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New governing council committee approved in November 2019.

## ANNUAL REPORT 2019-2020



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.

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- 5.2. 29<sup>th</sup> C-MET annual foundation day and international conference on purification and recycling of electronic materials (ICPREM-2020) during 8-10<sup>th</sup> March 2020 at Hyderabad
- 5.3. Workshop on Q-dot glass and solar energy for waste water processing technology (Q-dot water tech) at Pune, India sponsored by the royal society of UK, London during 15 -16<sup>th</sup> November 2019
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## **Executive Summary**

C-MET is a well-known leading R&D institution specialized in the development of requirement driven electronic materials. C-MET aims to be the think tank leading to the advancement of science and technology as well as the creation of innovation for the purpose of self-reliance of India in critical electronic materials. C-MET is working closely with industries as well as strategic sectors for specialized materials. C-MET has also forged 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, electronic e-waste recycling processes, sensors, microwave materials/circuits, radio frequency switches and biomedical materials.

Through radical advances in process capabilities, C-MET has realized niche materials including nanoparticles and nano-sheets for solar hydrogen from water, layered nanostructured materials for detection of ammonia with swift response and electrode formulations for photovoltaic cell applications which are very well accepted by Indian industry. Materials for renewable energy are another area of research, focused on zero emission of  $CO_2$  for generation as well as storage of energy. Several unique nanostructured materials including ZnO, TiO<sub>2</sub>, Nb<sub>2</sub>O<sub>5</sub> have been developed to fabricate Dye Sensitized Solar Cells (DSSC) with efficiency in the range of 6-7%. Li-ion flexible batteries using commercial Lithium Cobalt Oxide (LCO) and Graphite on carbon cloth have been demonstrated. Efficient electrodes like MoS<sub>2</sub> (Capacity: 120 mAhg<sup>-1</sup>), nano porous carbon, nano porous N-doped hard carbon (Capacity: 162 mAhg<sup>-1</sup>) for sodium ion batteries have also been developed. Battery pack of capacity 2000 mAh using indigenous LCO and LTO materials were realized for mobile applications. Centre of Excellence in Rechargeable battery is being established for supporting e-mobility and Make in India program with the support of MeitY and industry. The objective of the CoE is to support the indigenous materials technology for sustainable manufacturing of Li-ion battery in the country and new chemistry for other rechargeable batteries like sodium-ion, Al-air, Li-air, Li-S batteries etc.

C-MET has developed 99.99999% (7N) pure Germanium by a unique process catering to the requirement of SSPL (DRDO) and IGCAR (DAE), respectively. Hafnium metal of 98% purity is being supplied to Vikram Sarabhai Space Center (VSSC) for high temperature aerospace alloy applications. C-MET has grown high-quality silicon carbide single crystals, for the first time in the country, which are used for high power electronics.

India produces around 2.2 million metric tons of electronic waste every year and it is growing at the rate of 25% CAGR. Approximately, 70 percent of heavy metals found in landfills are accounted by E-waste. E-waste contains over 1000 different substances, many of which are toxic and potentially hazardous to the environment and human health, if not handled in an environmentally sound manner. Centre of Excellence on E-

waste management is being established at C-MET, Hyderabad campus under the aegis of MeitY and Telangana Government to develop self-sustainable ecosystem capable of processing India's E-waste. One of the important mandates of CoE is to attract Startups to develop new e-waste related technologies and/or absorb the already developed technology by C-MET for scaling up. A demonstration plant is established at C-MET Hyderabad with a capacity of 100kg PCB/day to process materials from informal sectors and for training interested industries in E-waste recycling technologies. Three dismantlers have already utilized services of C-MET Hyderabad for processing their spent PCB materials. Technology for processing of PCBs has been transferred to M/s Namo e-Waste Management Limited, Faridabad for commercial application. In addition, the NABL accredited facility for analysis of EEE products for the compliance of E-waste (Management) Rules 2016 is being successfully run to support Indian industry.

Microwave dielectrics and packaging is the need of the hour for miniaturization of wireless communication circuits. As part of this, magnetodielectric substrates which showed 35% miniaturization and 4% enhancement of bandwidth have been developed.

In Sensors and actuators area, C-MET has developed Negative Temperature Coefficient (NTC) compositions for low temperature ( $-100 \, {}^{0}$ C to  $+50 \, {}^{0}$ C) sensing and submillimeter sized chip thermistors for weather balloon applications. Proprietary Piezoelectric compositions and Piezo components like PZT Rings for underwater transducers as well as unique multilayer and Flextensional Actuators have been developed for strategic applications.

Considering the high demand for supercapacitors (estimated at US \$ 8.30 billion by 2025, out of which \$ 3.80 billion would be for power & energy sector and \$ 877 million for smart power grid applications), C-MET designed and established an indigenous facility for making aerogel carbon at pilot plant level and demonstrated the process of making supercapacitors in the range of 10F & 25F.

C-MET has also developed new and cost-effective materials based on transparent conducting oxide thin films with carrier density (> $10^{21}$ /cc) for plasmonic applications in near Infrared (IR) region.

The Annual report 2019-20 of C-MET is prepared with an objective to disseminate the achievements and other initiatives of C-MET among citizens of the country. It highlights major success stories of technologies developed at C-MET and transferred to industries for production. The report also includes the ongoing projects and their progress as well as new initiatives during the year 2019-20. Indigenous development and import substitution of critical materials will play a major role in achieving self-reliance.

## Foreword



It gives me immense pleasure to present the Annual Report of C-MET for the year 2019-20. This report provides consolidated information on the events, accomplishments, output and global impact on C-MET during this period.

C-MET has been focusing on the development of sustainable technologies based on advanced electronic and related materials. All research and development activities at C-MET are in accordance with its mission and vision. Keeping in mind the requirements of strategic sector, C-MET has aligned its activities in the area of nanotechnology. carbide. non-conventional silicon energy storage, materials for energy devices like batteries, supercapacitors, fuel cells and solar cells. To tackle the electronic waste problem in the country e-waste recycling process technology has been established. C-MET is also entering into new areas like 3D printing, Ouantum materials, advanced antenna materials. sensors and actuators. medical electronics with wearable and cancer detection devices.

Similar to past few years, this year has also been productive for C-MET. Two Centres of Excellence (CoE's), i.e., Center of Excellence in E-waste Management and Centre of Excellence in Rechargeable Battery Technology (Pre-cell) have been established. Besides, this year, 9 sponsored projects

have been completed; 16 new externally funded projects have been initiated and one technology has been transferred to industry for commercialization. C-MET has published 38 research articles in international journals, 4 patents, 32 conferences presentations in & symposia and grabbed several awards by the scientists. I am happy to place on extra budgetary record that our resources have touched Rs. 3105.30 lakhs.

I am pleased to inform that one technology has been transferred to M/s Namo e-Waste, Faridabad for the extraction of precious metals from ewaste. C-MET has successfully developed 6H SiC single crystals which can be used for high power electronics.

C-MET has signed MoUs with IIT-Hyderabad for initiating joint M.Tech program on E-waste Resource Engineering & Management with effect from the academic year 2020, Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram for supply of hafnium and Bharat Electronics Limited (BEL), Pune for reserve batteries.

C-MET has conducted 1<sup>st</sup> workshop on Li-ion cell fabrication, battery testing in collaboration with India Energy Storage Alliance (IESA) on 12th March 2020. A workshop on Q-dot glass and solar energy for waste water processing technology (Q-dot water tech) has been organized by C-MET, Pune which was sponsored by the Royal Society of Chemistry - UK, London during 15 -16<sup>th</sup> November 2019. Five scientists from UK have participated in the workshop and delivered lectures. Fortyfive delegates have participated in the workshop. During workshop, quantum dot technology for water purification has been discussed.

C-MET Annual Foundation Day (AFD) 2020 was celebrated at Hyderabad on 08<sup>th</sup> March 2020. Foundation day lecture was delivered by Prof. Animesh Jha, University of Leeds, UK. On this auspicious occasion, an international conference Purification on and of Electronic Materials Recycling (ICPREM 2020) was successfully organized during 08-10<sup>th</sup> March 2020. Seven eminent scientists from India and five foreign scientists from Canada, UK, Russia, Germany and Malaysia have delivered plenary lectures. Around 110 delegates attended the deliberations during the three-day conference. Nearly 26 abstracts were presented by students and R&D personnel from premier R&D institutions and industries in the field of recycling and purification. The outcome would be useful in realizing the Prime Minister's vision on "Make in India" campaign.

As envisaged by Honorable Governing Council and Steering Committee members, C-MET continues to excel in its commitment to R&D for strategic, commercial and social sectors in the multidisciplinary R&D areas.

I believe that C-MET will continue to excel even greater heights under the visionary guidance of MeitY for accomplishing 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. N. R. Munirathnam Director General rathnam@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 through 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 31.03.2020)

C-MET team consists of 44 no. of S&T officers, 31 nos. of S&T supporting staff and 40 nos. administrative staff. Among S&T officers and supporting staff, 43 nos. are having Ph.D. degrees. Additionally, there are 115 nos. project staff/Ph.D. students, DST Inspire/Young scientist and women scientists working at three laboratories of C-MET and are depicted in Fig. 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, energy storage systems, electronic packaging, communication systems, displays, and various sensors and actuators.

Information Technology (IT) 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. Flexible 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 facility for ultrapure materials, compound semiconductors, refractory metals, alloys, Restriction of Hazardous Substances (RoHS) and e-waste recycling.



Figure 4. 7N pure Zinc granules

### 2.2.3 Thrissur laboratory

Major thrust area of C-MET Thrissur includes microwave material (including microwave dielectrics and substrates), energy materials (Carbon aerogel and Graphene based super capacitors), Sensors and Actuators (Thermal sensors, Piezo ceramics and Piezo actuators) and Nanomaterial (nano structured oxides, thin films, thick films and materials for Plasmonic application).



Figure 5. First version of portable biosensor

## 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 strategy for project execution based on in-house expertise, competence and infrastructure to maximize the participation in strategic and industrial sectors.

- To implement projects which are expected to generate technologies which would be commercialized in 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 indigenous technologies in the area of Electronic materials to support strategic sector

Recently, C-MET has established Centre of Excellence in batteries and E-waste recycling processes 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

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 nanostructured semiconductors, Quantum dot semiconductor glasses, nanocomposites etc.

### 3. R&D activities and S&T contribution

During the year 2019-20, 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, BARC, BRNS, DRDO, DAE, private industry and public sector, etc.
- Technical and materials characterization services

#### 3.1 Core program:

It was proposed to have more coordinated and focused approach to the R&D area through inter-laboratory research interactions, where C-MET can deliver by exploiting its expertise gained hitherto in the development of traditional and advanced electronic materials.

In this context, six major core programs listed as follows are 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 Screen Printer (left) and In-house developed Dilatometer Magnetic sensors for BARC (right)

The facility comprises of  $\sim 200 \text{m}^3$  clean room of Class 10000 that houses the complete LTCC processing facility including tape casting and materials preparation.

C-MET Thrissur focuses on development of hexaferrite based magneto-dielectric (MD) ceramic compositions that can be exploited for fabrication of dielectric substrates with application in antenna miniaturization. The flexible MD substrates for Radome application are also developed.



Figure 7. Magneto-dielectric (MD) substrate

C-MET Thrissur also aims to develop ceramic compositions through scalable solid-state method for high dielectric constants substrates. The polybutadiene / ceramic composite laminates and Substrate Integrated Waveguides (SIW) are being developed for microwave and millimetre wave circuit applications



Figure 8. Polybutadiene- ceramic composites and substrates

## 3.1.2 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<sub>2</sub>S. 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.



Figure 9. Dye-Sensitized, Perovskite and CZTS Solar Cell, respectively

## 3.1.3 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 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. e.g., 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 10. Flexible Li-ion battery

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 upto 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 0.1F to 100F and achieved an ESR of 10 milliohms.

#### 3.1.4 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 11. Wearable piezoresistive sensors made for non-verbal communication

Under this programme the main thrust is on the development of thermal sensors for weather balloons, nano material based thick film sensors and development of micro actuators. Under thermal sensors, different NTC compositions, chip thermistors and chip in glass fast response thermal sensors are being developed suitable for various temperature ranges of sensing applications.



Figure 12. NTC Thermal Sensors

Under actuators the focus is on development of piezo actuators. Various designs of ceramic actuators help in meeting diverse field of applications. Flextensional (FT) actuators have been developed to meet the opposing requirements of displacement and generative force and gives excellent amplification of displacement. The heart of FT device is a stack of multi-layer actuators so that the device can be operated at lower voltages.



Figure 13. FT actuator

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

### 3.1.5 Nano materials

- C-MET Pune has expertise in preparation of nanostructure materials including 0, 1, 2 and 3-dimensions. Pune centre focuses on nano-materials required for solar cell, fuel-cell Liion battery, super-capacitor and for other applications.
- C-MET Pune has unique expertise for preparation of quantum dots in glasses and polymers for photonic applications. The Solar light driven hydrogen production from water and H2S using natural sunlight has been demonstrated. The water purification from Quantum Dots in glasses has also been explored as societal application.
- C-MET Thrissur focuses on synthesis of nanotubes of piezoelectric materials. Applications of these 1D materials for energy harvesting applications are being carried out.
- C-MET Thrissur is engaged in the development of low loss plasmonic materials and devices based on transparent conducing oxide films for various sensing applications. The centre is also engaged in the development of simple chemical routes such as spray coating for potential transparent heater films for defrosting and anti-icing applications.

## 3.1.6 E-waste & ultrapure materials

C-MET, Hyderabad is focuses on the development of process technology for 7N pure cadmium (Cd), Tellurium (Te), Zinc (Zn) and 4N Germanium (Ge) purification and it is one of the major activities of the recent times. The high 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. 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 been engaged in the growth of 2" SiC single crystal boules using physical vapor transport technique and grown 4H and 6H SiC single crystals first time in the country. The 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 and other R&D institutes.



Figure 14. 7N Pure tellurium (left) and SiC boule (right)

Replacement of electronic equipment is very often necessary, due to the rapid technological progress, leading to huge amounts that end up as electronic waste. C-MET Hyderabad has developed a process technology for the recovery of valuable and precious metals from spent printed circuit boards, which includes both hydrometallurgical and pyrometallurgical operations. The technology offered is environmentally safe which conforms to CPCB requirements and economically viable. The technology is demonstrated at laboratory level and semi pilot plant scale (100 kg/day) at C-MET Hyderabad.

A demonstration plant is established at C-MET, Hyderabad and the facilities are being extended to informal recyclers for processing of spent PCBs on chargeable basis. Three dismantlers have utilized C-MET facilities for processing their spent PCB materials. Technology know-how is transferred to M/s. Namo Ewaste, Faridabad for commercial utilization. A state-of-the-art rotary tilting furnace (TBRF) is established at C-MET, Hyderabad for single step processing of shredded PCBs to black copper.

C-MET, Hyderabad laboratory has also established a state-of-the-art chemical testing facility for the analysis of electronic and related samples to help the industries and developed a mechanism to identify and quantify the substances banned under RoHS, Directive. This is the only RoHS testing facility in India established with Ministry of Electronics & IT (MeitY), Government of India financial support.

C-MET has developed requisite infrastructure, state of the art characterization facility and Standard Operating Procedures (SOPs) as per IEC 62321:2012 standard. RoHS analysis of variety of samples are being carried out using these advanced characterization techniques. This RoHS test facility is accredited as per ISO 17025:2005 standard by National Accreditation Board for Testing & Calibration Laboratories (NABL), Department of Science & Technology, Government of India, with certificate No: T-1780 in the field of chemical analysis of electronic materials (polymers, metals, etc.).



Figure 15. Handing over of recovered metals from spent PCB to M/s. Deshwal Waste Management, Gurgaon

In view of the above, recently C-MET has signed MoU with CPCB and became a referral RoHS testing laboratory in order to help the Indian electrical, electronics, equipment (EEE) manufacturers and MSMEs to export their products to European Union countries with RoHS

compliance certification. As per the MoU, CPCB will send EEE products to C-MET for their RoHS compliance certification, collected by random checking from market.

## **3.2 Products developed for strategic sector**

## 3.2.1 Hafnium sponge for strategic applications

The first indigenous hafnium plant in India, with production capacity of 320 kg /annum of hafnium metal sponge using zirconium raffinate to meet the total annual requirement of Vikram Sarabhai Space Centre (VSSC) for their applications in rocket nozzles, has been established at C-MET, Hyderabad. C-MET is continuously supplying hafnium to VSSC. Hafnium oxide is also future high dielectric gate oxide material for silicon based MOSFETs due to combination of high dielectric constant (k), thermal stability and large band gap.



Figure 16. Hafnium oxide briquette (left) and Hafnium sponge (right)

## 3.2.2 7N pure Germanium and Zinc

Induction zone refining system designed and fabricated for the purification of scrap (3N) germanium to 7N pure germanium for detector applications. Zone refined samples analyzed by GDMS at NRC Canada confirms 7N Ge with respect to metallic impurities. 5 kg of 7N pure germanium prepared by induction zone refining was handed over to SSPL, DRDO.



Figure 17. 7N pure Germanium

High purity zinc (7N purity) is used in compound semiconductor production such as CdZnTe, ZnSe for  $\gamma$ -ray detectors and electro-optic modulators which is required for IGCAR. A dedicated metal granulation system has been designed and fabricated for converting 7N zinc ingot in to granules. C-MET developed granules of less than 3 mm diameter for applications at DAE.



Figure 18. 7N pure Zinc granules

## 3.2.3 Development of FT Actuators for DEBEL (DRDO)

Various designs of ceramic actuators help in meeting diverse field of applications. Compared to a bulk ceramic actuator, multi-layer actuators offer advantages in terms of miniaturization, volume efficiency & low voltage drive but the displacement that can be achieved is low. C-MET has designed and developed flextensional (FT) actuator using piezoelectric PZT-5 compositions and being supplied to DEBEL, DRDO, Bangalore.



Figure 19. ML stack for FT actuator

## **3.2.4 Fabrication of flexible Substrates for RCI**

Flexible substrates are fabricated using thermo-lamination method using elastomer as base matrix filled with magneto-dielectric ceramic material. The conformal antenna design for RCI radome application was fabricated on the flexible MD substrate.



Figure 20. Conformal Antenna on MD Substrate

**3.3 Technologies transferred** 

One technology has been transferred to the Indian industries during the year 2019-20.

1. Technology for the "Recovery of valuable and precious metals from spent Printed Circuit Boards" has been transferred to M/s. Namo E-Waste Private Limited, Faridabad on 10.01.2020.



Figure 21. Signing of ToT agreement with Namo E-waste, Faridabad

## 3.4 Technologies ready for transfer

The following technologies developed during 2019-20, which are ready for transfer. The glimpses of these technologies are given below.



