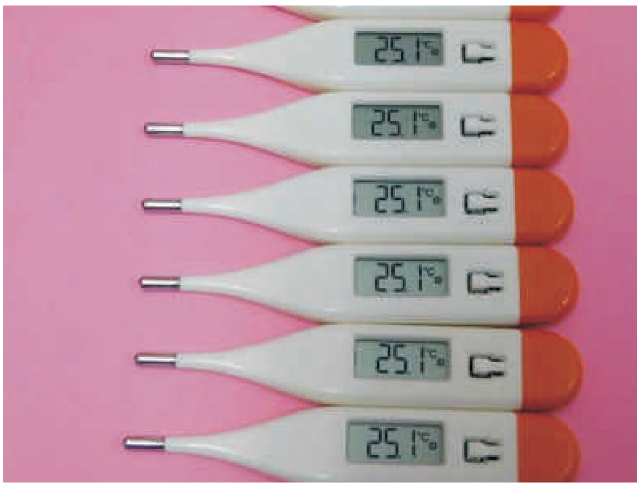


Figure 51: Digital thermometer for clinical applications

29. Entrepreneurial Training Programme for Scheduled Tribe Communities to produce Solar Lanterns/LED bulbs for Lighting Applications
(Sponsored by MeitY Outlay: Rs. 252.60lakhs, DoS: 15.11.2019, DoC: 14.11.2022)

Four different variants of solar lanterns were developed and given training to tribal beneficiaries.

Figure 52: Red: LiB battery Solar Lantern with FM radio, Green: Hybrid supercapacitor Solar Lantern White: LiB battery Solar Lantern, and Orange: supercapacitor solar lantern

30. Supply of Report system for wearable device with 2D analysis system
(Sponsored by Murata Business Engineering Pvt. Ltd., Outlay: Rs. 2.62 lakhs, DoS: 15.03.2021, and DoC: 14.04.2021)

Supplied Report system for wearable device with 2D analysis system and provided training.

31. Development of high energy density Lithium-ion capacitor with graphite/carbon aerogel electrodes through safe prelithiation method.
(Sponsored by DST, Outlay Rs. 78.62 lakhs, DoS: 25.09.2019 DoC: 24.09.2022)

Prepared carbon aerogel having surface area in the range of 1250-1500m2/g as positive electrode material for lithium-Ion Capacitor. Tested the specific capacitance of the positive electrode material by fabricating electrical double layer type supercapacitor and achieved the specific capacitance value of 59 F/g.

32. Development of supercapacitor-based power module for application in VVPAT of EVM
(Sponsored by MeitY, Outlay Rs. 660.35 lakhs, DoS: 25.10.2018 DoC: 24.10.2021)

Developed Aerogel super capacitor cells of 25 F capacitance and lower ESR value of 15-25 milliohm. Fabricated prototype Voter Verifiable Paper Audit trail (VVPAT) power module of Electronic Voting Machine using aerogel supercapacitor and achieved a preliminary printing capacity of 2000 numbers.

Figure 53: 25 F Aerogel super capacitor for VVAPT application

33. Development of Microwave Absorber Material
(Sponsored by BRNS, Outlay: Rs. 51.8 lakhs DoS: 29.08.2020; DoC: 28.08.2022)

In this project, C-MET attempt to develop the microwave absorber materials for a specific operating frequency range (1.0 to 4.0 GHz), whereas the commercially available absorbers are very generic in nature. C-MET has successfully synthesized and processed the ferrite/ferromagnetic based metal oxide-polymer composites as microwave absorbing material. The processing conditions were optimized using judiciously choice of vulcanizing agents along with the suitable surface fictionalizations on the oxide surface, as well as studied the temperature stability and surface vetting analysis of composites and its laminates.

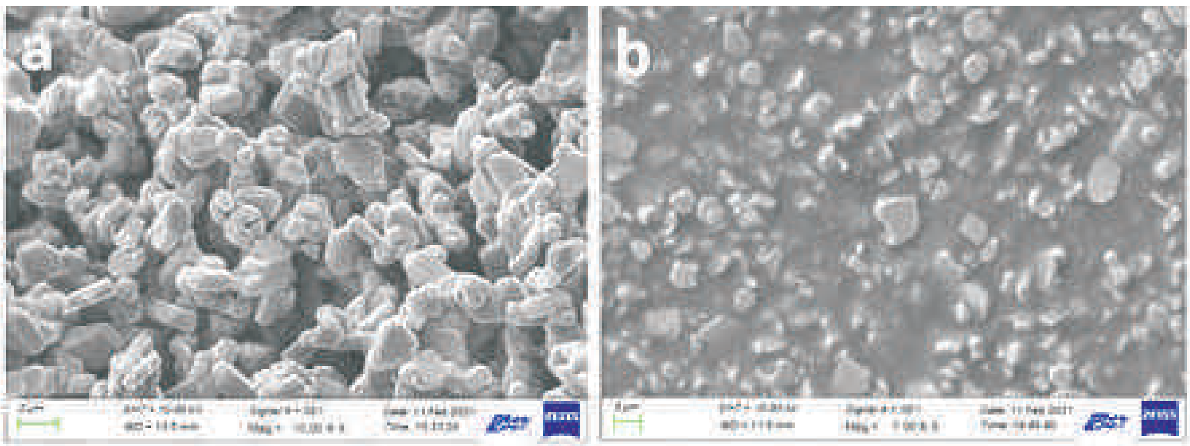


Figure 54: Microwave absorber materials developed at C-MET, Thrissur

34. Textured $Na_{0.5}Bi0_{.5}TiO_3$ based lead free Multilayer Piezoelectric Actuators (Sponsored by SERB (DST), Outlay: Rs. 49.74 lakhs, DoS: 13.05.2019, DoC: 14.05.2022)

Developed (001) oriented $BaTiO_3$ templates through MSS route with a logtering factor of 86 %. An $Na_{0.5}Bi_{0.5}TiO_3$ solid solution-based electro-strictive composition was developed showing a strain of 0.16 %. Textured 0.93 NBT - 0.07 BT through RTGG technique has been developed successfully with (001) orientation displaying a logtering factor of 92 %.

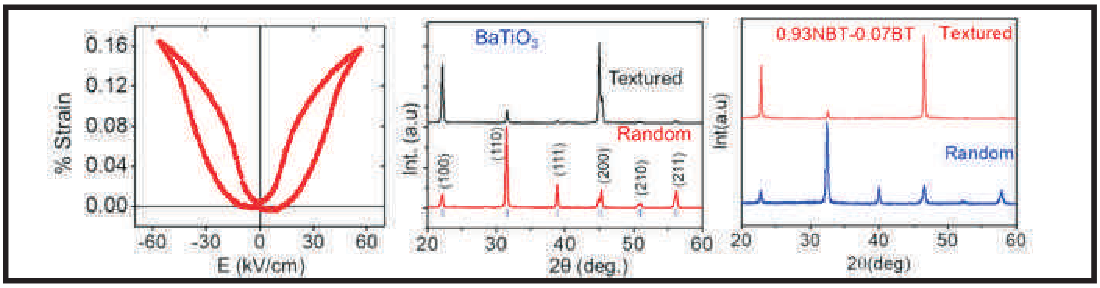


Figure 55: P vs. E curves, XRD pattern of textured $BaTiO_3$ templates and NBT-BT textured ceramics

35. Development of Polybutadiene/ ceramic composite laminates and Substrate Integrated Waveguides (SIW) for microwave and millimetre wave circuit applications
(Sponsored by MeitY, Outlay: Rs. 411.371 Lakhs (CMET: Rs. 351.372 Lakhs + M/s. Micro Pack Ltd: Rs. 60 lakhs - In Kind, DoS: 18.06.2019; DoC: 17.12.2021)

The ceramic filler with high dielectric constant and high-quality factor has been developed. The Polybutadiene/ ceramic composite laminates with dielectric constant 13 and 8 has been developed.