## 3.4.1 3D analysis system for wearable device for the prediction of tumour parameters

#### 3.4.2 3YSZ Ceramic Tapes for Oxygen sensor applications

	C-MET has developed oxygen sensors based
	on 3mol% yttria stabilized zirconia (1-2-
	micron particle size). The properties of the
	tapes are:
	• Tape Dimensions: length: 150 cm (± 1
Contraction of the second s	cm), width: $10 \text{ cm} (\pm 0.1 \text{ cm})$
	• Thickness range: 100 – 200 μm (± 3 μm)
	• Green density (dimensional): 63% (±1)
3YSZ Ceramic Tapes	

• Sintered Density (Archimedes): 98%
(±1)
• Tape formulation: 50 g batch size.
TRL level of technology is 4.

#### **3.5 Externally funded projects**

During the year 2019-20, C-MET has initiated 16 new grant-in-aid and technical services projects, in addition to 26 ongoing grant-in-aid projects from previous year. Also, 09 projects have been successfully completed during the year. C-MET has earned Internal and Extra Budgetary Resources (IEBR) to the tune of Rs. 3105.30 lakhs during the year 2019-20. The laboratory wise sponsored projects funding pattern is depicted in figure 21.



Figure 22. Sponsored projects funded by various agencies at C-MET Pune, Hyderabad and Thrissur

The growth in IEBR is graphically shown in Figure 22.



Figure 23. Budgetary support (BS), Internal Revenue (IR) and Extra-Budgetary Resources (EBR) of C-MET since 2015-2016

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 24. The trend clearly evidences better scientific recognition of the R&D capability of C-MET.



Figure 24. Intellectual output of C-MET since 2015-16

## 3.5.1 Completed grant-in-aid projects

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

#### C-MET, Pune

#### 1. Fabrication of 2D heterostructures by chemical vapor deposition

(Sponsored by BRNS, Outlay: Rs. 34.99 lakhs DoS: 01.04.2017; DoC: 31.03.2020)

Within the scope of the project, a new chemical vapor deposition unit has been set-up. Successful heterostructures have been fabricated using PLD  $MoS_2$  substrates with CVD ReS<sub>2</sub>. Large area  $MoS_2$  few layers have also been fabricated. Ta<sub>2</sub>O<sub>5</sub> films have also been made and been tested optically. The films on different substrates have been supplied to BARC.



Figure 25. FESEM image of ReS<sub>2</sub> on Quartz substrates

# 2. Development of Sn-Ag-Cu based binary and ternary lead- free electrolyte system for PCB applications

(Sponsored by DST, Outlay: Rs. 69.25 lakhs DoS: 01.05.2016; DoC: 31.12.2019)

The co-deposition baths for Sn-Ag, Sn-Cu and Sn-Ag-Cu baths have been developed. Sn-Cu bath was tested at the local PCB manufacturing industry *viz*. M/s Shogini Technoarts (Pvt.) Ltd., Pune. The bath was used to electroplate PCB test coupons at their facility and evaluated for the routine tests. The bath has been optimized and passed all the tests as per international standards of Interconnecting and Packaging Electronic Circuits (IPC standards).



Figure 26. a) CMET's Sn-Cu bath used to electroplate PCB at M/s Shogini Technoarts, Pune and b) Image of the plated PCB

#### 3. Plasmonic ionic liquid crystal stabilized nanoclusters for optical devices

(Sponsored by DST-SERB, Outlay: Rs. 32.72 lakhs DoS: 03.04.2017; DoC: 02.12.2019)

Imidazolium ionic liquid stabilized cadmium selenide (CdSe), cadmium sulphides (CdS) tin disulfide (SnS<sub>2</sub>) nanoparticles were successfully synthesized and used it as photocatalyst for

degradation of methylene organic dyes. The photocatalytic degradation of the methylene blue dye using ionic liquid stabilized nanoparticles exhibits remarkable  $k_{app}$  value of the order  $10^{-2}$  min<sup>-1</sup>. Finally, the Imidazolium based Ionic liquids-nanomaterials system implemented for the detection of hazardous metal ions by fabricating the devices.



Figure 27. TEM image of ionic liquid stabilized CdS

## 4. Development of RF circuits in LTCC

(Sponsored by SAC, ISRO; Outlay: 45 lakhs; DoS: June 2012; DoC: March 2020)

C-MET submitted the final set of samples, viz. one batch of the Iteration – IV samples with gold conductors. SAC Ahmedabad tested and confirmed that the samples have cleared all the evaluation tests. The project is completed with the submission and acceptance of this final batch of samples.



Figure 28. Iteration – IV sample submitted to SAC

## 5. Development of nanostructured manganese ferrite (MnFe<sub>2</sub>O<sub>4</sub>)

(Sponsored by MOIL Ltd. Nagpur, Outlay: Rs. 24.76 lakhs DoS: 01.02.2018; DoC: 31.01.2020)

The MOIL India ltd. has waste MnSO<sub>4</sub> in their mines. Process technology has been developed and optimized for the synthesis of nanostructured MnFe<sub>2</sub>O<sub>4</sub> by hydrothermal and co-precipitation techniques using different capping agents at 100 g scale.



Figure 29.  $MnFe_2O_4$  prepared by modified co-precipitation technique

#### **C-MET**, Hyderabad

# 6. Development of process technology for high scale production of 7N pure tellurium & cadmium

(Sponsored by SSPL, Outlay: Rs. 76.93 lakhs, DoS: 09.12.2015; DOC: 30.06.2019)

The high 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 for SSPL, DRDO. C-MET has successfully prepared 7N pure Te & Cd through resistive zone refining technique and supplied to SSPL, DRDO for night vision camera applications.

#### 7. Development of ultra-high pure zinc for detector applications

(Sponsored by BRNS, Outlay: Rs. 32.44 lakhs, DoS: 18.12.2016; DOC: 17.12.2018)

Ultra-high purity Zinc is used for making compound semiconductors such as CdZnTe (for detectors), ZnSe (for electro-optic modulators) and for doping of semiconductors to make p-type. Indigenous zone refining process has been developed. 7N Zn purity has been tested by HR-ICPMS at CSIR-NGRI. An optimized system is designed for granules of <3 mm diameter.

## **8.** Process development for the recovery of rare earths from waste phosphors, recovered from end-of-life fluorescent lamps (FLs) and CFLs

(Sponsored by DST, Outlay: Rs. 39.36 lakhs, DoS: 02.09.2016; DoC: 20.12.2019)

Rare Earth Elements (REEs) are used to make phosphors which are widely used for general illumination (fluorescent lamps) and displays (back lights for liquid crystal displays, and plasma display panels). End of life fluorescent lamps are a rich source of yttrium, europium, and terbium. Recycling of rare earths from phosphors provides an efficient way to recover high value heavy rare earth elements. The cost of rare earth oxides and metals are rising rapidly because of the recent restrictions on Chinese exports and lack of capacity elsewhere. Process knows - how has developed for the extraction of rare earths, especially Yttrium from waste phosphors of Compact Fluorescent Lamps (CFLs) and Fluorescent lamps (FLs) @ 2kg per batch with the purity more than 96 % using acid leaching followed by solvent extraction.

#### **C-MET**, Thrissur

#### 9. Supply of 1500 numbers of non-calibrated thermal sensor probes

(Sponsored by Murata Business Engineering Pvt. Ltd., Outlay: Rs. 1.50 lakhs, DoS: 06.11.2019, and DoC: 05.12.2019)

Supplied 1500 numbers of non-calibrated thermal sensor probes to Murata Business Engineering Private Ltd. This will be used for breast cancer screening wearable device technology developed by C-MET.



Figure 30. Non calibrated thermal sensor probes

## **3.5.2 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. Flexible solid-state supercapacitor device

(Sponsored by DST, Outlay: Rs. 60.64 lakhs DoS: 01.07.2017; DoC: 29.07.2020)

The development of flexible solid-state supercapacitors has been aimed in collaboration with NIT Nagpur. The aerogel-based materials have been successfully synthesized with the trail material of  $V_2O_5$  @C. Mesoporous carbon has been prepared using SiO<sub>2</sub> and TiO<sub>2</sub>. The flexible solid-state supercapacitor has been fabricated which showed the capacitance of 119.6 F/g.

# 2. 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: 29.11.2020)

The Nanostructured Perforated grapheme-based Na cell has been fabricated with the capacity of 125 mAh/g. The nanostructured  $MoS_2$ -SnS<sub>2</sub>-Graphene and  $MoS_2@MoO_3$  based Na-cell have fabricated with capacity of 420 mAh/g and 467 mAh/g, respectively.



**Figure 31.** (a,b) Nanowires of  $MoS_2$  and (c) cell of  $MoS_2@MoO_3 - 467 \text{ mAhg}^{-1}$ 

# **3.** Synthesis of nanosized AlN ceramic powder by transferred arc plasma reactor for electronic packaging applications

(Sponsored by ISRO, Outlay: Rs. 28.64 lakhs DoS: 24.01.2018; DoC: 06.09.2020)

Nano sized AlN powder required for high power electronics using transferred arc thermal plasma reactor has been prepared under different reaction conditions. However, partial

formation of AlN (<100 nm) along with Al was observed. To increase the % of AlN in the sample further optimisation is required which is in progress.



Figure 32. FE-SEM of AlN Nanopowder

## 4. 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)

Designed and fabricated flow type PCR chip samples having buried channels of dimensions 350  $\mu$ m (w)  $\times$  200  $\mu$ m (h)  $\times$  5 m (l) (Volume: about 350 $\mu$ l) and brass tubing for channel connections. The sample was submitted to IIT Delhi for testing and found satisfactory. As per the requirement, the design of new external heaters is being finalized along with selective cooling to maintain the required temperature gradient in the device.





# **5.** Three dimensional nanostructured based miniaturized and flexible rechargeable lithium batteries for flexible electronics

(Sponsored by MeitY, Outlay: Rs. 454.10 lakhs DoS: 05.06.2018; DoC: 04.06.2021)

Performed trials for the fabrication of flexible Li-ion battery /cell using commercial active (LCO and Graphite) and developed solid polymer electrolyte. The fabricated cells were then tested for electrochemical performance at different bending angles (0, 45, 90,  $180^{\circ}$ ). Fabricated prototype of thin, flexible cells using Li<sub>4</sub>Ti<sub>2</sub>O<sub>12</sub> and LiFePO<sub>4</sub> respectively, using copper and graphene coated aluminum foils as electrode substrates. The capacity was achieved around 60 mAh/g and 5% fading after bending the cells.



Figure 34. Prototype Thin, Flexible Battery and Demonstration by illumination of LED

# 6. 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: 05.08.2020)

A Quantum dot glass has been designed (CdS-  $Bi_2Te_3$ ). The quantity 500gm Q-D glass has been supplied to UK and IIT BHU for coating to solar evaporator.



Figure 35. Q-dot CdS- Bi<sub>2</sub>Te<sub>3</sub> glass

# 7. 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<sub>2</sub> atmosphere and found excellent chemical stability. The conductivity of electrolyte is found to be ~10<sup>-3</sup> 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 36. Proton conducting dense electrolyte membrane

# **8. Nanostructure NMC as a cathode material for rechargeable lithium-ion batteries** (Sponsored by ISRO, Outlay: Rs. 25.54 lakhs DoS: 08.11.2018; DoC: 08.11.2020)

Trial runs were conducted for the synthesis of NMC (811) and NMC (111). Physicochemical characterization is in progress. Literature survey is completed. Procured the standard NMC materials for the project activity and fabricated cells with capacity of 85mAh/g at 0.5C rate (C/2).



Figure 37. NMC 811 based cell

## 9. 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: 13.12.2018; DoC: 12.12.2021)

- Developed and Optimized the Organics in terms of Transparent appearance, consistency, viscosity, drying time (which is 10 mins at 60°C) and compatibility with the silver powder.
- Optimization in surface morphologies of silver powder was carried out w.r.t. the paste formulations. It was found that directly synthesized silver flakes are more suitable and compatible with the synthesized organic system.
- Formulated Silver Paste with in-house synthesized silver flakes showed good results in terms of Viscosity of 3000 Cps @25° C, Resistivity is  $0.52\Omega$ -cm which is compatible to commercial sample.
- Prepared nano silver and formulated silver ink for inkjet printing showed good results in terms of conductivity.
- Different patterns RFID antenna were designed and screen printed using the formulated thick film silver ink on PET and Paper substrates.


Figure 38. Synthesized vs commercial silver powders

### 10. Development of hybrid battery power module with indigenously developed super capacitor and Li-ion Cell

(Sponsored by MeitY- CSIR NEIST, Outlay: Rs. 62.07 lakhs DoS: 11.02.2019; DoC: 10.02.2021)

Developed the coin cells with the capacity of 128 mAh/g at C with the operating voltage 2.5 V to 4.1 V. Developed the pouch cells of capacity 128 at C/10 with the operating voltage 2.5 V to 4.1 V.



Figure 39. Pouch cell developed at C-MET, Pune

### C-MET, Hyderabad

### 11. Processing and supply of hafnium sponge

(Sponsored by VSSC/ISRO, Outlay: Rs. 633.08 lakhs, DoS: 01.07. 2016 to 30.03.2020)

VSSC requires Hf metal for using ultra-high temperature alloys for rocket thrust bearer applications. The current requirement of Hf sponge for VSSC is around 320 kg per annum. C-MET has established Hf production facility to meet this requirement. 70 Kg Hf sponge supplied to VSSC during this year. Another 4 Kg Hf sponge has been EB refined at NFC.

### 12. Recycling of scrap germanium to ultra-high pure germanium

(Sponsored by DRDO, Outlay: Rs. 122.072 lakhs, DoS:17.10. 2016; DoC:16.4.2020)

Indigenously developed Induction zone refining has been utilized for purification of scrap germanium to ultra-high pure germanium and uniform germanium ingot was produced. The pure germanium metal was re-crystallized out of melt for the production of high purity ingot (7N). 5 kg of 7N pure Germanium prepared by induction zone refining and handed over to SSPL, DRDO.

#### 13. Environmentally sound methods for recovery of metals from PCBs: phase - II

(Sponsored by MeitY, KBITS, Outlay: Rs. 1229.80 lakhs, DoS: 22.08.14; DoC: 31.12.2019 in collaboration with E-Parisaraa, Bangalore)

Environmentally benign process for recovery of metal from PCB has been developed and obtained approval as per CPCB norms. Established a chemical reactor for processing 54 kg cathode copper, 24g gold and 40g silver. EOI advertised for extending services to informal sector. A front firing rotary tilting furnace (FFRTF) has been indigenously designed, fabricated and installed. Electro-refining facility is scaled up to 5kg/day capacity.

# 14. To develop process for the growth of 6H SiC (undoped/ vanadium doped) single crystal boule

(Sponsored by DRDO, Outlay: Rs. 998.78 lakhs, DoS: 27.07.2016; DoC: 26.07.2020)

Clean room facility of class 100000 has been established for growth of 2" diameter 6H SiC single crystal boules using physical vapor transport (PVT) technique. Single crystal bowls have been grown and handed over to DRDO for device fabrication.



Figure 40. 15 mm thick SiC boule grown at C-MET

### 15. 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)

Navigation with Indian Constellation (NavIC) is an independent regional navigation satellite system developed in the country beyond up to 1500 km from its boundary. Designed circularly polarized L5 band antenna using high frequency structure simulator (HFSS). Planar ceramic substrate was prepared using phase pure microwave materials, screen printed radiating pattern and tested using vector network analyzer. Alternatively, L5 antenna was also realized on indigenously developed copper cladded substrates for NavIC applications.

## 16. Design and fabrication of MEMS bionics sensors for autonomous underwater vehicles (AUVs)

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

MEMS Bionics sensor is used for underwater applications in Autonomous Underwater Vehicles (AUVs). It can provide accurate positioning and object information of underwater species. The design and structural parameters of MEMS bionic sensors are optimized through simulation using commercial software (COMSOL, ANSYS).

### **C-MET**, Thrissur

### 17. Magneto-dielectric substrates for miniaturized antenna application

(Sponsored by MeitY, Outlay: Rs. 80.51 lakhs, DoS: 23.08.2016; DoC: 07.02.2020)

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 were prepared and laminated to obtain MD substrate. Antenna fabricated showed miniaturization of 30% and bandwidth enhancement of 4%.



**Figure 41.** Conformal Antenna on MD Substrate (left) and Amplifier Circuit on MD substrate (Astra Microwave, Hyderabad)

# 18. 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)

ZnO based transparent conducting oxide films with surface plasmon properties for wavelength >1600nm and low loss for efficient plasmonic applications in near IR were developed. TiN films were also developed with thickness <100nm for visible region. The preliminary studies indicated SPR dip in the visible region for TiN films. These films can be used as low loss alternative plasmonic materials in near IR/visible regions Thick hyperbolic layers of AZO/ZnO plasmonic structure were prepared.



Figure 42. Plasmonic film for near IR (left) and Plasmonic film for visible region (right)

# **19.** 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: 19.10.2020)

Transparent conducting oxide based optical fibers system has been developed as a gas sensor. Surface plasmon dip required for sensing was developed in the range of 1700-1800nm. Fibre-optic based ammonia sensor probe with 12cm length and 1cm was developed.



Figure 43. Fibre - optic sensor probe

# **20.** 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: 14.03.2021)

The nano NTC thermistor compositions and sub millimeter sized chip thermal sensors for low temperature applications (-100  $^{\circ}$ C to +50  $^{\circ}$ C) have been developed. These sensors will be used in space applications for monitoring weather.



Figure 44. Evaluation of thermistor developed at C-MET vs reference material

### 21. 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)

The graphene supercapacitor bank having 12V working voltage and 10,000µF capacitance is developed using coin cells 2032 and 2025 types for ARDE, Pune (DRDO).



Figure 45. Graphene coin cell supercapacitors (left) and Graphene coin cell module (right)

# 22. 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: 11.06.2020)

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 clinical trial results are in line with mammogram results.



Figure 46. 3D analysis system

# 23. 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: 30.10.2020)

Transparent conducting oxide films were developed on BK7 glass exhibiting surface plasmon resonance upto wavelengths of 1400nm, crossing telecommunication window. The bioreceptors immobilized on TCO film to identify the different pathogens. C-MET has fabricated the first version of this biosensor to work with wavelength interrogation.

# 24. 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)

Aerogel super capacitor-based power module for application in Voter Verifiable Paper Audit trail (VVPAT) of Electronic Voting Machine has been developed.



Figure 47. 20 F aerogel supercapacitors

# 25. 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: 30.09.2020)

The graphene-based supercapacitors having capacitance in the range of 50F to 200F and capacitor bank has been developed. Cylindrical graphene supercapacitors with capacitance 50F to 100 F and ESR of  $15m\Omega - 10m\Omega$ , and working voltage: 2.5 V to 2.7 V were developed.



Figure 48. Comparison of 100F and 25F supercapacitor of C-MET and imported Maxwell supercapacitor

# 26. 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: 31.07.2020)

The design of flextensional (FT) actuator for breathing regulators for aircrew using commercially available soft piezoelectric PZT-5 compositions and the Pt based metallic paste is being developed.