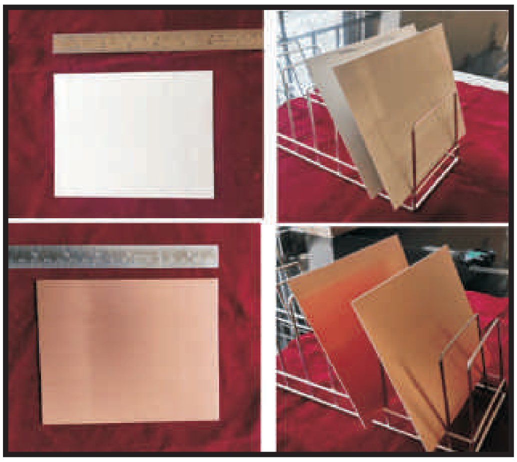


Figure 56: The Uncladded and copper cladded laminates

3.4.3 Newly initiated Projects

The consolidated progress in respect of newly initiated grant-in-aid projects is furnished below:

C-MET, Pune

1. Centre of Excellence on Additive Manufacturing (CoE AM)
(Sponsored by MeitY, Outlay: Rs.488.17 Lakhs, DoS: 17.08.2020, DoC: 16.08.2023)

Objectives of the project are:

Vertical A
- Developemnt of Metal powers such as Silver and Copper, Semicondutor (ZnO) and Ceramic (Al_2O_3) is initiated
- Development of FFF spools using the metal, ceramic and semiconductor powder with the help of CIPET Bhuwaneshwar has been initiated
- Signing of Memorandum of Understanding (MoU) with industry partners is underway

Vertical B
- Development of Digital Light Projection (DLP) based 3D printer for fabrication of LTCC circuits and packages
- To develop LTCC materials suitable for the DLP based 3D printing technology
- To demonstrate 3D printing of LTCC through design and fabrication of low-cost optoelectronic packages

2. Development of LTCC based hot water-cooling technology for High performance Computing
(Sponsored by National Supercomputing Mission (CDAC) + IIT-Bombay, Outlay: Rs.358.22 Lakhs, DoS: 8.09.2020, DoC:7.09.2023)

The Objectives of this project include:
Developing several designs of the LTCC based micro cooler and optimizing the design to achieve 200W and 350 W of cooling power for microprocessors. Fabricate and supply the required number of cooling devices using CMET's LTCC tape. Present Status of the project is design of micro cooler in progress and material preparation for tape casting of LTCC tapes in progress.

3. Fabrication of High Temperature Spiral coils using LTCC Technique (Sponsored by National Metallurgical Laboratory (CSIR), Outlay: Rs.20 Lakhs, DoS: 22.07.2020, DoC: 21.07.2021)

The objective of this project is to fabricate and supply 10 Numbers each of LTCC based Spiral coils as per the specified design. Three iterations of the design to be made. Current status of the project is fabrication of first set of sensors is initiated

4. Development of aluminium based reserve batteries (Sponsored by M/s. Hytronics Enterprise Pvt. Ltd., Outlay: Rs.10.15 Lakhs, DoS: 29.06.2020, DoC: 28.06.2022)

The objectives of the project are i) Preparation of aluminium anode for reserve batteries ii) Preparation of electrolyte for reserved batteries, iii) Preparation of cathode for reserved batteries, iv) Designs and final casing will be provided by M/s HYTRONICS Enterprises, v) Final test will be done at M/s HYTRONICS Enterprises, Hyderabad.

Developed 100 % indigenous Al-air 12 V battery for emergency and of the low applications. Battery is developed using Indian raw materials, so that the final cost will be less. The major component, cathode (activated carbon) for the battery is developed from bamboo available in India. Other counter electrode is Al foil coated with metals to reduce the corrosion. The amount of Al-foil, electrolyte and cathode has been optimized. The battery is tested with 12 V and 1.2 watt for 24 hours.

(a) (b)

Figure 57: (a) Activated carbon derived from Bamboo (b) Watt Motor running with Al-air battery

C-MET, Hyderabad

5. Development of Flaky Fe-Si-Al Alloy Powders suitable for applications in Tunable Microwave Absorption
(Sponsored by BRNS, Outlay; Rs. 72.90 Lakhs, DoS: 10.08.2020, DoC: 09.08.2023)

Specifications finalized for Induction Melting Furnace and Purchase Order placed. Modeling studies for charge calculation with various recoveries of elements carried out for alloy preparation. Melting and Milling experiments conducted by making use of facilities at IIT, Hyderabad. Characterization studies like XRD, SEM and ICP-OES carried out on for the samples.

6. Skills development training program for schedule tribe students on E-waste recycling technologies and testing of Restricted Hazardous Substances (RoHS)
(Sponsored by MeitY, Outlay: Rs. 51.58 lakhs, DoS: 17.07.2020, DoC: 16.07.2023)

Signed MoU with Dalit Indian Chamber of Commerce and Industry (DICCI), Telangana. Contacted Telangana SC&ST commission, Secretary for students Stipend. Contacted ST Corporation for student's stipend financial assistance. Collected the addresses of ST colleges in Telangana State.

7. Skills development training program for schedule caste students on E-waste recycling technologies and testing of Restricted Hazardous Substances (RoHS)
(Sponsored by MeitY, Outlay: Rs. 108.14 lakhs, DoS: 09.07.2020, DoC: 08.07.2023)

EDXRF spectrometer procured. The MoU has been Signed with Dalit Indian Chamber of Commerce and Industry (DICCI), Telangana and contacted Telangana SC & ST commission, Secretary for students Stipend. Collected the addresses of SC colleges in Telangana State and contacted nodal officers for deputing interested students for training.

8. Feasibility Study for development of technology to recover valuable materials from end-of-life silicon solar modules (HD/SP/45)
(Sponsored by MeitY, Outlay: Rs. 110.43 lakhs, DoS: 09.07.2020, DoC: 08.07.2023)

Thermal and chemical treatment for de-laminating solar modules were completed. Successfully separated broken solar cell fragments from EVA and PVF layers. Mixed solvent and thermal experiments were carried out to optimize process time and temperature. Specifications are finalized for solar panel shredding machine and high temperature muffle furnace.

4. Major pilot plant and infrastructure facilities

4.1 C-MET, Pune

4.1.1 Li-ion batteries: facility for synthesis of active materials, prototype cell fabrication and testing of cells

Lithium batteries are characterized by high specific energy, high efficiency and long life. These unique properties have made lithium batteries the power sources of choice for the consumer electronics market with a production of the order of billions of units per year. These batteries are also expected to find a prominent role as ideal electrochemical storage systems in renewable energy plants, as well as power systems for sustainable vehicles, such as hybrid and electric vehicles.

In order to develop the Li-ion battery technology Indigenously, C-MET has initiated and is actively working for the development of active materials (cathode and anode) and has developed an entire battery fabrication and testing facility for button/coin type and pouch / rectangular cells under one roof. The development of materials for high energy batteries is a continuous process and C-MET is working for the development of novel materials for the high charge capacity and energy density. Lithium cobalt oxide ($LiCoO_2$) and Lithium iron Phosphate ($LiFePO_4$) has been synthesised and optimized as a cathode material. Lithium titanium oxide ($Li_4Ti_5O_{12}$) as an anode material has also been synthesized. Another anode material, spherical hard carbon has been synthesized using novel natural sources (potato, banana and sweet potatoes). These developed cathode and anode materials were compared with the commercially available active materials (Aldrich and MTI, Corporation USA make) and fabricated prototype button/coin (2032type) cells and pouch/rectangular cells using the active materials developed by C-MET. The electrochemical performances of these cells are found to be similar to that of the commercially available active materials. We also have successfully developed thin, flexible & light weight batteries and also working for the development of polymer-based electrolyte for Li-Polymer batteries. We have also initiated the activities for the development Na-ion batteries for hybrid/electric vehicles for smart, green & clean transportation.

Figure 58: Prototype pouch type of cell fabricated using active materials developed at C-MET

Under the umbrella of CoE, C-MET have developed a Li-ion battery modules of capacity 48 V, 7 Ah and 60V, 2A using cell fabricated at C-MET with indigenously developed materials. These modules are used to demonstrate an electric two-wheeler running in the C-MET campus. This breakthrough gives confidence to the researchers working on this project to develop Li-ion modules with high capacity for driving the three-wheeler and four-wheelers. Consequently, a finished product with BMS having specifications 15V and 8A was fabricated and successfully demonstrated to replace the conventional Lead acid battery to crank the four-wheeler.