### **3.5.3 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 in rechargeable battery technology (Pre-Cell)

(Sponsored by MeitY, Outlay: Rs. 1287.67 lakhs DoS: 13.09.2019; DoC: 12.09.2024)

- 2. Digitalization and quantification studies of high sensitive indigenous NOx sensor and its optical calibration. (Sponsored by ISRO, Outlay: Rs. 32.83 lakhs DoS: 31.10.2019; DoC: 30.10.2022)
- 3. 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)
- 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)
- 5. Design of new anodes for biogas fuelled protonic ceramic fuel cells. (Sponsored by DST-SERB, Outlay: Rs. 30.03 lakhs DoS: 26.12.2019; DoC: 25.12.2021)
- 6. 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)
- 7. 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)

### C-MET, Hyderabad

- 8. Establishment of centre of excellence on e-waste management. (Sponsored by MietY & Govt. of Telangana, Outlay: Rs. 3580.00 lakhs, DoS: 30.09.2019; DoC: 29.09.2024)
- 9. 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)
- Development of carbide derived carbon for storage applications. (Sponsored by VSSC, Outlay: Rs. 38.00 lakhs, DoS: 24.12.2019; DoC: 23.12.2021)

### **C-MET**, Thrissur

- 11. Textured Na<sub>0.5</sub>Bi<sub>0.5</sub>TiO<sub>3</sub> based lead free Multilayer piezoelectric Actuators. (Sponsored by SERB (DST), Outlay: Rs. 49.74 lakhs, DoS: 13.05.2019, DoC: 14.05.2022)
- 12. Development of polybutadiene/ceramic composite laminates and substrate integrated waveguides (SIW) for microwave and millimetre wave circuit applications. (Sponsored by MeitY, New Delhi Outlay: Rs. 411.372 lakhs, DoS: 18.06.2019, DoC: 14.12.2021)
- 13. 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)
- 14. 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)

- 15. Entrepreneurial training programme for scheduled tribe communities to produce solar lanterns/LED bulbs for lighting applications. (Sponsored by MeitY, Outlay: Rs. 252.60 lakhs, DoS: 15.11.2019 DoC: 14.11.2022)
- 16. Ceramic dielectric thin film capacitors for electric vehicle applications. (Sponsored by SERB (DST), Outlay; Rs. 35.32 lakhs, DoS: 18.3.2019, DoC: 17.9.2022)

### 4. Major pilot plant and infrastructure facilities

### 4.1 C-MET, Pune

### 4.1.1 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  $10^{11}$   $\Omega$ .cm, electrolyte with ionic conductivity 0.035 S.cm<sup>-1</sup> for LTSOFC and magnetic sensors and magnetic coils for strategic applications.



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

Figure 49. LTCC facility at C-MET Pune

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

C-MET, Pune has Li-ion battery facility which can be used for the preparation of coin cells upto 2032 and punches of size 120x75 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.



Lithium-ion cell fabrication and testing facility **Figure 50.** Battery fabrication facility at C-MET, Pune

### 4.2 C-MET, Hyderabad

### 4.2.1 E-waste plant: recycling demonstration facility

A demonstration plant is established at CMET Hyderabad for the recovery of valuable metals such as copper, silver and gold from obsolete printed circuit boards (100 kg PCBs/day capacity) in an environmentally friendly way. Processing facilities such as depopulation, shredding, smelting, re-melting, electro refining and leaching units have been established with gas cleaning systems complying to CPCB norms. A front fired rotary tilting furnace is designed and fabricated indigenously with a view to mechanize the smelting process and thereby improving the yield as well as cost reduction. In order to promote environmentally recycling practices among informal sector, e-waste recycling facilities are extended to informal sector on chargeable basis. Silver 2N pure, copper ~ 90% pure and gold 99.9% pure are extracted using C-MET developed process.



Rotary Tilting furnace (TBRF) with accessories



Molten metal being poured from TBRF to mould during smelting operations

Figure 51. E-waste processing facility at C-MET, Hyderabad.

### 4.2.2 Silicon carbide single crystal facility

C-MET has established facility for the growth of 2" diameter SiC single crystal boule using physical vapor transport technique – first time in the country, sponsored by DRDO and in collaboration with DMRL and SSPL.



Figure 52. a) Class 100000 Clean room facility and b) PVT Reactor for single crystal growth created at SiC laboratory

### 4.2.3 High pure materials facility

C-MET, Hyderabad has evolved as a unique facility for high pure materials in the country, where in the process technology development for tellurium, zinc and cadmium 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 53. Resistive zone refining system

### **Recycling of ultra-high pure materials**

An induction zone refining system for recycling of germanium (Ge) greater than 6N pure is developed. Samples analyzed by GDMS at NRC Canada is found to be >6N (99.9999 at. %) Ge.



Figure 54. Induction zone refining system

### 4.2.4 Hafnium sponge for strategic applications

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



Figure 55. Solvent extraction system, wet & dry hafnium hydroxide, hafnium tetra chloride and hafnium sponge.

### 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<sup>6+</sup>, polybrominated compounds, under e-waste (management) rules 2016 in the area of polymers, metals. This is the only government owned testing facility in India established with the financial support of Ministry of Electronics & IT (MeitY), Government of India. In addition to NABL accreditation, C-MET is also having Bureau of Indian Standards (BIS), Govt. of India recognition for testing of mercury levels in CFLs and Fluorescent Lamps (FLs) as per standard methods. More details can be found at http://cmet.gov.in/rohs-services.





### 4.3 C-MET Thrissur

### 4.3.1 Pilot plant for production of carbon aerogel

CMET Thrissur has established facility for the production of aerogel at pilot plant level through supercritical drying method with financial support of DST Govt. of India. This unique facility has capability to produce 5 kg carbon aerogel material in single batch required for production of ~10000 numbers of 1 F aerogel supercapacitor. One of the main attractions of this facility is the recycling of the supercritical fluid medium during the aerogel production and thereby making the process energy efficient and more environmentally friendly.



Figure 57. Pilot plant facilities for the prototype development of supercapacitors

### 4.3.2 Microwave substrates for high power microwave and millimetre applications

SMECH process has been optimized for the fabrication of dimensionally stable and ultralow loss ceramic filled PTFE substrates having a dielectric constant varying from 2.9 to 14.8 together with a loss tangent of 0.002 at 10 GHz. Further C-MET is working on ceramic filled polybutadiene substrates for substrate integrated waveguide (SIW) circuits, a new concept for high-frequency electronics, which yields high performance from very compact planar circuits by the integration of non-planar 3-D structures within a multilayer circuit.



Figure 58. 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)

Equipment Photo

- 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. Graphite furnace atomic absorption spectrometer (GFAAS)

- 1. Make: GBC (AvantaSigma)
- 2. User Charges: Rs. 2750/- per sample









3. Applications: Quantitative analysis of trace metal impurities in solutions.

### 5. 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-polymerglasses and plasma monitoring.

### 6. 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.

### 7. 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

### 8. 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

### 9. 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 metal, ceramic and glass materials.

### 10. 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 metal, ceramic and glass materials.













### 11. 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.

# 12. 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.
- 3. Applications: Morphology & microstructure study of inorganic compounds. Analysis of nanostructured materials with particle size.

# 13. 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.

### 14. X-Ray Computed Tomography (X-CT)

- 1. Make: X radia, Model No.: Micro XCT-400
- 2. User Charges: (a) For Industry Rs. 13200.00 (for 4 h) per sample, (>4 h, Rs. 3500.00/hour), (b) For Academic/Govt. Institutions -Rs. 6600.00(for 4 h) per sample, (>4 h, Rs. 1750.00 per hour) and (c) For Internal samples Rs. 1320.00 (for 4 h) per sample, (>4 h, Rs. 350.00 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**

### 15. 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 metal, soil, ceramic and glass materials. The direct solid sample is used for analysis.

### 16. Atomic absorption spectrometer (AAS)

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

# **17. 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.

# **18. 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.

### 19. UV-Visible spectrophotometer

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

### 20. Ion chromatography

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

### 21. 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.













### **CMET Thrissur laboratory**

### 22. DSC/TGA

- 1. Make: TA Instruments, USA (SDTQ600)
- 2. User Charges: Rs. 3815 per sample (Excluding tax)
- 3. Applications: Thermal properties of any inorganic/organic metal, ceramic and glass materials.

### 23. 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

### 24. 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 and glasses.

### 25. Surface Area & Pore size Analyser

- 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.

### 26. 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.

### 27. 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.











### 28. 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 equipment available at C-MET are available at website <u>http://www.cmet.gov.in/equipments-list.</u>

### 5. Important events

## 5.1 International workshop on "E-waste policy awareness workshop" during 27-29 November 2019, hotel Novatel at Hyderabad.

The workshop was organized by C-MET in association with MeitY, NITI Aayog & ITU at hotel Novatel, Hyderabad, 27-29 November, 2019. Senior officials (Secretary and Joint secretary level) from ministries, Government departments, state and local level entities, industry representatives and academia attended the workshop. The delegates from different parts of the globe including UK, Japan, Bangladesh, Srilanka, etc. also participated in the event. About 75 delegates attended the deliberations and interactive sessions.



Figure 59. Final day gathering at E-Waste policy awareness workshop

# 5.2 29<sup>th</sup> C-MET annual foundation day and international conference on purification and recycling of electronic materials (ICPREM-2020) during 8-10<sup>th</sup> March 2020 at Hyderabad.

C-MET, Hyderabad has organized C-MET's 29<sup>th</sup> Annual Foundation Day along with International conference on Purification and Recycling of Electronic Materials (ICPREM-2020) during 8-10<sup>th</sup> March 2020. The conference was aimed to review the sustainable ewaste management and processing of substantial volumes of waste electronic & electrical equipment generated. Dr. G. Sateesh Reddy, Secretary, Department of Defence R&D and Chairman, DRDO blessed the event as Chief Guest, Prof. B.S. Murty, Director, Indian Institute of Technology, Hyderabad was the Guest of Honor and Prof. Animesh Jha, University of Leeds, UK delivered C-MET Foundation Day Lecture. There were 7 national and 5 international speakers from different parts of the globe including Canada, UK, Russia, Germany and Malaysia who participated and delivered invited/plenary lectures and about 110 delegates attended the deliberations.



Figure 60. Release of ICPREM-2020 conference souvnir

# 5.3 Workshop on Q-dot glass and solar energy for waste water processing technology (Q-dot water tech) at Pune, India sponsored by the royal society of UK, London during 15 -16<sup>th</sup> November 2019

C-MET, Pune has organized a workshop on Q-dot Glass and Solar Energy for Waste Water Processing Technology (Q-dot Water Tech), sponsored by the Royal Society of UK, London during 15-16 November 2019. The workshop has covered a broad area of topics related to the Qdot structures in glass and inorganic materials for energy harvesting, water purification, energy transduction and storage applications. The eminent scientists Dr. Animesh Jha, UoL, Leeds, UK, Dr. David Bryant, University of Aberystwyth, North Wales, UK, Dr. Nandish Thippaswamy, Manrochem Limited, Brighouse, UK, Dr. Venkat Subramnaian, University of Leeds, UK, Prof. Anant Paradkar, University of Bradford, UK and other renowned scientists from India have delivered the lectures.



Figure 61. Final day gathering at Q-dot Glass and Solar Energy

### 5.4 Workshop by IESA, C-MET, Pune

India Energy Storage Alliance (IESA), Pune conducted 1<sup>st</sup> workshop on Li-ion cell fabrication, battery testing at their premises in collaboration with C-MET, Pune. The delegates of the workshop have visited C-MET on 12<sup>th</sup> March 2020 and had exposure to, overview of the battery materials, fabrication and testing. Officials from industries and ministry have participated in the workshop. The possibility of future project activities as well as commercialization of the existing developed technologies were discussed during the interaction. This activity was held as a part of one of the objectives of the Centre of Excellence (CoE) in rechargeable batteries at C-MET, Pune.



Figure 62. Photo captured during India Energy Storage Alliance (IESA) workshop at C-MET

### 5.5 Subject expert committee meeting (SEC) for woman scientists

C-MET, Pune has organized Department of Science and Technology's (DST)-subject expert committee meeting (SEC) for woman scientists during 27-29<sup>th</sup> June 2019.



**Figure 63.** Photo captured during department of science and technology's (DST)-subject expert committee meeting (SEC) for woman Scientists

### 5.6 National science day celebrations 2020

C-MET, Pune has celebrated national science day (NSD) on 28<sup>th</sup> February 2020. On this occasion, a scientific talk on "Engineered nanosized metal oxides for heterogeneous catalysis" was delivered by Dr. Putla Sudarsanam, scientist from physical and materials science division, CSIR-national chemical laboratory, Pune.



Figure 64. National science day 2020 at C-MET, Pune

National science day was celebrated at C-MET Hyderabad on 28.02.2020. On this occasion, Prof. Seshu Bai Vummethala of University of Hyderabad, has delivered a lecture on "superconducting materials and their applications". Around 120 students from local engineering colleges have attended the lectures and visited C-MET laboratory.



Figure 65. National Science Day celebrations at C-MET, Hyderabad

On National science day 2020, C-MET Thrissur laboratory was kept open to the public and students and they were explained about the technologies/products developed at C-MET. The National science day lecture was delivered by Dr. T D Mercy, Head ESD, PCM, Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram on 'batteries for space application'. Dr. Mercy discussed various aspects of the indigenous development of Li batteries for space applications.



Figure 66. National science day lecture by Dr. T. D. Mercy (Head ESD, PCM, VSSC, Trivandrum)

### 5.7 Digital India 4th Anniversary

C-MET Hyderabad has organized a lecture on "Digital India: new India" by Dr. Akshdeep Sharma. C-MET Thrissur has organized a lecture on "Digital India: New India" presented by Dr. Abhisek Choudhary, Scientist, C-MET, Thrissur on 5<sup>th</sup> July 2019.

### 5.8 Industry visit to C-MET, Hyderabad

Delegates of AICTE sponsored faculty development programme on "precision engineering and mechanical processing (FDP PEMP)" organised by CVSR, Anurag group of institutions, Hyderabad, visited C-MET, Hyderabad on 26<sup>th</sup> November, 2019 as part of industry visit. They were apprised of C-MET activities and achievements in the area of electronic materials.

### 5.9 Workshop on condensed matter and materials science

C-MET Thrissur has organised a workshop on "condensed matter and materials science" along with Srinivasa Ramanujam Institute for Basic Science (SRIBS), Kottayam during 20-22

September 2019. Experts from various institutions have delivered lectures for MSc physics students, young faculty members of colleges/ university departments and research scholars in physics/materials science on various topics in the condensed matter and materials science area.



Figure 67. Participants of workshop on condensed matter and materials science

### 5.10 Swachhta pakhwada

As per the guidelines of MeitY, Govt. of India, C-MET Pune, Hyderabad and Thrissur laboratories have organized swachhta pakhwada from 01-15<sup>th</sup> February 2020. Several activities were undertaken for this swachhta pakhwada 2020 in order to make C-MET premise clean and tidy. Most of the staff of C-MET has participated in this event towards the special cleanliness drive. All three centers of C-MET have displayed the banners at main gate along with details of activities planned on notice board as well as on electronic display system. Various lectures were arranged time to time under the swachhta pakhwada. C-MET scientists have delivered lectures in workshop on "RoHS – Latest Directives as per E-Waste Management amendment rules 2020" on 11<sup>th</sup> February 2020 at ETDC - STQC, MeitY at ECIL, Hyderabad.



Figure 68. Swachhta pakhwada observed at C-MET Pune, Hyderabad and Thrissur during 01-15<sup>th</sup> February 2020

### 5.11 150th Birthday of Mahatma Gandhi

C-MET observe as open day from 10.00 to 15.00 hours for public on 02<sup>nd</sup> October, 2019. Many people including students, recyclers and faculties were visited C-MET. The e-waste plant was demonstrated to the visitors and interacted with C-MET scientists. Trees were planted inside the campus and essay writing competition was held on topic "Cleanliness is next to Godliness" by students. E-waste was also collected from students/public. A lecture on "Gandhian Thoughts" was delivered by C-MET scientist.



H. V. Desai college, Pune visit

Cancer awareness lecture



Campus cleaning

Impact of plastic on environment lecture

Figure 69. Activities undertaken on the occasion of 150th birthday of Mahatma Gandhi

### 5.12. Inauguration of Medical Camp for early detection of breast cancer

Government of India has prioritized the public health and Hon'ble Prime Minister, Shri Narendra Modi ji has lunched schemes like 'Ayushman Bharat''. Moreover, 'Make in India' scheme emphasizes affordable indigenous technologies to every Indian citizen. On the day of assuming of charge on 3<sup>rd</sup> June 2019, Hon'ble MEIT and MoS (E&IT), had stressed to concentrate on medical electronics, wherein medical devices form an important segment. Today India is witnessing one such product, developed by Centre for Materials for Electronics technology (C-MET) towards the vision of affordable medical care.

The developed device does not cause any radiation exposure and does not inflict any pain to the patient as it senses surface skin temperature. It is economical, portable, works on battery power and ideal for rural India and remote locations. Privacy of the women is ensured. Device is operator friendly and minimum training is adequate for operation. It is suitable for younger women and can prove to be boon for early detection of breast cancer by bringing down breast cancer related mortality rate in India.

Initial clinical trials were conducted on 117 patients and around 200 volunteers, and showed results comparable with that of the standard diagnostic tools such as mammogram, ultrasound and CT scan. The technology has been transferred to M/s Murata Business Engineering India Private Limited, Hyderabad, a subsidiary of Murata Manufacturing Company, Japan, for mass production and for making it available for women across India and globe.



**Figure 70.** Today (27<sup>th</sup> July 2019), Hon'ble Minister of State (E&IT), Shri Sanjay Dhotre inaugurated the medical camp at Government Medical College, Akola, for "early detection of breast cancer through wearable device", developed by CMET to provide affordable health care to all.

### 6. Collaborative research activities

- 1. C-MET, Pune is collaborating with University of Leeds, UK for quantum dot glasses for water purification.
- 2. C-MET, Pune is collaborating with IIT-BHU for solar water purification using quantum dots.
- 3. C-MET, Pune is collaborating with SPPU, Pune for characterization and electrolyte for batteries.
- 4. C-MET Thrissur is collaborating with Rajiv Gandhi Center for Biotechnology (RGCB), Thiruvananthapuram, under DBT, Govt. of India for the development of a cost-effective portable biosensor.
- 5. C-MET Thrissur is collaborating with SAMEER, Chennai, under MeitY Sponsored project for the development of Magneto-Dielectric substrates for Miniaturized antenna application.
- 6. C-MET Thrissur is collaborating with IGCAR, Kalpakkam, under DAE, Govt. of India for the development of Transparent conducting oxides and metal nitrides as low Plasmonic Materials in near IR and visible Frequencies.
- 7. C-MET Thrissur is collaborating with ECIL, Govt. of India for the Dev. of Aerogel Supercapacitor based power module for applications in VVPAT of EVM.
- 8. C-MET Thrissur is collaborating with IHRD, Kochi, under Govt of Kerala, for the Entrepreneurial Training Programme for Scheduled Caste Communities to produce Digital Thermometers & Entrepreneural Training Programme for Scheduled Tribe Communities to produce Solar Lanterns/ LED Bulbs for lighting applications.