Figure 59: Battery Module (60 V, 2A) fabricated using the Pouch cells developed at C-MET

Figure 60: Ready to use Battery Module (15 V, 8A) for four-wheeler cranking fabricated using the Pouch cells developed at C-MET

Furthermore, C-MET has developed a Li-ion battery pouch cell of capacity 350 mAh for smart phone using cell fabricated at C-MET with indigenously developed materials. This pouch cell battery is successfully integrated in the Blackberry smartphone.

Figure 61: Pouch type battery for mobile fabricated at C-MET using indigenously developed cathode material

C-MET, Pune has Li-ion battery facility which can be used for the preparation of coin cells (type 2032) and pouche cells of sizes 120 x75 mm (manually) 45x58 mm (automatic mode). C-MET Pune developed 24 cell stacked battery for mobile with conventional circuit. The battery has shown the capacity of around 1200 mAh at C/20 rate. C-MET Pune has established fabrication process for flexible Li-ion cell as well as Na-ion cells.

Figure 62: Electro spin setup

4.1.2 Low Temperature Co-fired Ceramic (LTCC) based packaging facility

C-MET, Pune has established a state-of-the-art Low Temperature Co-fired Ceramic (LTCC) facility for research and development in a wide range of applications. LTCC finds applications in microwave circuits, IC packaging, micro-sensor packaging, actuators and integrated microsystems. The facility possesses high quality machines required for standard LTCC process and specialized process machines, such as LASER micromachining, CNC milling and dicing.

C-MET has developed products like low dielectric loss (10^{-4} @ 13 GHz), ferromagnetic materials with resistivity 1011 Ω.cm, electrolyte with ionic conductivity 0.035 $S.cm^{-1}$ for LTSOFC and magnetic sensors and magnetic coils for strategic applications.

Figure 63: Clean room of class 10000 and LTCC facility at C-MET, Pune

4.2 C-MET, Hyderabad

4.2.1 E-waste recycling plant

A pilot plant facility is established for the recycling of obsolete electronic equipments. Processing facilities ranging from dismantling to recovery of precious metals are established. This pilot plant facility will also be used as incubation centre for various startups which are being registered with CoE till the startups were trained properly and establish their own facilities elsewhere. Smelting system has the capacity to process ~ 300 kg shredded PCB per day, which is being scaled up to 1000 kg/day capacit. Facilities for depopulation, shredding and electro refining are also being scaled up to meet the augmented capacity. New CoE building is being constructed through CPWD for housing startups, ToT partners and skill development.

Figure 64: E-waste processing facility at C-MET, Hyderabad

4.2.2 Silicon carbide single crystal facility

Single crystal silicon carbide (SiC) is a strategically important electronic material. It is a wide bandgap semiconductor and suitable for high temperature and aggressive (chemical, nuclear) environments where the conventional semiconductors such as silicon can't function. It is useful in power electronics, pressure sensors for high temperatures and as a substrate material for GaN high electron mobility transistors (HEMTs) and GaN photonics. C-MET has created a chain of activities: (a) an imported PVT reactor (Aixtron-make) facility was established (Under an MOU between DMRL and C-MET, Hyderabad) in a clean room environment and the feasibility study for growing two-inch diameter 6H n-type SiC boule was demonstrated; (b) process optimization study, actively aided by the design of experiments (DOE), was conducted to produce 2- inch diameter n-type 6H SiC single crystal boules first time in the country.

Figure 65: PVT Reactor for single crystal growth (left) created at SiC laboratory and SiC wafers (right) cut from grown boule

4.2.3 Ultra high pure materials facility

The demand for ultrahigh purity metals is increasing rapidly because of more stringent specifications for materials used in high performance information devices. The principle of removing trace impurities from metals looks simple, but the process is extremely intensive because of the segregation coefficient of impurities present. Impurities in metal or semi-metals can be removed by lowering the chemical potentials of the impurity elements. Since the chemical potential of impurity approaches minus infinity as the concentration tends to zero, there are practical limits to ultra-purification. It is even more difficult to remove impurities which have a strong affinity for the metals. C-MET, Hyderabad has evolved as a unique facility for high pure materials in the country, where in the process technology development for tellurium, cadmium, zinc and germanium purification is one of the major activities. C-MET has been supplying these materials for the R&D needs for the development of optoelectronic devices. The state-of-the-art facility can meet complete demand in the country.

Figure 66: Induction zone refining system

4.2.4 Hafnium sponge for strategic applications

C-MET, Hyderabad has established first indigenous hafnium (Hf) metal sponge pilot plant to meet ISRO requirement. Hf sponge is also catering the needs of department of atomic energy (DAE) in control rods for nuclear reactors. C-MET is also working on developing novel spin off products based on the indigenous availability of Hf in different forms.

Figure 67: Electron Beam consolidated Hafnium Pellets

4.2.5 Restriction of hazardous substances (RoHS) test facility

C-MET, Hyderabad laboratory has established an NABL accredited chemical testing facility (bearing no. T-1780) for the analysis of electrical, electronic equipment and related products to help the industries and developed a mechanism to identify and quantify the banned hazardous substances such as Pb, Cd, Hg, Cr^{6+}, polybrominated compounds, under e-waste (Handling) Rules 2018. This is the only government owned testing facility in India established with the financial support of Ministry of Electronics & IT (MeitY), Government of India. (http://cmet.gov.in/rohs-services)

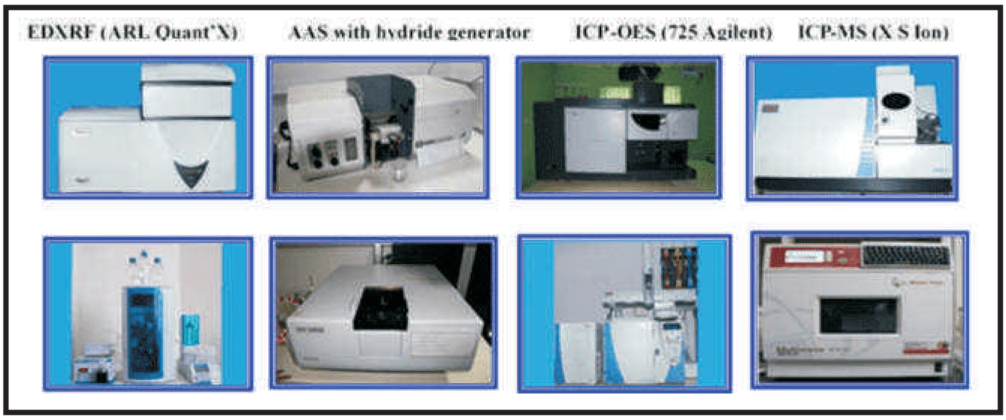


Figure 68: RoHS laboratory facility for the detection of hazardous materials

4.3 C-MET, Thrissur

4.3.1 Pilot plant for production of carbon aerogel and supercapacitor

With the financial support of DST and MeitY, Govt. of India a pilot plant facility for the production of carbon aerogel and carbon aerogel based supercapacitor was established at C-MET Thrissur. This facility includes pilot plant for the production of carbon aerogel and its processing in kilogram batch levels. This facility also includes carbon aerogel powder processing equipments , electrode fabrication facilities , supercapacitor fabrication equipments and testing equipments for super capacitors.

Figure 69: Pilot plant facilities for the prototype development of carbon aerogel and supercapacitor

4.3.2 Microwave substrates for microwave and millimetre applications

The C-MET Thrissur has been established the pilot level fabrication facility for PTFE and hydrocarbon based ceramic composite-based microwave substrates for high power applications. C-MET has indigenously developed th first time in the country patented process for fabrication of PTEF-ceramic substrates. Also, C-MET is working on ceramic filled polybutadiene substrates for substrate integrated waveguide (SIW) circuits and other applications like parch antenna.

Figure 70: Processing facility for microwave materials

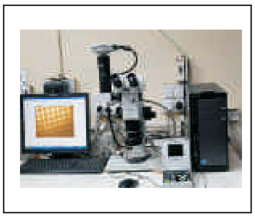
4.4 Major characterization and testing equipment available at C-MET

C-MET, Pune laboratory

1. Thickness measurement unit (TMU)

1. Make: Taylor Hobson (Talysurf CLI 2000)
2. User Charges: Rs. 2000 for inductive gauze and Rs.1900 for laser CLA gauze
3. Applications: TMU can be used for surface profiling, thickness measurement of coatings and deposits, roughness parameter and similar surface evaluation parameters.