### 6.1 Memorandum of understandings (MoUs)

- 1. C-MET, Hyderabad singed MoU with IIT Hyderabad on December 9, 2019 to generate an advanced two-year joint M.Tech program in e-waste resource engineering & management from august 2020.
- 2. C-MET, Pune signed MoU with Bharat electronics, Pune for reserve batteries.

### 6.2 Distinguished visitors



Figure 71. Visit of honorable union minister of state Shri. Sanjay Dhotre



Figure 72. Visit of secretary (MeitY) Shri. Ajay Prakash Sawhney



Figure 73. Visit of Prof. Yee -Shyi Chang from national Tsing Hua university of Taiwan

### 6.3 International research activities

- 1. **Dr. B.B. Kale** has visited the University of Leeds under the Royal society, UK project during 16<sup>th</sup> August-15<sup>th</sup> September 2019.
- 2. **Dr. R. Prasada Rao** has visited solid state NMR facility at National University of Singapore during June 2019.

- 3. DST sanctioned India-Bulgaria joint collaborative research project under project entitled "purification of hafnium metal sponge using electron beam melting and preparation of hafnium metal targets for electronic applications" with institute of electronics Bulgarian academy of sciences (IE-BAS), Bulgaria.
- 4. **Dr. V. Kumar** has submitted a project on PZT nanotube array-based vibration energy harvesters India Japan cooperative science programme by DST and JSPS in August 2019.



### 7.1 National/ International patents awarded

- 1. A low temperature co-fired ceramic substrate miniature fuel cell and manufacturing method thereof, Shekhar Dimble, Shrikant Kulkarni, Tarkeshwar Patil, Ramesh Pushpagandhan, Girish Phatak and S. Duttagupta, US patent no. 10608267 granted on **31.03.2020**.
- 2. Automatic speed controller for zone refiner, N.R. Munirathnam, D.S. Prasad and T.L. Prakash Indian patent no. 311525 granted on **24.04.2019**.
- 3. Carbon aerogel, process of preparation and application thereof, N.C. Pramanik, P.A. Abraham, Rani Panicker N, K. Stanly Jacob, Indian patent no. 326298 granted on **29.11.2019**.
- 4. Carbon aerogel compositions, process of preparation and application thereof, N.C. Pramanik, P.A. Abraham, Rani Panicker, K. Stanly Jacob, Indian patent no. 312066 granted on **30.04.2019**.

### 7.2 National/ International patents filed

1. Moisture sensitive resistance-based nanocomposite (semiconductor NPS/Agar) chemical nanosensor and a method for fabrication thereof, Jayant Rajaram Pawar, Manish Shinde, Amit Patwardhan, Sudha Mattigitti, Rabinder Henry, Indian Patent Application No. 202021010152 A, filed on **20.03.2020**.

### 7.3 Books and monographs

- 1. Pesticides as an occupational hazard facts and figures, N. Tarannum, M. Singh, R. Hawaldar, in a book entitled "handbook of research on the adverse effects of pesticide pollution in aquatic ecosystems", 2019, pages:201-214, publisher: IGI global.
- 2. Electronics: Polymer–graphene composites, S. Ansari and M.N. Muralidharan in a book entitled "Encyclopedia of polymer applications", CRC press 2019.

### 7.4 Publications in peer-reviewed journals

- Gas sensing properties of thick films prepared using Pt Loaded TiO<sub>2</sub> nano particles, Sapana S. Rane, Sudhir Arbuj, Neha Joshi, Rahul Ghuge, Sunit B. Rane, and Suresh W. Gosavi, *Sensor Lett.*, **2019**, 17(4), 269-276. (IF:0.31)
- Effect of nanosecond and femtosecond pulse laser on the formation of WS<sub>2</sub> nanostructures and field emission characteristics, P. Koinkar, K. Sasaki, A. Furube, Kei-Ichiro Murai, T. Moriga, M. Shinde, S. Rane, S. Bhopale, M. A. More, *Mod. Phys. Lett. B*, **2019**, 33(14-15), 1940014. (IF: 0.731)

- 3. Stable lithium ion conducting thiophosphate solid electrolytes  $Li_x(PS_4)_yX_z$  (X = Cl, Br, I); R. Prasada Rao, H. Chen, S. Adams; *Chem. Mater.*, **2019**, 31 (21), 8649-8662. (I.F. 10.15)
- Mechanochemical synthesis of fast sodium ion conductor Na<sub>11</sub>Sn<sub>2</sub>PSe<sub>12</sub> enables first sodium-selenium all-solid-state battery, R Prasada Rao, X Zhang, KC Phuah, S Adams, J. *Mater. Chem. A*, **2019**, 7 (36), 20790-20798. (I.F.10.73)
- Revisiting the layered Na<sub>3</sub>Fe<sub>3</sub>(PO<sub>4</sub>)<sub>4</sub> phosphate sodium insertion compound: structure, magnetic and electrochemical study; G.S Shinde, R. Gond, M. Avdeev, C. D Ling, R. Prasada Rao, S. Adams, P. Barpanda, *Mater. Res. Express.*, **2019**, 7,014001. (I.F. 1.44)
- 6. Micro flowers of SrS/Bi<sub>2</sub>S<sub>3</sub> nanocomposite and its field emission properties, Gunjal, Aarti, Kawade, Ujjwala, Sethi, Yogesh, Panmand, Rajendra, Ambekar, Jalindar, Kulkarni, Milind, More, Mahendra, Kale, Bharat, *J. Compos. Sci.*, **2019**, 3(4), 105. (IF: 2.690)
- Characterisation of spectroscopic and magneto-optical faraday rotation in Mn<sup>2+</sup>- doped CdS quantum dots in a silicate glass, R. P. Panmand, S. P. Tekale, K. D. Daware, S. W. Gosavi, A. Jha, B. B. Kale, *J. Alloys Compd.*, **2019**, 152696.
- Ruthenium-decorated vanadium pentoxide for room temperature ammonia sensing, S.N. Birajdar, N.Y. Hebalkar, S.K. Pardeshi, S.K. Kulkarni, P.V. Adhyapak, *RSC Adv.*, 2019, 9(49), 28735-28745. (IF: 3.049)
- ZnO decorated Sn<sub>3</sub>O<sub>4</sub> nanosheet nano-heterostructure: a stable photocatalyst for water splitting and dye degradation under natural sunlight, S.D. Balgude, Y.A. Sethi, B.B. Kale, D.P. Amalnerkar, P.V. Adhyapak, *RSC adv.*, **2019**, 9(18), 10289-10296. (IF: 3.049)
- Nanocomposite of polypyrrol and silica rods-gold nanoparticles core–shell as an ammonia sensor, V. Khambalkar, S. Birajdar, P. Adhyapak, S. Kulkarni, *Nanotechnology*, **2019**, 30 (10), 105501. (IF: 3.339)
- ZnCl<sub>2</sub> loaded TiO<sub>2</sub> nanomaterial: an efficient green catalyst to one-pot solvent-free synthesis of propargylamines, D. B. Bankar, R. R. Hawaldar, S. S. Arbuj, M. H. Moulavi, S. T. Shinde, S. P. Takle, M.D. Shinde, D. P. Amalnerkar, K. G. Kanade, *RSC adv.*, **2019**, 9(56), 32735-32743. (IF: 3.049)
- Two-dimensional hexagonal SnS<sub>2</sub> nanostructures for photocatalytic hydrogen generation and dye degradation; S. R. Damkale, S. S. Arbuj, G. G. Umarji, R. P. Panmand, S. K. Khore, R. S. Sonawane, S. B. Rane, B. B Kale, *Sustain. Energy Fuels*, **2019**, 3, 3406-3414. (IF: 4.912)
- N-Enriched carbon nanofibers for high energy density supercapacitors and Li-ion batteries, S. B. Kale, M. A. Mahadadalkar, C. H. Kim, Y. A. Kim, M. S. Jayswal, K. S. Yang, B. B. Kale, *RSC Adv.*, **2019**, 9, 36075-36081. (IF: 3.049)
- Ionic Liquid Responsive Phase Transfer of Gold Nanoparticles: Anionic Metathesis, S. Thawarkar, T. Nirmale, S. More, J. D. Ambekar, B. B. Kale, N. D. Khupse, *Langmuir*, 2019, 35, 9213-9218. (IF: 3.683)
- Porous MoS<sub>2</sub> Framework and Its Functionality for Electrochemical Hydrogen Evolution Reaction and Lithium-Ion Batteries, S. R. Kadam, U. V. Kawade, R. B. Ziv, S. W. Gosavi, M. B. Sadan, B. B. Kale, ACS Appl. Energy Mater., 2019, 2, 5900-5908.
- Lignin-Mediated Biosynthesis of ZnO and TiO<sub>2</sub> Nanocomposites for Enhanced Antimicrobial Activity, K. M. Samb-Joshi, Y. A Sethi, A. A. Ambalkar, H. B. Sonawane, S. P. Rasale, R. P. Panmand, R. Patil, B. B Kale, M. G. Chaskar, *J. Compos. Sci.*, **2019**, 3, 90. (IF: 2.690)

- Unique CdS@MoS<sub>2</sub> Core Shell Heterostructure for Efficient Hydrogen Generation Under Natural Sunlight, S. R. Kadam, S. W. Gosavi, B. B. Kale, N. Suzuki, C. Terashima, A. Fujishima, *Sci. Rep*, **2019**, 9, 1-10. (IF: 4.011)
- Plasmonic Ag decorated CdMoO<sub>4</sub> as an efficient photocatalyst for solar hydrogen production, Y. A. Sethi, A. K. Kulkarni, S. K. Khore, R. P. Panmand, S. C. Kanade, S. W. Gosavi, M. V. Kulkarni, B. B Kale, *RSC Adv.*, **2019**, 9, 28525–28533. (IF: 3.049)
- A review on sintering technology of proton conducting BaCeO<sub>3</sub>-BaZrO<sub>3</sub> perovskite oxide materials for protonic ceramic fuel cells. F.J.A. Loureiro, N. Nasani, G. Srinivas Reddy, N.R. Munirathnam and D.P. Fagg, *J. Power Sources*, **2019**, 438, 226991. (IF: 7.467)
- 20. Increased performance by use of a mixed conducting buffer layer, terbia-doped ceria, for Nd<sub>2</sub>NiO<sub>4+δ</sub> SOFC/SOEC oxygen electrodes. D. Ramasamy, N. Nasani, D. Pukazhselvan and D.P. Fagg, *Int. J. Hydrog. Energy*, **2019**, 44(59), 31466-31474. (IF: 4.084)
- 21. Effect of Graphite Content on the Polymer Based Resistor Paste for an Intergated Resistor on Printed Circuit Boards (PCB), M. Kolpe, S. Gosavi, G.J. Phatak, *J. Nanoelectron. Optoelectron*, **2019**, 14 (7), 1030-1036.
- 22. Enhanced electrostrain in Copper-doped Barium Strontium Titanate, K. Vani, A. Anil and V. Kumar, *Ferroelectrics*, **2019**, 550, 136-140. (IF-0.52)
- Influence of Zr/Sn ratio on the Transverse Piezoelectric Coefficient e<sub>(31,f)</sub> in Lanthanum doped Lead Zirconate Titanate Stannate Thin Films, S. Laxmipriya, V. Kumar and I. Kanno, Integrated *Ferroelectrics*, **2019**, 201, 86. (IF-0.486)
- 24. Study on the doping effect of spin coated Al and In doped and (Al/In) codoped ZnO thin films for near-infrared plasmonic applications, K. Soumya, I. Packia Selvam, S.N. Potty, *Thin Solid Films*, 2019, 687, 137482. (IF-1.88)
- 25. Palladium loaded on ZnO nanoparticles: Synthesis, characterization and application as heterogeneous catalyst for Suzuki–Miyaura cross-coupling reactions under ambient and ligand-free conditions, D. B. Bankar, R. R. Hawaldar, S. S. Arbuj, S. T. Shinde, J. R. Gadde, D. S. Rakshe, D. P. Amalnerkar, K. G. Kanade, *Mater. Chem. Phys.*, **2020**, 243, 122561. (IF: 2.781)
- 26. Influence of NaF on the ionic conductivity of sodium aluminophosphate glass electrolytes. S. R Keshri, V. V Bodewad, A. A Jagtap, N. Nasani, S. Balaji, Annapurna K, A.A. Reddy, *Mater. Lett.*, **2020**, 271,127763. (IF: 3.019)
- 27. Bismuth molybdate (α-Bi<sub>2</sub>Mo<sub>3</sub>O<sub>12</sub>) nanoplates via facile hydrothermal and its gas sensing study, A. K. Kulkarni, M. S. Tamboli, D. Y. Nadargi, Y. A. Sethi, S. S. Suryavanshi, A. V. Ghule, B. B. Kale, *J. Solid State Chem.*, **2020**, 281,121043. (IF: 2.291)
- 28. Synergic effect of decoration of nickel oxide nanoparticles on silicon for enhanced electrochemical performance in LIBs, U. V. Kawade, S. R Kadam, M. V. Kulkarni, B. B. Kale, *Nanoscale Advances*, **2020**, 2, 823-832. (IF: 6.23)
- 29. ZnO Decorated Flexible and Strong Graphene Fibers for Sensing NO<sub>2</sub> and H<sub>2</sub>S at Room Temperature, AD Ugale, GG Umarji, SH Jung, NG Deshpande, W Lee, HK Cho, JB Yoo, *Sens. Actuators B Chem.*, **2020**, 308, 127690. (IF: 6.39)
- Highly sensitive label-free bio-interfacial colorimetric sensor based on silk fibroin-gold nanocomposite for facile detection of chlorpyrifos pesticide, P. C. Mane, M. D. Shinde, S. Varma, B. P. Chaudhari, A. Fatehmulla, M. Shahabuddin, D. P. Amalnerkar, A. M. Aldhafiri, R. D. Chaudhari, *Sci. Rep.*, **2020**, 10(1), 1-14. (IF: 4.011)

- Facile synthesis of hollow urchin-like Nb<sub>2</sub>O<sub>5</sub> nanostructures and their performance in dyesensitized solar cells, N. Mohite, M. Shinde, A. K. Gupta, Y. Waghadkar, S. W. Gosavi, K. C. Mohite, R. Chauhan, S. Rane, *J. Solid. State. Electr.*, **2020**, 24, 273–281. (IF: 2.531)
- 32. Solvothermally synthesized nickel doped tin dioxide based thick films for H<sub>2</sub> and NH<sub>3</sub> gas sensing, S.S. Rane, M.D. Shinde, S.S. Arbuj, N. Joshi, S.B. Rane, S.W. Gosavi, *Materials Today: Proceedings*, **2020**, 23, 154. (IF: 0.97)
- 33. Silver Nanoparticles-Silk Fibroin Nanocomposite Based Colorimetric Bio-Interfacial Sensor for On-Site Ultra-Trace Impurity Detection of Mercury Ions, P. Mane, R. Chaudhari, N. Qureshi, M. Shinde, T. Kim, D. Amalnerkar, J. Nanosci. Nanotechnol., 2020, 20(4), 2122-2129. (IF: 1.354)
- 34. Unique N doped Sn<sub>3</sub>O<sub>4</sub> nanosheets as an efficient and stable photocatalyst for hydrogen generation under sunlight, S Balgude, Y Sethi, A Gaikwad, B Kale, D Amalnerkar, P. V. Adhyapak, *Nanoscale*, **2020**, 12(15), 8502-8510. (IF: 6.970)
- 35. Effect of casting solvent on the structure development, electrical, thermal behavior of polyvinylidene fluoride (PVDF)–carbon nanofiber (CNF) conducting binary and hybrid, BTS Ramanujam, PV Adhyapak, S Radhakrishnan, R Marimuthu, *Polym. Bull.*, **2020**, 1-17. (IF: 1.858)
- 36. Facile synthesis of SnO<sub>2</sub>@ carbon nanocomposites for lithium-ion batteries, AA Ambalkar, RP Panmand, UV Kawade, YA Sethi, SD Naik, MV Kulkarni, *New J. Chem.*, **2020**, 44 (8), 3366-3374. (IF: 3.069)
- Hierarchical Nanostructured Benzoic Naphthalene Tetracarboxylic Di-imide Organic Cathode for Lithium-Ion Battery, S. More, N. Khupse, M. Bhosale, J. Ambekar, M. Kulkarni, B. B. Kale, *Chemistry Select*, 2020, 5, 2157-2163. (IF: 1.811)
- 38. Electrochemical energy storage systems: India perspective, B. B. Kale, S. Chatterjee, *Bull. Mater. Sci.*, **2020**, 43, 1-15. (IF: 1.392)

### 7.5 Presentations in Conferences and Symposia

- Synthesis of copper chromium oxide (Cu-Cr-O) using thermal plasma route for propellant application, S.S. Puranik, V. L. Mathe, S. V. Bhoraskar and S. B. Rane, at Raman Memorial Conference, Department of Physics, SPPU, Pune, 3-5<sup>th</sup> February, 2020.
- Deposition and characterization of seed layer-assisted CuO thin film by using chemical bath deposition technique, R. S. Pokharkar, M. D. Shinde, D. R. Shinde, S. S. Jagtap, G. R. Pansare, K. D. Diwate in International Conference on Sustainable Materials for Advanced Research in Technology, 5- 6<sup>th</sup> February **2019** at YCIS Satara, India
- Ammonia sensor based on modified V<sub>2</sub>O<sub>5</sub> nanostructures, S. Birajdar, S. Kulkarni, P. Adhyapak, Raman Memorial Conference-2020 on Novel Materials for a sustainable future, Department of Physics, Savitribai Phule Pune University, 14-15<sup>th</sup> February 2020.
- High ionic conducting Na<sub>11</sub>Sn<sub>2</sub>Pse<sub>12</sub> for Na<sup>+</sup> ion rechargeable batteries, R. Prasada Rao, S. adams at "International Conference on Materials for Advanced Technologies (ICMAT-2019) held at Marina Bay Sands, Singapore, 23-28<sup>th</sup> June **2019**.
- Nanostructured ε-MnO<sub>2</sub> grown on Ni foam using microwave synthesis as cathode catalyst for rechargeable Li–Air batteries, R. Prasada Rao, N. Nasani, N.R. Munirathnam at International Conference on Materials for Advanced Technologies (ICMAT-2019) held at Marina Bay Sands, Singapore, 23-28<sup>th</sup> June 2019.
- 6. Nanostructured CuCo<sub>2</sub>O<sub>4</sub> morphology grown on Ni foam using microwave synthesis as cathode catalyst for rechargeable Li–Air batteries, R. Prasada Rao, N. Nasani, N.R.

Munirathnam, at International Conference on Materials for Advanced Technologies (ICMAT-2019)" held at Marina Bay Sands, Singapore, 23-28<sup>th</sup> June **2019**.