2. Stereo microscope



1. Make: Olympus (SZX12-TBI-Japan)
2. User Charges: Rs.2750 per sample
3. Applications: Real time surface image of PCB, polymers and other substrates.

3. Measuring microscopes

1. Make: Nikon (MM-40)
2. User Charges: Rs. 2750 per sample
3. Applications: It is used for the optical inspection of the fabricated devices, substrates, films, etc.

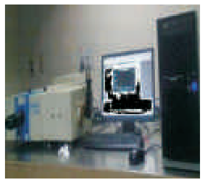
4. Spectro-fluoro-photometer

1. Make: Shimadzu (RF-5301 PC)
2. User Charges: Rs. 500 per sample
3. Applications: It can be used in biofuels analysis, optical-polymer-glasses and plasma monitoring.

5. UV-VIS Spectrometer

1. Make: Perkin Elmer (Lambda 950)
2. User Charges: Rs. 1000 for solid sample, Rs. 500 for liquid sample
3. Applications: UV spectroscopic analysis of inorganic, organic and glasses

6. Photo luminescence spectrometer



1. Make: Horiba Jobin Yron (Fluorolog 3, FL3-11)
2. User Charges: Rs. 500 per sample
3. Applications: To study the luminescence characteristics of materials, photo generation and photo light to matter interaction

7. Thermo/dynamic mechanical analyzer (TMA/DMA)

1. Make: Perkin Elmer (DMA7e)
2. User Charges: Rs.2200 per sample for DMA and Rs. 2200 per sample for TMA
3. Applications: Stress, strain, mechanical strength of films analysis

8. Differential scanning calorimetry (DSC-DPC)

1. Make: Mettler Toledo (821)
2. User Charges: Rs. 2000 per sample
3. Applications: Thermal properties of any inorganic/organic materials, ceramic and glass materials

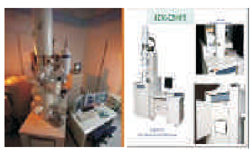
9. Thermo gravimetric analyzer (TG/SDTA)

1. Make: Mettler Toledo (851)
2. User Charges: Rs. 1400 up to 900°C and Rs. 1600 Above 900°C
3. Applications: Thermal properties of any inorganic/organic materials, ceramic and glass materials

10. X-Ray Diffraction (XRD)

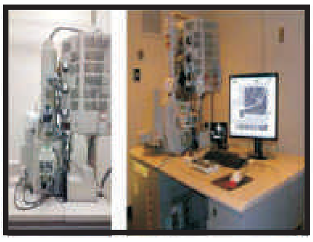
1. Make: Buker AXS (D8 Advance)
2. User Charges: Rs. 2400
3. Applications: Crystallographic study of powered samples, metal, metal oxides, polymers, and microstructure

11. Field emission transmission electron microscope (FETEM)



1. Make: JEOL (2200FS)
2. User Charges: Only for TEM Rs. 10,000, TEM+EDS Rs. 13,000, TEM+EDS+STEM Rs. 16,000, TEM+EDS+STEM+EELS Rs. 19,000 (50% discount for academic/govt institutions and 90% discount for internal samples)
3. Applications: Morphology & microstructure study with particle size of nanostructured materials

12. Field emission scanning electron microscope (FESEM)



1. Make: Hitachi (S-4800)
2. User Charges: FESEM+EDAX: Rs. 6000, Only FESEM-Morphology: Rs. 5000.
3. Applications: It is used to analyze the morphology, microstructure and elemental composition of materials.

13. X-Ray Computed Tomography (X-CT)

1. Make: X radia, Model No.: Micro XCT-400
2. User Charges:
   (a) For Industry - Rs.13200 (for 4 h) per sample,
   (>4 h, Rs.3500/hour),
   (b) For Academic/Govt. Institutions-Rs. 6600
   (for 4 h) per sample,
   (>4 h, Rs.1750 per hour) and
   (c) For Internal samples - Rs.1320 (for 4 h)
   per sample, (>4 h, Rs.350 per hour)
3. Applications: The system provides non-destructive method to a view into deeply buried micro structures, defects such as, PCBs, ICs, BGA cracks in electronic packages, micro pores in rocks, measures 3D size and spatial distribution of crystals.