- 7. High Sodium ion conducting solid electrolyte for all-solid-state battery applications, R. Prasada Rao at "ADMAT 2019" held at Hyderabad, 23-25<sup>th</sup> September **2019**.
- Wearable sensors for artificial human-machine communication systems, Rahul Bakolia, Arul Kashmir at International Conference on Multifunctional and Hybrid Composite Materials for Energy, Environment and Medical Applications (ICMHCEE 2019) held at NIT-Trichy during 9-11<sup>th</sup> September 2019. (Best oral presentation award)
- 9. Electrically conductive carbon-based wearable sensors for artificial human-machine intelligence systems, Dhanashri Gaikwad, Arul Kashmir at 26<sup>th</sup> Raman Memorial Conference (RMC-2020) held at the Department of Physics, Savitribai Phule Pune University during 14-15<sup>th</sup> February 2020. (Late Prof. P. S. Damle prize for the **best interdisciplinary oral presentation**)
- 10. Selective dissolution of interdiffused p-n junctions: an approach to enhance the charge carrier mobility in organic field effect transistors, Mrudul Modak, Dr Arul Kashmir at 26<sup>th</sup> Raman Memorial Conference (RMC-2020) held at the Department of Physics, Savitribai Phule Pune University between 14,15 February 2020. (Best poster presentation award)
- 11. Optimization of proton conducting materials for metal supported solid oxide fuel cells, N. Nasani at International Conference on Advanced Materials and Processes for Defence Applications (ADMAT), organized by DMRL, DRDO during 23-25<sup>th</sup> September **2019** in Courtyard by Marriott, Hyderabad, India.
- 12. Advanced materials for metal supported solid oxide fuel cells, N. Nasani at 4<sup>th</sup> International Conference on Recent Advances in Materials Chemistry (ICRAMC-2020) organized by Dept. of Chemistry, SRM Institute of Science and Technology in association with CEA France during 19-21<sup>st</sup> February **2020** in Kattankulkathur, Chennai, India.
- 13. Process development for the recovery of rare earths from waste phosphors, Dr. U. Rambabu, at an International Conference on Advanced Materials and Processes for Defence applications (ADMAT-2019), organized by DMRL, Hyderabad, during 23-25 September 2019 held at Hotel Marriott, Hyderabad.
- 14. Recycling of rare earths from spent fluorescent lamps and permanent magnets as an urban ore, Dr. U. Rambabu at XVIII Mineral Processing Technology (MPT-2019), conducted by NMDC, Hyderabad, during 16-19<sup>th</sup> December **2019** at Hotel Marigold, Hyderabad.
- 15. Investigation of impurities in high pure 6H-SiC single crystals, C. R. Kesavulu, H. Sampath Kumar, Ch. P. L. Madhu Prasad, K. Sharath, M. V. Rokade, Sandeep Mahajan and S. T. Ali in International conference on Purification and Recycling of Electronic Materials (ICPREM-2020) held on 8-10<sup>th</sup> March **2020**.
- Tantalum processing: technological challenges and Indian status, A. Kumar, R. Govindaiah, Y. Purushotham in International Conference on Non-ferrous Minerals and Metals (ICNFMM -2019) organised by Corporate Monitors at Hotel Lalit Great Eastern, Kolkata on 12-13<sup>th</sup> July **2019**.
- 17. Preparation of hafnium sponge from zirconium process raffinate solution for advanced space applications – an overview, A. Kumar, S. Rajesh Kumar, Raghu C. Reddy, Y. Purushotham in International Conference on Advanced Materials and Processes for Defence Applications (ADMAT 2019) organised by DMRL, ASM and IIM at Courtyard by Marriot Hotel, Hyderabad on 23-25<sup>th</sup> September, **2019**.

- Wet chemical synthesis of zirconium oxychloride for high temperature coating applications, Raghu C. Reddy, Swathi Chenna, Arbind Kumar in International Conference on Advanced Materials and Processes for Defence Applications (ADMAT 2019), Hyderabad, 23-25<sup>th</sup> September 2019.
- Preparation of hafnium oxide for ultra-high temperature applications, Raghu C. Reddy, Arbind Kumar in International Conference on Advanced Thermostructural Materials & Thermal Protection Systems, (ADTHERM'20), Thiruvananthapuram, 19 -21<sup>st</sup> January 2020.
- Processing of silica free zircon sand using alkali fusion method, C. Swathi, G. Prabhakar Reddy in International Conference on Purification and Recycling of Electronic Materials (ICPREM), Hyderabad, 8-10<sup>th</sup> March **2020**.
- 21. Aerogel based indigenous supercapacitors for application in electric vehicles & other high-power electronics, K. Nithin, A. Madanan, V. Vishnuprasad, K. R. Sumesh, N. Rani Panicker, P. A. Abraham, E. K. Sunny, K. Stanly Jacob, N. C. Pramanik in National Symposium on Opportunities & Challenges in Materials for Energy Conservation & Storage for Electric Vehicles 2020, held at College of Engineering, Pune, during 3-4<sup>th</sup> January **2020**.
- 22. Effect of electrode compositions on the energy storage performance of aerogel supercapacitors, H. Venu, P. J. Ajithkumar, A. Madanan, V. Vishnuprasad, N. Rani Panicker, P. A. Abraham, E. K. Sunny, K. Stanly Jacob, N. C. Pramanik in International Conference on Frontiers of Material Science (FOMS-19), held at St. Joseph's College, Devagiri, Kozhikode during 16-18<sup>th</sup> December **2019**.
- Preparation and characterisation of electrode material for Lithium-ion capacitor, M. G. Anugraha, Arjun K Udayan, P. A. Abraham, N. Rani Panicker, E. K. Sunny, N. C. Pramanik, K. Stanly Jacob in International Conference on Frontiers of Material Science (FOMS-19), held at St. Joseph's College, Devagiri, Kozhikode during 16-18<sup>th</sup> December 2019.
- Role of hydrothermal pre-treatment in the conversion of biomass into carbon suitable for the supercapacitor applications, E. K. Sunny, P. A. Abraham, N. Rani Panicker, N. C. Pramanik, K. Stanly Jacob in International Conference on Advance Materials & Processes for Defence Applications (ADMAT 2019), held at Hyderabad during 23-25<sup>th</sup> September 2019.
- 25. Development of indigenous super capacitor aerogel bank for VVPAT and other power electronics applications, A. Madanan, E. K. Sunny, P. A. Abraham, N. Ranipanicker, K. Stanly Jacob, S.R.C. Reddy, and N. C. Pramanik in International conference on Advance Materials & Processes for Defence Applications (ADMAT 2019) held at Hyderabad during 23-25<sup>th</sup> September **2019**.
- 26. Low-cost Multilayer Piezoelectric Actuators, S. Susanth, K.G. Vasanthakumari, Nimisha Kumaran, T. Radhika, T. Karthik and N. Raghu in International Conference on Advanced Materials and Processes for Defence Applications (ADMAT 2019) organised by DMRL, ASM and IIM at Courtyard by Marriot Hotel, Hyderabad on 23-25<sup>th</sup> September 2019.
- 27. Development of In doped ZnO films for plasmonic applications, V.G. Sajeesh, I. Packia Selvam, S. N. Potty in Light Matter Interaction at Nanoscale (LMIN-2019) held at Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam, during 15-17<sup>th</sup> July **2019**.
- 28. Development of titanium nitride thin films by DC magnetron sputtering for plasmonic applications, V. G. Sajeesh, K. Sumesh, I. Packia Selvam, S. N. Potty in International Conference on Advanced Materials (ICAM-2019) held at the Department of Physics, Nirmalagiri College, Kannur during 12-14<sup>th</sup> June **2019**.

- 29. Sol-gel derived aluminum and indium co-doped zinc oxide films by spray coating for nanophotonic applications, K. Soumya, I. Packia Selvam and S. N. Potty in International Conference on Advanced Materials (ICAM 2019) held at the Dept of Physics, Nirmalagiri College, Kannur during 12-14<sup>th</sup> June, **2019**.
- 30. Production and characterization of supercapacitor grade activated carbon from cashew nutshell waste, Merin Pulikkottil, P. Jimmy Joy, M. N. Muralidharan, A. Seema in National Seminar- Frontiers in chemical sciences FCS-2020 in Department of Chemistry, University of Calicut, 29-31<sup>st</sup> March **2020**.
- 31. Computational modelling for tumour parameter estimation in a soft tissue from discrete surface temperature data, K. Arathy, N. Sudarsan, A. Seema in the National Conference on Soft Matter and Functional Materials (SMFM2020) organized by Department of Physics, NIT Calicut, 2-4<sup>th</sup> March 2020.
- 32. Conductive coatings of 2D MXene-in water for Electronics Applications, T. Radhika, U.M. Uzma Sulthana, K. G. Vasanthakumari in International Conference on Science and Technology of Advanced Materials (STAM20) conducted at Mar Athanasius College (Mahatma Gandhi University), Kothamangalam, Kerala on 14-16<sup>th</sup> January **2020**.

### 7.6 Invited lectures by C-MET Scientists

- 1. **Dr. B.B. Kale** has delivered an invited talk on energy materials in international conference on Functional and hybrid materials at Yashavantrao Chavan Institute of Science (YCIS), 29<sup>th</sup> January 2020.
- 2. **Dr. B.B. Kale** has delivered a talk on the occasion of Science day in Photonic department of Cochin University on 28<sup>th</sup> February 2020.
- 3. **Dr. B.B. Kale** has delivered a talk on Nanostructured Materials for Hydrogen production at IIT Jammu on 5<sup>th</sup> November 2020.
- 4. **Dr. B.B. Kale** has delivered a talk on Nanostructured Materials for energy application Science college, Vashi Navi Mumbai on 5<sup>th</sup> March 2020.
- 5. **Dr. B.B. Kale** has delivered a talk on Energy materials at Banaras Hindu University, Varanasi on 13<sup>th</sup> March 2020.
- 6. **Dr. B.B. Kale** has delivered a talk at workshop Q-dot water technology on quantum dot glass on 16<sup>th</sup> November 2019.
- 7. **Dr. B.B. Kale** has delivered an inaugural talk at Transfinite i-Lab (Social Virtual Innovative App) in association with Rayat Shikshan Sanstha`s S. M. Joshi College, Pune 12<sup>th</sup> July 2019
- 8. **Dr. B.B. Kale** has delivered inaugural talk on Energy storage devices at national workshop "Multifunctional Materials and Instrumentation for Emerging Applications" (MMIEA-2020), SPPU, Pune on 16<sup>th</sup> January 2020.
- 9. **Dr. B.B. Kale** has delivered an invited talk to Science graduate students of Bhausaheb Throat College Sangamner on 28<sup>th</sup> August 2019.
- 10. **Dr. B.B. Kale** has delivered a talk in workshop on IPR protection in Pimpri Chinchiwad College of engineering on 15<sup>th</sup> February 2020.
- 11. **Dr. B.B. Kale** has delivered an inaugural lecture of Degree award ceremony of Zeal Engineering college, Pune on 22<sup>nd</sup> February 2020.

- Dr. B.B. Kale has delivered a key note address in National conference on Energy by Dada Patil College, Karjat on 24<sup>th</sup> January 2020.
- 13. **Dr. G.J. Phatak** has delivered an invited talk "How did Electronics become all pervasive?", at Science Park, Chinchwad, Pune, on 18<sup>th</sup> April 2019.
- Dr. G.J. Phatak has delivered an invited talk "Optoelectronic Packaging: LTCC and future", for Defence Equipment Manufacturer's Association (DEMA) meeting, MCCIA, 25<sup>th</sup> July 2019.
- 15. **Dr. G.J. Phatak** has delivered an invited talk "National Program on Integrated Photonics", at EMCD, MeitY, on 24<sup>th</sup> June 2019.
- 16. **Dr. G.J. Phatak** has delivered an invited talk "LTCC @ C-MET", Electrical Engg. Dept, IIT, Madras on 28<sup>th</sup> June 2019.
- Dr. G.J. Phatak has delivered an invited talk "Partnership opportunities in 3D printing and optoelectronic packaging", for invited gathering of DEMA members at C-MET, Pune on 19<sup>th</sup> August 2019.
- 18. **Dr. G.J. Phatak** has delivered an invited talk "Partnership opportunities in 3D printing optoelectronic packaging", Meity-ELCINA meeting at MeitY on 9<sup>th</sup> September 2019.
- 19. **Dr. G.J. Phatak** has delivered an invited talk "C-MET plans in additive manufacturing and optoelectronics", at Sahasra Electronics, Nioda, UP on 30<sup>th</sup> September 2019.
- 20. **Dr. G.J. Phatak** has delivered an invited talk "Centre of excellence for additive manufacturing: vertical B", MeitY-ICEA meeting, at MeitY, on 01<sup>st</sup> October 2019.
- 21. Dr. G.J. Phatak has delivered an invited talk "Present and Future of Electronic Packaging and LTCC", at the Faculty Development Programme, 7-11 November 2019 (Initiative of MeitY), IIIT, Pune, on 07<sup>th</sup> November 2019.
- 22. Dr. G.J. Phatak has delivered an invited talk "Electronic Packaging and LTCC", at Refresher Course in Advanced Instrumentation (MD), 18-30 Nov. 2019, organized by UGC-HRD centre, Babasaheb Ambedkar Marathwada University (BAMU) on 22<sup>nd</sup> November 2019.
- Dr. G.J. Phatak has delivered an invited talk "Characterization techniques for dielectric materials development", at Refresher Course in Advanced Instrumentation (MD), 18-30 Nov. 2019, organized by UGC-HRD centre, Babasaheb Ambedkar Marathwada University (BAMU) on 22<sup>nd</sup> November 2019.
- 24. **Dr. G.J. Phatak** has delivered an invited talk "LTCC: Technology for Integration", at Multifunctional Materials and Instrumentation for Emerging Applications (MMIEA 2020) Organized by Dept. of Instrumentation and SES, Skill Dev. Centre,16-18 January 2020, delivered on 16<sup>th</sup> January 2020.
- 25. Dr. G.J. Phatak has delivered an invited talk Micro Solid Oxide Fuel Cells (μ-SOFC) in Low Temperature Co-fired Ceramic (LTCC) Technology" at Industry Academia Conclave on Hydrogen and Fuel Cells, Organized by DST, IISER, Thiruvananthapuram, 27-28<sup>th</sup> February 2020, Delivered on 27<sup>th</sup> February 2020.
- 26. Dr. G.J. Phatak has delivered an invited talk "Solid Oxide Fuel Cells (SOFC) as Sustainable Energy Source: Issues, and Solutions Through Packaging", at Conference on Sustainable Electric Mobility, Auto Expo 2020, 07<sup>th</sup> March 2020.

- 27. Dr. G.J. Phatak has delivered an invited talk "Solid Oxide Fuel Cells (SOFC): Issues and Solutions Through Packaging" at Third National Seminar on Energy opportunities and challenges, 5-6 March 2020, organized by Asian College of Science and Commerce, Pune. Delivered on 5<sup>th</sup> March 2020.
- 28. **Dr. R. Prasada Rao** has delivered an invited talk on "Reitveld refinement for crystal structure: theory" at "Hands-on-Experience on Fabrication of Nanocomposite materials for Engineering Applications (FNMEA 2019)" held at NIT, Warangal, during 6-10<sup>th</sup> May 2019.
- 29. **Dr. M.V. Kulkarni** has delivered an invited guest lecture on "Nano Materials and Nanocomposites for Advanced Multifunctional Applications" at IEEE Workshop on Nano bioelectronics organized by Department of Electronics and Telecommunication Engineering, Bharati Vidhyapeeth College of Engineering, Pune (BVCOE) on 17<sup>th</sup> September 2019.
- 30. Dr. M.V. Kulkarni has delivered an invited guest lecture on "Nano Materials and Polymer Nanocomposites: Synthesis, Characterization and Applications" at Department of Mechanical Engineering, Cusrow Wadia Institute of Technology, Pune (CWIT) on 18<sup>th</sup> September 2019.
- 31. Dr. M.V. Kulkarni has delivered an invited lecture as a resource person on "Nano Materials and Their Applications" at Faculty Development Programme (FDP) on Nanomaterials organized by Department of Mechanical Engineering, College of Engineering, (COEP) Pune on 20<sup>th</sup> December 2019.
- 32. Dr. M.V. Kulkarni has delivered an invited lecture as a resource person on "Nanomaterials and Polymer Nanocomposites: Synthesis and their multifunctional Applications" on Science Day Celebration organized by Department of Chemistry, MITWPU, Pune on 29<sup>th</sup> February 2020.
- 33. **Dr. Sunit Rane** has delivered an invited talk entitled "Analysis tools for multifunctional materials for emerging applications", at National Workshop on Multifunctional Materials and Instrumentation for Emerging Applications (MMIEA-2020), 16-18<sup>th</sup> January 2020.
- 34. Dr. Sunit Rane has delivered an invited talk entitled "Materials development at C-MET for Electronic components, devices and solar cells" at National Symposium, Vidya Pratisthans Arts, Comerce and Science College, Baramati on 04<sup>th</sup> January 2020.
- 35. **Dr. Sunit Rane** has delivered an invited talk entitled "Development of Electronic Materials for components, devices and solar cells at C-MET" at Indian Institute of Information Technology (IIIT), Pune on 06<sup>th</sup> November 2019.
- 36. **Dr. Sunit Rane** has delivered an invited talk entitled "Electronics Grade Materials for Additive Manufacturing", at Elcina representatives' meetings at MeitY on 09<sup>th</sup> September 2019.
- 37. **Dr. Sunit Rane** has delivered an invited talk entitled "Development of Electronic Materials at C-MET for components, devices" at 9<sup>th</sup> International Conference on Additive Manufacturing Technologies at The Lalit Ashok, Bengaluru, 06-07<sup>th</sup> September 2019.
- 38. **Dr. Sunit Rane** has delivered an invited talk entitled "Electronics Grade Materials for Additive Manufacturing", at AMSI meeting, Bangalore, 07<sup>th</sup> August 2019.
- 39. **Dr. Sunit Rane** has delivered an invited talk entitled "Advance Program on Additive Manufacturing", at EIL, Gurgaon, 17<sup>th</sup> June 2019.

- 40. **Dr. R. S. Sonawane** has delivered an invited talk on aqueous sol-gel synthesis of Cu-TiO<sub>2</sub> and its performance for degradation of spent wash under natural sunlight at International Conference on Advances in Chemical Sciences during 18-19<sup>th</sup> December 2019 in S.M. Joshi College Hadapsar, Pune.
- 41. **Dr. Parag Adhyapak** has delivered an invited talk at workshop ASMD-2019 ARCI, Hyderabad on 23<sup>rd</sup> August 2019.
- 42. **Dr. Parag Adhyapak** has delivered an invited talk at D. Y. Patil College, Pimpri, Pune on 31<sup>th</sup> August 2019.
- 43. **Dr. Parag Adhyapak** has delivered talk on Project Based Learning under the Induction Program recommended by AICTE, at Zeal College of Engineering & Research, Narhe, Pune on 16<sup>th</sup> January 2020.
- 44. **Dr. Ranjith Hawaldar** has delivered a talk on Synthesis of nanomaterials and atomically thin materials at Advance Materials and Nuclear Science (AMNS-2020) during 27-29<sup>th</sup> February, 2020 organized by Department of Physics, Central University of South Bihar Gaya, Bihar India.
- 45. **Dr Arul Kashmir** has delivered an invited talk on "Bioelectronic Devices to Monitor the Mental and Physical Health: Approach Through acid-base concept and Ohms Law" at the conference "National conference on Innovative Research in Science & Technology", organized by the department of chemistry at Shri Sivaji Science College, Amravati during 17-18<sup>th</sup> December 2019.
- 46. Dr. Sudhir Arbuj has delivered an invited talk entitled 'Synthesis of Semiconductor Nanostructures and Its Applications' as Resource Person in National Level Seminar on "Interdisciplinary Research in Chemical and Life Sciences" on 18<sup>th</sup> February 2020, organized by Maharaja Jivajirao Shinde Mahavidhyalaya, Shrigonda, Ahmednagar.
- 47. **Dr. Manish Shinde** has delivered an invited lecture entitled "Introduction to Nanomaterials" at Prof. Ramkrushna More Arts, Commerce and Science College, Akurdi, Pune organized under DBT Star College Scheme on 13<sup>th</sup> February 2020.
- 48. **Dr. Manish Shinde** has delivered an invited lecture entitled "An overview of Nanomaterials Characterization Techniques with special emphasis on by Electron Microscopies" at faculty Development Programme at IIIT Pune from 7- 11<sup>th</sup> November 2019.
- 49. **Dr. Manish Shinde** has delivered an invited lecture entitled "Present Status and Future Scope of Renewable Energy" at H. V. Desai College, Pune organized under Skill Development Course I on 09<sup>th</sup> September 2019.
- 50. Dr. N.R. Munirathnam has delivered an invited talk on "Rare earth-based Ceramics and composites for microwave circuit applications" in the "International Conference on Science, Technology and Application of Rare Earths (ICSTAR 2018)" held at Tirupati, AP, India during 23-25<sup>th</sup> September 2018.
- 51. Dr. U. Rambabu, has delivered an invited talk "Development of procedure for recycling of E-Waste, Development of standard procedure for analysis" at 3-day training program on Ewaste Management –Recycling options for MSME, conducted by Nat'l Institute of Micro Small and Medium Enterprises (ni-MSME), Hyderabad during 18-20<sup>th</sup> September 2019 at ni-MSME, Hyderabad.
- 52. Dr. U. Rambabu, has delivered an invited talk on "RoHS introduction for effective management" at one day training program on Electronic & Electrical Management focus on E-Waste Management rule 2016 & Amendments 2018, GoI, EPR Compliance & Establishment of E-waste Recycling, on 31<sup>st</sup> January 2020 conducted by Shamsodhan an E-Waste Exchange at T-Hub, Hyderabad.
- 53. **Dr. U. Rambabu**, has delivered an invited talk on "Latest Directives on Restriction of Hazardous Substances (RoHS)"to ETDC employees on the occasion of Swachhta pakhwada on 11 February 2020 at ETDC, MeitY, Hyderabad.
- 54. **Mr. Arbind Kumar** has delivered a key note address on "Preparation of Niobium from columbite ore for Space applications" at the International Conference on Mineral Processing Technology (MPT 2019) organized by Indian Institute of Mineral Engineers (IIME) at Hotel Marigold, Hyderabad on 16-18<sup>th</sup> December 2019.
- 55. **Mr. Arbind Kumar** has delivered Invited Talk on "Elements for Consideration in Technology Development: Hafnium Preparation, A case study" at CVSR, Anurag Group of Institutions, Hyderabad on 22<sup>nd</sup> November 2019.
- 56. **Dr. Raghu C. Reddy** has delivered an invited talk on "Role of Materials in Advancement of Technology" at National Institute of Technology (NIT), Raipur, 20<sup>th</sup> September 2019.
- 57. Dr. V. N. Mani has delivered an invited lecture on "preparation of high pure gallium & indium and their materials for advanced electronic applications- a bird's eye view" in the International Conference on Recent Advances in Materials and Manufacturing (ICRAMM 2019) organised by Dr. M S Sheshgiri College of Engineering & Technology, Belagavi-12-14<sup>th</sup> September 2019.
- 58. **Dr. S. Rajesh Kumar** has delivered an invited lecture on "Ways of reuse/recycling of E-Waste, Hazardous Waste" at seminar on "E Waste Management- Sustainable Development" on 27<sup>th</sup> February 2020 at FTCCI Surana Auditorium, Federation House, Hyderabad.
- 59. Dr. R. Ratheesh has delivered an invited lecture on "Strategic Electronic Materials for High End Microwave Circuit Applications" in Advances in Science, Engineering and Technology (ASET) at Tata Institute of Fundamental Research (TIFR), Mumbai on 31<sup>st</sup> May 2019.
- 60. **Dr. R. Ratheesh** has delivered a keynote address on "Development of Miniaturized Antenna for Navigation with Indian Constellation (NavIC)" in the National Conference on Innovations and Technologies for Ceramics (InTeC-2019) at NIIST, CSIR, Thiruvananthapuram.
- 61. **Dr. V. Kumar** has delivered an invited talk on "Piezoelectric vibration Energy Harvesters" in the Workshop on Condensed Matter and Materials Science organized by KSCSTE-SRIBS (Kerala state Council for Science, Technology and Engineering-Srinivasa Ramanujan Institute for Basic Sciences) and C-MET at C-MET, Thrissur on 21<sup>st</sup> September 2019.
- 62. **Dr. V. Kumar** has delivered an invited talk on "Nanomaterials for Device Applications" at the Faculty Development Programme sponsored by APJ Abdul Kalam Technological University organized by MGM College of Engineering and Technology, Pampakuda on 13<sup>th</sup> June 2019.

- 63. **Dr. N. C. Pramanik** has delivered a lecture on "Design and fabrication of indigenous aerogel supercapacitor module for specific power electronic applications", 21<sup>st</sup> National Conference of Electrochemists (NCE-21), held at VIT, Chennai during 30-31<sup>st</sup> January 2020.
- 64. **Dr. N. C. Pramanik** delivered a talk on "Development of Indigenous Aerogel Supercapacitor bank for high power electronic application", at International Conference on Advance Materials & Processes for Defence Applications (ADMAT 2019), held at Hotel Mariott, Hyderabad during 23-25<sup>th</sup> September 2019.
- 65. Dr. N. C. Pramanik has delivered a lecture on "Aerogel Supercapacitor & Applications: Technological Challenges & Achievements in r/o Process Upscaling & Manufacturing Possibilities", National Conference on Manufacturing Trends in Electrochemical Energy Systems (MEES 2019), held at Hotel SP Grand, Thiruvananthapuram on 21<sup>st</sup> September 2019.
- 66. Dr. N. C. Pramanik has delivered a talk on "Indigenous Aerogel Supercapacitor Technology: Challenges & Achievements in r/o process Upscaling towards the Energy Storage Roadmap", Industry- Academia Conclave on Energy Storage (IACES-2019), held at MNIT, Jaipur on 30<sup>th</sup> September 2019.
- 67. **Dr. N.C. Pramanik** has delivered a lecture on "Aerogel Supercapacitor: Technological Challenges on Product Development & Applications", Placement Opportunities & Scope of Higher Studies, held at ECE Department, Vidya Academy of Science & Technology, Thrissur during 18<sup>th</sup> January 2019.
- 68. Dr. S. N. Potty has delivered an invited talk on "Non-vacuum deposition of CZTS absorber for low-cost thin film solar cells" in the faculty development programme on "Recent Advances in Solar Systems" held at Department of Mechanical Engineering, National Institute of Technology, Calicut during 8-12<sup>th</sup> July 2019.
- 69. **Dr. S. N. Potty** has delivered an invited talk on "Low-cost processing of kesterite photovoltaic absorber by solution-based approaches" in the National Seminar on Advanced condensed matter Physics (NSACMP2019) held at Department of Physics, University of Calicut during 04-05<sup>th</sup> December 2019.
- 70. Dr. S. N. Potty has delivered an invited talk in the National Seminar on Nano and Energy Materials (NAEM 2019) held at KKTM Govt. College, Kodungallur during 16-17<sup>th</sup> December 2019.
- 71. Dr. S. N. Potty has delivered an invited talk on "Solution-based Processing of Kesterite Absorber Films for Photovoltaic Applications" in the 14<sup>th</sup> International Conference on Ecomaterials (ICEM-14) held at CSIR-National Institute of Interdisciplinary Science & Technology (NIIST), Thiruvananthapuram, during 5-7<sup>th</sup> February 2020.
- 72. **Dr. A. Seema** has delivered an invited talk on "Wearable Device for Early Detection & Mass Screening of Breast Cancer" in Midzone WIMA fest 2019 conducted by Indian Medical association (IMA) and Woman Doctor's wing (WDW) at Thrissur on 19<sup>th</sup> May 2019.
- 73. **Dr. A. Seema** has delivered an invited talk on "Chemistry of Sensors" in chemistry association programme 2019 at Department of Chemistry, St. Joseph College, Irinjalakuda, Thrissur on 03<sup>rd</sup> September 2019.

- 74. **Dr. A. Seema** has delivered an invited talk on "2D Materials- Graphene" on Science Popularization programme conducted by Vidya Academy of Science and Technology for the school students sponsored by KSCSTE on 28<sup>th</sup> September 2019.
- 75. **Dr. A. Seema** has delivered an invited talk on "Women in Science" on the programme "WOMEN ACHIEVERS IN SCIENCE" conducted by the Department of Chemistry and Center for Research, St. Teresa's College (Autonomous), Ernakulam on 04<sup>th</sup> October 2019.
- 76. **Dr. A. Seema** has delivered an invited talk on "Chemistry to Technology" in chemistry association programme 2019 at Research department of Chemistry, Sri Vyasa NSS College, Thrissur on 16<sup>th</sup> November 2019.
- 77. **Dr. A. Seema** has delivered an invited talk on "Sensors Challenges and Innovations" in National Seminar on Recent Trends in Material Science (NSRTMS- 2019) at Department of Chemistry, Government college Chittur, Palakkad on 05<sup>th</sup> December 2019.
- 78. Dr. A. Seema has delivered an invited talk on "Women and Science: Prejudice and Facts" in "Women in Science' Programme conducted by Postgraduate and Research Department of Physics, Vimala College, Thrissur on 16<sup>th</sup> January 2020.
- 79. **Dr. A. Seema** has delivered an invited talk on "Negative Temperature Coefficient Resistance Thermistors: Future Perspective" at National seminar Frontiers in Chemical Sciences at Department of Chemistry, University of Calicut on 30<sup>th</sup> January 2020.
- Br. A. Seema has delivered an invited talk on "Chemistry of Sensors" in Prof. P P Krishnan Memorial Endowment lecture at Department of Chemistry, Malabar Christian college, Calicut on 31<sup>st</sup> January 2020.
- 81. Dr. A. Seema has delivered an invited talk on "Women and Science: Prejudice and Facts" at National Science Day programme of CIPET: Institute of Plastics Technology (IPT), Kochi on 14<sup>th</sup> February 2020.
- 82. Dr. T. Radhika has delivered an invited talk on "Material Challenges and Opportunities for Next Generation Electronics Applications" in the National Conference on Fundamental and Applied Physics (NFAP 2019) held at Department of Physics, University College, Trivandrum, Kerala on 12<sup>th</sup> November 2019.
- 83. Dr. T. Radhika has delivered an invited talk on "Electronic Materials" in the National Science Day at Department of Physics, Sri Vyasa NSS College Wadakkanchery, Thrissur on 20<sup>th</sup> February 2020.
- 84. **Dr. N. Raghu** has delivered an invited talk on "Electronic packaging" at Workshop on Condensed Matter and Materials Science during 20-22<sup>nd</sup> September 2019 organized by Sri Ramanujam Institute of Basic Science, Kottayam.
- 85. Dr. N. Raghu has delivered an invited talk on "Exciting world of Electronic Materials" at Prof. K. S. Seetharaman Memorial Lecture Series – 2020 on 27<sup>th</sup> February 2020 organized by St. Thomas College, Thrissur & Instituted by Prof. T. R. Viswanathan, Texas University, USA.

### 7.7 Honours and recognitions

- 1. **Dr. B. B. Kale** has received an international award Fellow of Asian Pacific Advanced Material Society (APAM) Academician, Singapore.
- 2. **Dr. B. B. Kale** has received an international award Fellow of Royal Society of Chemistry (FRSC), London.

- 3. **Dr. B. B. Kale** has been elected as a vice chairman of Materials Research Society of India, Pune chapter.
- 4. **Dr. B. B. Kale** has been nominated as Member of Board of Studies (BoS) for Chemistry, SPPU, Pune.
- 5. **Dr. Girish Phatak** has been nominated as Member of Board of Studies (BoS) for Applied Physics, DIAT, Pune.
- 6. **Dr. R. Prasada Rao** has been selected as Associate Fellow of Andhra Pradesh Academy of Sciences.
- 7. **Dr. Milind V. Kulkarni** has been nominated as Member of the Society for Polymer Science, India.
- 8. **Dr. Milind V. Kulkarni** has been nominated as Member of Board of Studies (BoS) for Electrical Engineering, D. Y. Patil University, Ambi, Pune from 06.03.2020 onwards.
- 9. **Dr. Sunit Rane** has been elected as Secretary of Materials Research Society of India, Pune Chapter.
- 10. **Dr. Parag V. Adhyapak** has been nominated as Board of Studies (BoS) member for Chemistry, D. Y. Patil University, Ambi, Pune from 06.03.2020 onwards.
- 11. Dr. Narendar Nasani has been awarded Start up Research Grant (SRG) (formerly known as Early Career Research Award (ECRA)) from Science and Engineering Research Board (SERB)-DST, New Delhi on 15<sup>th</sup> October 2019.
- 12. **Dr. Akshdeep Sharma** has been awarded Early Career Research Award (ECRA) from Science and Engineering Research Board (SERB), New Delhi on 22<sup>nd</sup> March 2019.
- 13. **Dr. N. C. Pramanik** has received best technology innovation award from the juries of innovation pavilion of ADMAT 2019.
- 14. Dr. A. Seema was awarded with "OPPI recognition" by organization of pharmaceutical producers of India for accessible medical device. The award was presented by Shri. Mansukh Mandaviya, Hon'ble Minister of State of the Ministry of Shipping and Minister of State in the Ministry of Chemicals.

### 8. C-MET's future area of research

### 8.1 Future area of research

The following activities are planned to explore the cutting-edge technologies in advanced electronic materials;

- High energy storage devices by researching on active materials for batteries for e-vehicle applications (supercapacitors, lithium-ion battery).
- Development of 3-D printing inks and microwave devices for strategic and commercial applications.
- Development of 3-D printing machine and materials for fabrication of LTCC packages and circuits.
- LTCC based liquid cooling devices for high performance computing.
- Development of Perovskite and thin film Solar Cells.
- Indigenous sensors for internet of things (IoT) and smart cities applications.
- Microwave substrates, terahertz and milli meter wave materials.
- Cost effective and environmentally friendly recycling technologies and RoHS testing.

- Silicon carbide electronic device grade substrates for strategic applications.
- NTC materials for low temperature applications for airport weather monitoring system (-90°C to +50°C).
- EMI-shielding materials, nanopowders of aluminum, iron, boron, Boron nitride, boron carbide, aluminum nitride for strategic applications.
- Graphene based electrical, optical and acoustic attenuators for medical, consumer and strategic applications.
- Plasmonic for photostable nanoparticles in medical applications.
- Medical electronics.
- Stretchable electronic devices.
- COE on rechargeable batteries.
- Additive manufacturing.
- MXene based 2D materials for electronics applications.
- Plasmonic devices for cancer detection.
- Development of  $Si_3N_4$  based high speed RADOMES.

### C-MET's Roadmap for 2025:

### **C-MET Pune**

1. Centre of Excellence in Rechargeable Battery Technology

Funded by: MeitY; duration: 13.09.2019 to 12.09.2024; Total cost: 2087.67 Lakh

Vision: Nurture Indian industry for manufacturing of rechargeable battery (Li-ion/Na-ion).

**Mission:** To build capacity in all verticals of Indian rechargeable battery (Li-ion/Na-ion) manufacturing eco-system through focused and coordinated R&D.



### Manpower to be trained under COE

• About 25 project students and 60 number of R&D personnel from industries will be trained under this CoE.

• About 25 start-ups will also be targeted to generate from this CoE.

2. Center of Excellence on Additive Manufacturing (CoE AM)

Funded by: MeitY; duration: 3 years; Total cost: 5711.88 Lakh

Vision- Nurture manufacturing in India through the process of Additive Manufacturing

**Mission-** To build capacity in all verticals of Indian Additive Manufacturing Eco-system, through focused and coordinated research, design and development.

The objective of the project includes creation of a self-sustaining Center of Excellence on Additive Manufacturing which will support to Indian Additive Manufacturing Eco-system with a focus on developing indigenous materials (metal, ceramic, semiconductor and composite) and machine for AM technology for current and next generation electronic components/ products.

### C-MET, Hyderabad

3. Center of Excellence in E-waste Management (CoE E-waste)

Funded by: MeitY; duration: 30.09.2019 to 29.09.2024; Total cost: 3580.00 Lakh

Vision: To create an e-waste management ecosystem in India

**Mission:** To lead transformation by creating a conducive e-Waste Management ecosystem which nurtures innovation, entrepreneurship, and capability building

The COE will host incubation centers to create prototypes for addressing various domestic needs in the field of E-waste eg. dismantling, plastic recycling, designing and automation of various process equipment for environmentally friendly recycling of PCBs, recovery of precious metals, separation of rare earth oxides from spent phosphors, recovery of Silicon from PV modules, nurturing of start-ups etc. This facility will also nurture start-ups to develop their ideas, offer training to MSMEs for dismantling practices, attract informal E-waste recyclers to practice environmental recycling practices, providing training to empower the Indian electronics and electrical industries on the E-waste Management Rule (2016) etc. The RoHS facility available at C-MET, Hyderabad will be helpful in this respect. The schematic shows triple helix model – partners for key strategic pillars of Centre of Excellence.

### **Triple Helix Model – Partners for Key Strategic Pillars**



### **C-MET Thrissur**

4. Centre of Excellence on Piezoceramics (To be submitted)

Piezoelectric devices are in great demand for commercial and strategic application. The global market for piezoceramics is estimated to increase by 37 % from US \$ 29.2Billion (2019) to US \$ 40.1 Billion (2024).



### Piezoelectric devices Market-Global Forecast

(Source: Acmite Market Intelligence (2017) Mordar Intelligence (2018))

C-MET Thrissur proposes a Centre for excellence in piezoelectric devices including development of improved and/or novel materials for enabling miniaturized piezoceramic components as well as enhanced electromechanical devices especially for strategic applications and will be submitted soon.