C-MET, Hyderabad laboratory

14. Energy dispersive x-ray fluorescence (ED-XRF)

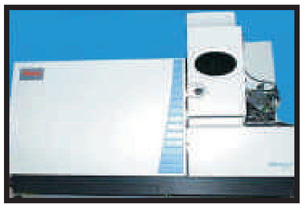
1. Make: Thermo Fishers (ARL Quant' X)
2. User Charges: Rs. 500 per sample
3. Applications: Analysis of inorganic/organic materials, soil, ceramic and glass materials.
4. The direct solid sample is used for analysis.

15. Atomic absorption spectrometer (AAS)

1. Make: GBC (GBC 932AA)
2. User Charges: Rs. 250 per element
3. Applications: Analysis of trace metal impurities

16. Inductively coupled plasma -optical emission spectrometer (ICP-OES)

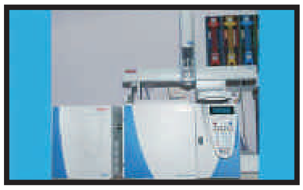
1. Make: Agilent Technologies (700 series ICP-OES)
2. User Charges: Rs. 250 per element
3. Applications: Analysis of trace metal impurities in ppm and ppb



17. Inductively coupled plasma- mass spectrometer (ICP-MS)
1. Make: Thermo scientific (X series II)
2. User Charges: Rs. 250 per element
3. Applications: Analysis of trace metal impurities in ppb and ppt.

18. UV-Visible spectrophotometer
1. Make: Shimadzu (UV-2450)
2. User Charges: Rs. 250 per sample
3. Applications: UV spectroscopic analysis of inorganic, organic materials and glasses.

19. Ion chromatography
1. Make: Metrohm (850 professional IC)
2. User Charges: Rs. 1000 per sample
3. Applications: Analysis of cations and anions.



20. Gas chromatography mass spectrometry (GC-MS)
1. Make: Thermo Fisher Scientific (Trace GC Ultra with DSQ-II)
2. User charges: Rs. 2000 per sample
3. Applications: Analysis of organic compounds and inorganic anions like sulfate, phosphate and halides.

C-MET Thrissur laboratory

21. DSC/TGA
1. Make: TA Instruments, USA (SDTQ600)
2. User Charges: Rs. 3815 per sample (excluding tax)
3. Applications: Thermal properties of inorganic/organic materials, ceramic and glass materials.

22.Thermo mechanical analyzer
1. Make: SII Japan (TMA/SS6100)
2. User Charges: Rs. 1303 per sample (excluding tax)
3. Applications: Measurement of thermal expansion coefficient of materials. Expansion, tension, penetration and volume expansion measurements possible

23. UV-Visible spectrometer
1. Make: Perkin Elmer, USA (Lambda 35)
2. User Charges: Rs. 681 per sample (excluding tax)
3. Applications: UV spectroscopic analysis of inorganic, organic materials and glasses.

24. Surface Area & Pore size Analyzer

1. Make: M/s Quantachrome Instruments, USA (Quadrasorb- Evo-KR/MP)
2. User Charges: Rs. 5220 per sample (excluding tax)
3. Applications: Evaluation of specific surface area and determination of distribution of pores of solids samples.

25. SEM with EDS

1. Make: M/s Carl Zeiss USA (EVO 18)
2. User Charges: Rs. 4000 per sample (excluding tax)
3. Applications: It is used to analyze the morphology, microstructure and elemental composition of materials.

26. Hall measurement system

1. Make: M/s Ecopia (HMS-3000)
2. User Charges: Rs. 300 per sample (excluding tax)
3. Applications: It is used for the measurement of resistivity, carrier density, mobility and identification of p/n type.

27. X-ray diffractometer

1. Make: M/s Rigaku, Japan (Ultima IV)
2. User Charges: Rs. 660 per sample (excluding tax) for normal scan
3. Applications: Crystallographic study of powered samples, metal, metal oxides, polymers, and microstructure.

The detailed information of equipments is available at C-MET at website http://www.cmet.gov.in/equipments-list