### 9. Others

### 9.1 Plans and prospects

C-MET implemented the projects in accordance with its approach and strategy. The key features of plans and prospects are:

- 1. To enhance the competency in advanced areas of science and technology in order to keep pace with the world scenario of electronic materials through in-house and grant-in-aid projects with inter and intra laboratory involvement.
- 2. To continue the interactions / working relations with strategic sector for development of critical materials and products through sponsored projects.
- 3. To continue the technical and materials characterization services to industries for enhanced scope for consultancy projects, chemical analysis and certification for the compliance.
- 4. To be a front runner in R&D of electronic materials and collaborate with esteemed international and national institutes / universities for creating common platform on knowledge sharing basis.
- 5. To develop impactful products and technologies through exploratory and requirement driven applied research.

### 9.2. RTI matters

Central Public Information Officer (CPIO)/ Appellate Authority (AA)/ Assistant Public Information Officer (APIOs) are identified in C-MET for receipt and disposal of applications/ appeals under RTI Act, 2005. C-MET has also hosted relevant inputs/ documents in website, as required under Section 4 of the RTI Act. The relevant contents are reviewed and updated periodically.

During the year 2019-20, 26 RTI applications (16 online and 10 physical) were received on the following subjects:

Sr.	RTI Subjects	No. of Application recd.
No.		
1.	Fellowship-Grants unpaid	01
2.	Leave Rules for CSIR- JRF	01
3.	Hierarchy level to Admin Staff	01
4.	Employment Pjt staff	01
5.	List of employees attended ICSEA	01
	Conference	
6.	Skill development scheme in C-MET	01
7.	PRMRPY Scheme	01
8.	Working hours in C-MET	01

9.	Children & Education allowance reg.	01
10.	Compensate appointment	01
11.	Reservation (Disability)	01
12.	Skilled/unskilled workers in C-MET	01
13.	Peer Review information	01
14.	New Pension Scheme	01
15.	Outside information & lien on the post	01
16.	Contracts to various agencies	01
17.	Recruitment Rules for- Advt. 1/2020	01
18.	Personal Information of employees	01
19.	Not related to C-MET	08
	Total applications received:	26 Nos.

Appeal Subjects	No. of Appeal recd.
Children education allowance reg.	01
DPC/Promotion related	01

### 9.3. Public grievances

No public grievances were reported in C-MET during 2019-20.

### 9.4. Parliament matters

During the year 2019-20 the following Parliament Questions were replied: Lok Sabha 11 (3 Starred and 8 Unstarred), Rajya Sabha 19 (11 Starred and 8 Unstarred). The above questions related to SC/ST Scientist recruited in the last five years indicating the level of the different posts along with category, Cases pending before Tribunals, Inter-Ministerial Litigation, Internal Complaints Committee, Sexual Harassment of Women at Workplace, Assessment of Employment generation during the last 5 years, Vacancies under reservation in govt. Organizations, Employment recruited through Outsourcing, Vacant posts in Central Government, Foreign training of officials, High expenses on government litigation, Law Suits faced by Department, Funds used under Corporate social Responsibility, Promotion on Public rating, Employment Opportunities to youth, Prosecution of Government employees, Equal Pay for Equal Work, Representation of scientists from SCs & STs- seeking inputs, Women and Child Development, Appointment of Consultant etc.

### 9.5. Gender empowerment/Prevention of sexual harassment of women at work place

No cases of sexual harassment on women were reported in C-MET during 2019-20.

### 9.6. Activities undertaken for the benefit of differently abled persons

- Identifying and reserving the type of jobs which could be easily performed by PwD for Group 'B', 'C' & 'D' posts.
- Imparting post-recruitment & pre-promotion training.
- Providing aids / assistive devices.
- Providing barrier-free and accessible work-station to PwD.
- Redressing grievance through Liaison Officer to look after the reservation matters relating to PwD as well as issues relating to providing of amenities to them.

- Sanctioning 4 days' Special Casual Leave to PwD for specific requirements relating to their disabilities subject to exigencies of work. Also granting 10 days' Special Casual Leave in a calendar year to differently abled employees for participating in Conferences / Seminars / Training / Workshops related to disability and development.
- Exempting PwD from rotational transfer and posting as far as possible. Also considering choice posting in case of PwD subject to administrative constraints.

#### 9.7. Details related to vigilance cases

At various intervals of time, Monthly Report, Quarterly Report and Annual Reports were sent to CVO, MeitY. More than 44 cases of vigilance clearance certificates were issued to staff in c/w promotion, passport, outside applications, and visit of abroad etc. Vigilance Awareness Week was observed during 28<sup>th</sup> Oct to 02<sup>nd</sup> Nov, 2019 and taken pledge by each one of the staff. Banners were prepared and put them on various places in this office. During the period under report, no vigilance case is pending or contemplated against any of the employees.

### Acknowledgment

C-MET is grateful to the Ministry of Electronics & Information Technology (MeitY), Govt. of India for its whole-hearted support and guidance during the entire year. It is my pleasure to acknowledge the support to C-MET in the form of specific sponsored projects for the technology/product development from the government and private organizations such as MeitY, ISRO, DST, DRDO, DAE, IUSSTF, CPRI, h2e Power Systems, Pune, J-Group Robotics, Mumbai, and MOIL, India Ltd., Nagpur, and Royal Society, UK.

The guidance and proactive support of the honourable Chairman, Deputy Chairman, Executive vice-Chairman and members of the Governing Council of C-MET have been invaluable for effective functioning. The advice of the Steering and Executive Committee of C-MET in carrying out the programmes effectively and efficiently requires special mention. I sincerely thank all of them.

I place on record very special thanks to all the officers and staff members of Electronic Materials and Components Development (EMCD) division, finance division, Autonomous Bodies Coordination Division (ABCD) and the other divisions of MeitY, for their extraordinary support and prompt co-operation in implementing C-MET's programs. I am also obliged to our bankers, Punjab National Bank, Canara Bank, State Bank of India, Indian Overseas Bank, Andhra Bank and Bank of India at Pune, Hyderabad and Thrissur for rendering timely services.

I earnestly owe all the staff members and project staff working in various projects of C-MET for their dedicated professional efforts in the R&D activities, administrative services and financial support in achieving the overall progress of C-MET during the year.

**Dr. N. R. Munirathnam** Director General On behalf of C-MET staff



## **C-MET, PUNE**

# 10. AUDITOR'S REPORT AND ANNUAL ACCOUNTS

## **FOR THE YEAR 2019-20**

### M/S. VDA Associates, Chartered Accountants

10, Satsnag Society, Near Vaikuntha, Opp. L B Shashtri Road, 977, Navi Peth, Pune - 411030.

### INDEPENDENT AUDITORS' REPORT TO THE CENTRE FOR MATERIALS FOR ELECTRONICS TECHNOLOGY (C-MET)

### **Report on the Financial Statements**

We have audited the accompanying financial statements of **Centre for Materials for Electronics Technology, C-MET**, which comprise the Balance Sheet as at 31<sup>st</sup> March, 2020, and Income & Expenditure Account for the year then ended, and a summary of the significant accounting policies and other explanatory information.

### Management's Responsibility for the Financial Statements

The Management of Centre for Materials for Electronics Technology, is responsible for the preparation of these financial statements that give a true and fair view of the financial position and financial performance in accordance with the Accounting Standards applicable to non-corporate entities issued by Institute of Chartered Accountants of India in accordance with the accounting principles generally accepted in India. This responsibility includes the design, implementation and maintenance of internal control relevant to the preparation and presentation of the financial statements that give a true and fair view and are free from material misstatement, whether due to fraud or error.

### Auditors' Responsibility

Our responsibility is to express an opinion on these financial statements based on our audit. We conducted our audit in accordance with the Standards on Auditing issued by the Institute of Chartered Accountants of India. Those Standards require that we comply with ethical requirements and plan and perform the audit to obtain reasonable assurance about whether the financial statements are free from material misstatement.

An audit involves performing procedures to obtain audit evidence about the amounts and the disclosures in the financial statements. The procedures selected depend on the auditor's judgment, including the assessment of the risks of material misstatement of the financial statements, whether due to fraud or error.

In making those risk assessments, the auditor considers internal control relevant to the Society's preparation and presentation of the financial statements that give a true and fair view in order to design audit procedures that are appropriate in the circumstances. An audit also includes evaluating the appropriateness of the accounting policies used and the reasonableness of the accounting estimates made by the Management as well as evaluating the overall presentation of the financial statements.

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our audit opinion.

### Opinion

In our opinion and to the best of our information and according to the explanations given to us, the aforesaid financial statements read with Annexure to Audit Report and Notes to Accounts

(schedule 6) annexed herewith give a true and fair view in conformity with the accounting principles to the extent applicable to the Society:

- a) in the case of the Balance Sheet, of the state of affairs of the Society as at 31<sup>st</sup> March, 2020; and
- b) in the case of the Income & Expenditure Account, of the surplus of the Society for the year ended on that date;

**For M/s VDA Associates Chartered Accountants** Firm Registration No. 119179W

**CA Pavan Sharma** Membership No. 170497 (Partner)

Place: Pune. Date: 15.1.2021

### ANNEXURE forming part of Audit Report of

Centre for Materials for Electronics Technology for the Year ended 31<sup>st</sup> March 2020.

#### 1) Fixed Assets pertaining to projects:

a) At present, the fixed assets pertaining to projects are shown in the books as project expenses. As suggested, project fixed assets are shown separately in the Balance Sheet. In respect of those assets, which relate to the projects that are completed and the fixed assets which are not likely to be returned to the sponsors, feasibility to dispose off such assets may be assessed.

b) There are few expenses incurred by C-MET Thrissur section for major repairs of Rs.6,06,673/- which was supposed to be capitalised. Whereas the same is books as revenue expenditure on the basis of management representation letter issued by them.

#### 2) Statutory Dues:

a) Income Tax Refunds of previous years to be followed up and if not receivable then it should be written off in next financial year.

#### 3) Internal audit:

Internal audit report of C-MET Thrissur is not submitted to us for verification.

**For M/s VDA Associates Chartered Accountants** Firm Registration No. 119179W

**CA Pavan Sharma** Membership No. 170497 (Partner)

Place: Pune. Date: 15.1.2021

### BALANCE SHEET AS AT 31stMARCH, 2020

			(Amount ₹)
<u>Corpus / Capital Fund and</u>		As at	As at
Liabilities:	Schedule	31.3.2020	31.3.2019
Corpus/ Capital fund	1	631,535,221	496,312,552
Current Liabilities and Provisions (Including sponsored project)	2	439,155,293	307,181,432
TOTAL		1,070,690,514	803,493,984
Assets:			
Fixed Assets Current Assets, Loans and	3	140,351,874	151,203,160
Advances	4	930,338,640	652,290,824
Miscellaneous Expenditure (to the extent not written off or adjusted)		-	-
TOTAL		1,070,690,514	803,493,984
Significant Accounting Policies	5		
Notes to Accounts and Contingent Liabilities	6		

We hereby certify the above balance sheet to be true and correct to the best of our knowledge and belief, subject to notes to accounts and schedules attached hereto.

Sd/-Dr. N. R. Munirathnam **Director General**  Sd/-G. B. Rao **Sr. Finance Officer** 

As per our report of even date attached. **For M/s VDA & Associates** Chartered Accountants F.R. No. 119179W

Sd/-**CA Pavan Sharma** (M.No.: 170497) (Partner)

Place: Pune Date: 15.1.2021

	-		(Amount ₹)
		<b>Current Year</b>	<b>Previous Year</b>
Income:	Schedule	2019-20	2018-19
Revenue Grants	7	322,666,536	219,326,538
Income from Services	8	24,694,850	11,145,728
Interest Earned	9	39,230,797	30,432,485
Other Income	10	744,268	14,185,840
Total (A)		387,336,451	275,090,591
Expenditure: Establishment Expenses	11	194,510,340	162,651,947
Laboratory and Administrative Expenses etc. Depreciation	12	46,752,156 20,684,750	40,773,543 24,034,372
Total (B)		261,947,246	227,459,862
Surplus / (Deficit) for the year (A - B)		125,389,205	47,630,729
Balance transferred to / from Corpus/Capital Fund		125,389,205	47,630,729

### INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31<sup>ST</sup> MARCH, 2020

We hereby certify the above Income & Expenditure account to be true and correct to the best of our knowledge and belief, subject to notes to accounts and schedules attached hereto.

Sd/-Dr. N. R. Munirathnam **Director General**  Sd/-G. B. Rao **Sr. Finance officer** 

As per our report of even date attached. **For M/s VDA & Associates** Chartered Accountants F.R. No. 119179W

Sd/-CA Pavan Sharma (M.No.: 170497) (Partner)

Place: Pune, Date: 15.1.2021

### Centre for Materials for Electronics Technology, Pune. RECEIPTS AND PAYMENTS FOR THE YEAR ENDED 31st MARCH, 2020.

				1	(Amount ₹)
	Current	Previous		Current	Previous
RECEIPTS	Year	Year	PAYMENTS	Year	Year
	2019-20	2018-19		2019-20	2018-19
I. Opening Balances			I. Payments		
			Establishment		
a) Cash in Hand	-	1,373	Expenses	173,855,698	128,339,822
			Administrative		
b) Bank Balances:	539,444,344	542,339,257	Expenses	70,542,349	55,850,243
<u>II. Grants Received</u>			II. Project Payments Sponsored Projects	16,29,61,98 7	13,82,90,909
Conital Counts	0 922 464	27 772 462			
Capital Grants	9,833,464	27,773,462			
Revenue Grants	322,666,536	219,326,538	III. Fixed Assets Purchase of Fixed Assets	9,833,464	2,352,425
III. Interest On deposits			Capital Work in Progress	-	-
On Bank deposits	39,169,896	31,663,512	<u>IV. Other</u> <u>Payments</u> Loans & Advances to Staff and Others	120 711 005	6 00 02 200
IV. Other Income				129,711,095	0,99,02,390
Analysis Income	68,631,008	1,067,354	V. Closing		
receipts	20.238.356	3,726,148	<u>V. Closing</u> Balances		
1000-p.05	20,200,000	0,720,110			
			a) Cash in Hand	-	-
			b) Bank Balances:	74,84,57,06 6	539,444,345
V. Other Receipts					
Sponsored Project Receipts Loans & Advances	280,244,812	102,125,337			
from Staff and Others	15,133,243	6,157,153			
TOTAL	1,295,361,659	934,180,134	TOTAL	1,295,361,659	934,180,134

### Schedules forming part of balance sheet as at 31<sup>st</sup> march, 2020

(Amount ₹)					
Schedule 1 - Corpus / Capital fund:	as at 31	.3.2020	3.2020 as at 31.3		
Balance as at the beginning of the year	469,960,159		44,21,86,697		
Add: Contribution towards Corpus / Capital Fund	9,833,464 479,793,623		2,77,73,462 469,960,159		
Add / (Less): Balance of net income / Expenditure transferred from income and expenditure account:					
As per last year Add: Surplus / (deficit) for the year	<b>26,352,393</b> 125,389,205		<b>21,278,337</b> 47,630,730		
	151,741,598	631,535,221	26,352,393	496,312,552	
Balance at the year end		631,535,221		496,312,552	

### Schedule 2 - current liabilities and provisions:

(Schedules forming part of Balance Sheet as at 31<sup>st</sup> March, 2020)

		, ,		(Amount ₹)
	as at 31	.3.2020	as at 31	.3.2019
A. Current Liabilities:				
1.Sundry Creditors:				
a) For goods & others	810,829		97,671	
b) For E.M.D and deposits	13,551,995	14,362,824	4,140,308	4,237,979
2. Statutory Liabilities:				
Profession tax / ITDS / GST/		1,367,840		1,039,308
Service tax / GIS		, ,		<i>, ,</i>
3. Other Current Liabilities:			100 546 001	
Sponsored projects	223,545,582		138,546,291	
Other liabilities	56,672,175	280,217,757	43,276,150	181,822,441
Total (A)		295,948,421		187,099,728
<u>B. Provisions:</u>				
1.Gratuity Payable	78.650.735		66.367.265	
2.Leave Encashment Pavable	61.204.193		52.050.395	
3. Expenses Payable	3,351,944	143,206,872	3,464,044	120,081,704
1 2	, ,	, ,	, ,	, ,
Total (R)		143 206 872		120 081 704
		420 155 202		207 101 /22
$1 \text{ otal } (\mathbf{A} + \mathbf{B})$		439,155,293		307,181,432

### Centre for Materials for Electronics Technology, Pune. Schedules forming part of balance sheet as at 31<sup>st</sup> march, 2020

#### Schedule 3 - Fixed Assets:

(Amount ₹) Depreciation Description Gross block Net block deleti additions deletions/ Total up to as at as at as at the for ons/ as at as at Adj. Adj. durin 1.4.2019 31.03.2020 31.03.2020 31.03.2019 31.3.2019 during during beginning the g the of the year the year the year year year 1. Buildings on freehold land 55,892,291 12,953,2040 131,462,501 1,930,461 73,639,749 5,703,145 79,342,894 52,119,607 2. Lab equipment 85,617,204 -----318,460,373 226,432,215 239,755,617 78,704,756 312,049,420 6,410,953 13,323,402 3,375,208 3. Furniture, fixtures -----9,998,463 13,373,670 406,540 13,780,210 365,348 10,363,811 3,416,399 4. Office equipment 3,845,309 -----17,980,600 17,547,842 432,758 13,702,534 14,317,769 3,662,831 615,235 5. Computer/peripherals 893,699 ------12,984,477 561,156 13,545,633 12,090,777 480,510 12,571,287 974,346 6. Electric fittings 902,204 -----1,765,724 0 -1,765,724 863,520 90,220 953,740 811,984 7. Electric substation 502,064 0 -3,689,196 3,187,132 75,310 -----3,262,442 426,754 3,689,196 143,840 8. Air conditioners ------813,174 91,596 904,770 669,335 697,781 206,990 28,446 31,341 9. Tube well ------95,494 0 95,494 64,153 3,134 67,287 28,207 151,203,160 -----491,851,037 9,833,464 501,684,501 **340,647,878** 20,684,750 361,332,628 140,351,874 **Total of current year** 

### Schedule 4 - Current Assets, Loans & Advances:

(Schedules forming part of Balance Sheet as at 31st March, 2020)

	, ,			(Amount ₹)
A. Current Assets:	as at 31	.3.2020	as at 31	.3.2019
1.Cash balances in hand				
2.Bank balances with scheduled banks:				
- On deposit accounts	362,683,586		361,500,448	
- On savings accounts	65,413,074		27,245,414	
- Project deposits (including flc margin money)	303 167 130	731 263 790	187 452 980	576 198 842
(mending he margin money)	505,107,150	751,205,790	107,452,900	570,170,042
Total (A)		731,263,790		576,198,842
<b>B.</b> Loans, Advances and Other				
Assets				
	254 760		261 556	
Loans and advances to staff	234,700		204,550	
Loans and advances to others	64.187.283		5.687.513	
	0.,107,200		0,007,010	
Amount recoverable	4,664,495		7,819,810	
Advance to suppliers	29,704,346		4,504,095	
	06 405 200		50 279 722	
Security and other deposits	96,405,322		50,378,733	
Prenaid expenses	0		3 1 5 5	
r repaid expenses	0		5,155	
Interest Accrued on FDRs	3,858,644	199,074,850	74,34,120	76,091,982
Total (B)		199,074,850		76,091,982
Total (A + B)		930,338,640		652,290,824

### Centre for Materials for Electronics Technology (C-MET) Schedules forming part of the accounts for the year ended 31<sup>st</sup> March 2020.

### SCHEDULE: 5 SIGNIFICANT ACCOUNTING POLICIES

### 1. Accounting Conventions:

The Financial Statements are prepared on *historical cost convention*, going concern, and accrual basis and the same are followed consistently, except for Bonus, which is accounted for on cash basis.

### 2. <u>Revenue Recognition:</u>

- ▷ Income from operation includes, Income from analysis receipts, overhead receipts and Professional/consultancy services. Income from these activities is accounted for as and when services are rendered.
- ▷ Grants are recognized when there is a reasonable assurance that, the grants will be received.
- ▷ C-MET being research body, its entire expenditure relates to *research activity*. The expenditure incurred is debited to the appropriate accounts.
- ► All significant items of incomes and expenses are accounted on accrual basis unless otherwise stated.

### 3. Fixed Assets:

- ► Fixed Assets stated in the Balance Sheet are valued at their cost of acquisition inclusive of freight, octroi and other direct and indirect cost in respect thereof.
- Society has been directed to charge depreciation on its assets on the written down value basis vide instructions issued by Ministry of Electronics & Information Technology. Accordingly, depreciation has been charged as per rates prescribed under the Income Tax Act, 1961.
- ▷ Fixed Assets procured under the Sponsored projects, being the property of the respective Sponsoring agency, are not accounted under the head C-MET Fixed Assets.

### 4. Inventory:

As per the policy consistently followed by the Centre, expenditure incurred on consumable stores and spares is charged to revenue account.

### 5. <u>Foreign Currency Transaction:</u>

Transactions in foreign currency are recorded at the exchange rates prevailing on the date of transactions.

### 6. <u>Prior period and Extraordinary Items:</u>

Prior period income and expenses and extraordinary items, wherever material is disclosed separately. Prior period items include material items of Income or Expenses which arise in the current period as a result of error or omission in the preparation of financial statements of one or more prior periods. It does not include items, which are ascertained and determined during the year.

Expenses amounting to Rs. Nil/- pertaining to previous year have been accounted for in the current year. The details are given in Certificate taken from Management.

### 7. <u>Retirement Benefits</u>:

C- MET has set up Contributory Provident Fund separately. Leave Encashment and Gratuity is accounted for as per the actuarial valuation, liability whereof is as below:

a) Gratuity - Rs. 786,50,735/- (Previous Year Rs. 663,67,265/-) b) Leave Encashment - Rs. 612,04,193/- (Previous Year Rs. 502,10,045/-)

8. Amount equal to capital expenditure is credited to capital fund. Grants for sponsored projects are shown separately. Unspent amount of the sponsored projects is shown as liability.

For CENTRE FOR MATERIALS FOR ELECTRONICS TECHNOLOGY

**Dr. B B Kale** Director General **G. B. Rao** Sr. Finance Officer

**For VDA & Associates Chartered Accountants** Firm Registration No. 119179W

### CA Pavan Sharma

Membership No.: 170497 (Partner)

Place: Pune. Date: 15.01.2021

### CENTRE FOR MATERIALS FOR ELECTRONICS TECHNOLOGY (C-MET)

### Schedules forming part of the Accounts for the year ended 31<sup>st</sup> March 2020.

### SCHEDULE: 6 NOTES ON ACCOUNTS

- 1. <u>Current Assets, Loans & Advances:</u> In the opinion of the management, the current assets, loans and advances have a value on realization in the ordinary course of business equal at least to the aggregate amount shown in the Balance Sheet.
- 2. Foreign Currency Transactions:
  - a) Value of Imports (FOB basis): Capital Goods: Rs. 210,01,480/- (Previous Year Rs. 1,17,84,429/-)
  - b) Expenditure in Foreign Currency: Rs.129,27,025/- (Previous Year Rs. 40,65,434/-)

As the information of CIF basis for import of capital goods is not available, values are taken on FOB basis.

- 3. The Society is an approved institution in terms of sub-section (21) of section 10 of the Income Tax Act, 1961 and is exempt from Income Tax.
- 4. Since most of the materials/equipments are of technical nature, their allocation between equipments, stores and projects are taken as certified by the management.
- 5. C-MET, being a scientific Society and not a commercial, industrial or a business entity, the Management is of the opinion that reporting requirements as per AS-17 "Segment Reporting" are not mandatory.
- 6. The Management of C-MET is of the opinion that being a Scientific Society under Ministry of Electronics and Information Technology, Govt. of India and Societies Registration Act, the disclosure requirements as per AS-18 "Related Party Disclosure" are not applicable.
- 7. In the opinion of the Management, Accounting Standard 22 for "Accounting for taxes on income" is not applicable to the Society as it is exempt from payment of income tax.
- 8. Debit and Credit Balances of Personal Accounts are subject to confirmation.
- 9. Previous year's figures have been regrouped and rearranged wherever necessary.
- 10. Schedules 1 to 11 are annexed to and form an integral part of the Balance Sheet as at 31<sup>st</sup> March, 2020 and the Income & Expenditure Account for the year ended on that date.
- 11. The Financial Statements are prepared in accordance with the Accounting Standard 21-Consolidated Financial Statement of 3 operational units i.e., Pune, Hyderabad and Thrissur.

#### 12. Contingent liability not provided in the books of account: -

The TDS notices Unit wise are issued by the Income Tax Department and the dues are yet to be finalized and settled.

### For CENTRE FOR MATERIALS FOR ELECTRONICS TECHNOLOGY

**Dr. B B Kale** Director General **G. B. Rao** Sr. Finance Officer

For VDA & Associates, Chartered Accountants Firm Registration No. 119179W

CA Pavan Sharma Membership No.: 170497 (Partner)

Place: Pune. Date: 15.01.2021

		(Amount ₹)
Schedule 7 - Revenue Grants:	Current Year 2019-20	Previous Year 2018-19
Grants for Revenue Expenditure	322,666,536	219,326,538
TOTAL	322,666,536	219,326,538

Schedules forming part of Income & Expenditure A/c for the year ended  $31^{st}$  March, 2020

Schedule 8 - Income from Services:	Current Year 2019-20	Previous Year 2018-19
Income from Services:		
Analysis receipts Overhead/Consultancy services/Intellectual	43,986	89,053
Fee	20,496,864	9,254,175
ToT Fee	4,154,000	1,802,500
TOTAL	24,694,850	11,145,728

Schedule 9 - Interest Earned:	Current Year 2019-20	Previous Year 2018-19	
On Savings account and Term Deposits:			
a) With Scheduled Banks	39,148,800	30,424,925	
b) On Advance to Staff	81,977	7,560	
TOTAL	39,230,792	30,432,485	

Schedule 10 - Other Income:	Current Year 2019-20	Previous Year 2018-19	
Miscellaneous Income	744,268	14,185,840	
ТОТА	L 744,268	14,185,840	

Schedule 11 - Establishment Expenses:	Current Year 2019-20	Previous Year 2018-19
Salaries and allowances	147,646,009	130,610,952
Training		150,729
Leave travel concession	1,015,869	2,927,760
Medical reimbursement	6,004,628	6,285,568
Leave encashment	13,138,807	6,453,700
Gratuity	14,002,493	5,136,997
Employer contribution to cpf	4,999,102	4,673,475
Nps contribution	4,857,704	4,207,827
Honorarium	71,500	58,000
Canteen reimbursement	916,800	959,200
Newspaper & periodicals	178,904	115,993
Cea reimbursement	1,407,414	835,697
Membership fees		48,894
Recruitment expenses	109,639	76,119
Transfer TA	57,975	111,036
Telephone reimbursement to staff	103,496	
Total	194,510,340	162,651,947

Schedules forming part of Income & Expenditure A/c for the year ended  $31^{st}$  March, 2020.

### **Centre for Materials for Electronics Technology, Pune. Schedule 12 - Laboratory and Administrative expenses:**

(Schedules forming part of Income & Expenditure A/c for the year ended 31<sup>st</sup> March, 2020)

		(Amount ₹)
Particulars	<b>Current Year</b>	<b>Previous Year</b>
	2019-20	2018-19
Laboratory general expenses	5,105,934	2,176,019
Electricity charges	10,657,733	11,342,886
Water charges	4,720	10,845
Repairs and maintenance:		
On buildings	2,646,701	2,037,751
On electricals	718,571	453,029
On laboratory equipments	1,263,215	1,232,123
On office equipments	600,130	5 745
On furniture & fittings		1.597.686
Rates and taxes	1,815,056	91 201
Postage & telegram charges	65,038	81,301
Telephone, Telex & Fax charges	234,115	359,834
Printing and Stationary	525,606	/64,501
Conveyance	4,477	19,732
Vehicle hire	1,947,503	1,676,664
TA & DA	2,213,448	2,137,702
Security expenses	6,981,326	6,309,570
Office & general expenses	7,815,012	5,057,689
Diesel for Gensets	377,343	288,405
Auditor's remuneration	158,635	149,770
Audit expenses	131,098	59,348
Meeting expenses	1,155,804	759,795
Difference in Thrissur Dev. expenditure	-236,350	
Gardening expenses	492,864	1368,356
Bank charges	42,388	31,094
Advertisement and Publicity	94,822	148,923
Professional & consultancy expenses	140,900	433,150
Prior period Expenses	-	1133,228
Workshop/symposia	1,397,863	300,000
University affiliation fees	-	204,560
Legal expenses	66,207	-
Internet Charges	331,997	-
TOTAL	46,752,156	40,773,543

### **Bifurcation of Grants for the Year 2019-20**

Total Grants received during the year 2019-20				332,500,000.00
Particulars	Date / voucher no.	Plan	Non-plan	Total
Grants received for the year 2019-20				
1. Sanction letter no.2(1)/2019-EMCD dtd. 25.6.2019	2.7.2019 / BRV-32	83,300,000	-	83,300,000
2. Sanction letter no.2(1)/2019-EMCD dtd. 25.6.2019	2.7.19 / BRV-32	16,700,000	-	16,700,000
3. Sanction letter no.2(1)/2019-EMCD dtd. 13.9.2019	30.9.19 / BRV-56	30,000,000		30,000,000
4. Sanction letter no.2(1)/2019-EMCD dtd. 13.9.2019	30.9.19 / BRV-56	20,000,000		20,000,000
5. Sanction letter no.2(1)/2019-EMCD dtd. 13.9.2019	30.9.19 / BRV-56	100,000,000		100,000,000
6. Sanction letter no.2(1)/2019-EMCD dtd. 13.9.2019	30.9.19 / BRV-56	30,000,000		30,000,000
7. Sanction letter no.2(1)/2019-EMCD dtd. 13.9.2019	30.9.19 / BRV-56	20,000,000		20,000,000
8. Sanction letter no.2(1)/2019-EMCD dtd. 26.3.2020	31.3.20/BRV-165	32,500,000	-	32,500,000
Total Grants receipts		332,500,000	-	332,500,000
Expanditure for the year 2010-20				
Capital Expanditure		0 833 464		0 833 464
Capital Expenditure		9,033,404	-	9,055,404
Kevenue Expenditure.		322,000,530	-	322,000,330
	Total	332,500,000	-	332,500,000

(Amount ₹)

Details of project balances as on 31st March 2020

Details of project balances as on 31 <sup>st</sup> March 2020 (Amount									
S. No.		Name of Project	Opening balance as on	Receipts during	Paymen	ts during the year 2	019-20	Closing balance as on	
			1.4.2019	2019-20	Fixed Assets	Other Expenses	Total	31.3.2020	
		1	2	3	4	5	6 = (4+5)	7 = (2+3-6)	
	PUNE:								
1	SP41	UGC-JRF- JM Malli	63,629			242,382	0	63,629	
2	SP45	Devp of LTCC Materials for GPA	564,481	1,687,453		896,699	2,251,934	0	
3	SP46	CSIR-SRF-Ms. Bhirud	36,518			2,074,122	0	36,518	
4	SP47	CSIR-JRF-Mr. Pandit	201,026			1,073,181	0	201,026	
5	SP48	INSPIRE Faculty Award-Dr.Chauhan	95,586			6,847,066	91,100	4,486	
6	SP55	Inspired Faculty Award-D R Patil	641,758		73,812	388,365	636,475	5,283	
7	SP59	Proof of Patternable Thick film	1,286,575	101,113	725,025	234,013	1,252,159	135,529	
8	SP60	Devp. Of Electrolyte systems	105,575	821,625		127,549	907,548	19,652	
9	SP61	FAB of 2D Heterostructures	207,769	200,256		574,970	224,824	183,201	
10	SP62	SERB Young Scientist Dr Khupse	426,559	675,885	142,089	55,120	789,048	313,396	
11	SP63	Flexible Solidstate supercapacitor	-6,661	596,372		116,997	516,341	73,370	
12	SP64	Novel nanost hong perf anode mat	2,741,730	1,400,000	2,264,644	174,700	3,761,588	380,142	
13	SP65	Synth of Nanosized ANI Ceramic	618,023	900,000		480,000	730,539	787,484	
14	SP66	Dev. Of Nanostr Mng Ferrite	156,612	1,238,400			1,387,620	7,392	
15	SP67	Integrated low-cost water sensors	2,230	767,950		2,706,075	740,641	29,539	
16	SP68	3D Nano St. Lithium battery	7,981,446		446,250	191,428	4,627,839	3,353,607	
17	SP69	WOS Nano St. Layered MOS 2	160,246	714,110		132,750	672,677	201,679	
18	SP70	Engg. Of Q Dot based Solar Radiation	541,353	653,668			836,373	358,648	
19	SP71	Inspire Faculty award Dr Nasani	455,561	482,939	220,500		462,882	475,618	
20	SP72	Dev of Nano St. NMC Cathode Mt	1,013,133			448,516	896,699	116,434	
21	SP73	Dev. Of Print Silver ink for RFID	4,825,524	1,336,169	3,780,916	75,034	585,5038	306,655	
22	SP74	Dev. Of Hybrid Battery	4,262,759	1,707,000		234,785	1,073,181	4,896,578	
23	SP75	Centre of Excellence in Battery		33,527,500		1,097,640	6,847,066	26,680,434	
24	SP76	WOS - A-Tin & Germanium Battery		1,127,200		242,382	388,365	738,835	
25	SP77	Digitization & Quantification		1,741,000		896,699	234,013	1,506,987	
26	SP78	Devp. Of Smart Parking Mgt System		816,200		2,074,122	127,549	688,651	

27	SP79	Devp. Of U-SOFC in LTCC Technology		10,305,600		1,073,181	574,970	9,730,630
28	SP80	Design of newAnodes for Biogas		2,244,850		6,847,066	55,120	2,189,730
29	.9 SP81 Studies in Annealing on Mgn			2,247,000		388,365	116,997	2,130,003
30	SP82 WOS - A-Multiferroic Magn Comp 1,711,900		234,013	174,700	1,537,200			
31	SP83	Project for SC /ST Women		6,380,000		127,549	480,000	5,900,000
32	TS12	LTCC Based Circuits Fittings	-11,714			574,970	0	-11,714
33	TS13	LTCC Based Magnectic Sensors	4,180,559			55,120	2,706,075	1,474,484
34	TS15	Devp of Microcrystaliine	619,652			116,997	191,428	428,224
35	TS16	Sealing of Na Ion Battery cells	862,949		405,600	174,700	538,350	324,599
26	SP78	Devp. Of Smart Parking Mgt System		816,200		2,074,122	127,549	688,651
27	SP79	Devp. Of U-SOFC in LTCC Technology		10,305,600		1,073,181	574,970	9,730,630
28	SP80	Design of newAnodes for Biogas		2,244,850		6,847,066	55,120	2,189,730
29	SP81	Studies in Annealing on Mgn		2,247,000		388,365	116,997	2,130,003
30	SP82	WOS - A-Multiferroic Magn Comp		1,711,900		234,013	174,700	1,537,200
31	SP83	Project for SC /ST Women		6,380,000		127,549	480,000	5,900,000
32	TS12	LTCC Based Circuits Fittings	-11,714			574,970	0	-11,714
33	TS13	LTCC Based Magnectic Sensors	4,180,559			55,120	2,706,075	1,474,484
34	TS15	Devp of Microcrystaliine	619,652			116,997	191,428	428,224
35	TS16	Sealing of Na Ion Battery cells	862,949		405,600	174,700	538,350	324,599
36	-	CSIR SRF D Kajale	86			480,000	0	86
37	-	CSIR SRF Y. Sethi	114				0	114
38	-	INSA Sr Sci. Dr. S Kulkarni	31,606	459,994		2,706,075	448,516	4,3084
39	-	Workshop Q Dot Nmat 2019	75,034			191,428	75,034	0
40	-	Workshop Q Dot Glass Nov 2019		243,544		132,750	234,785	8,759
41	-	DST Sub expert com. on Engg & Tech Dev.		1,100,000			1,097,640	2,360
		TOTAL (a)	32,139,718	75,187,728	8,058,836	33,946,278	420,05,114	65,322,332
	HYDERA	BAD:						
42	SP31	GALLIUM-DST	4,856,144	30,000		4,886,144	4,886,144	0
43	SP32	E-WASTE-PCBs-DeitY	18,899,070	7,726,400	11,410,053	9,280,377	20,690,430	5,935,040
44	SP33	DRDO/SSPL/CARS/Cd & Te	-196,694	232,248		223,947	223,947	-188,393
45	SP34	Photosensitizers for visible light -SERB	52,377			52,377	52,377	0
46	SP35	SiC / DMRL	30,125,069	1,700	420,000	26,125,447	26,545,447	3,581,322
47	SP36	CFLs & FLs / DST	324,921	800,000		1,124,921	1,124,921	0

48	SP37	Recycling scrap Germanium DRDO SSPL	269,881	1,199,519		1,489,199	1,489,199	-19,799
49	SP38	Ultra-High Pure Zn BRNS IGCAR	380,464			380,464	380,464	0
50	SP39	NaviC Meity	7,607,084	4,054,000	5,093,302	2,273,671	7,366,973	4,294,111
51	SP40	Design & Fab. MEMS Bionic Sensors	2,396,310		1,347,231	593,651	1,940,882	455,428
52	SP41	Estab. Of COE on E-Waste Management		89,920,000	75,138	2,533,555	2,608,693	87,311,307
53	SP42	Process Optimization & supply of CDC		1,889,000		220,035	220,035	1,668,965
54	SP43	Purification-Hf Metal -Indo-Bulgaria coll. Pjt		591,175			0	591,175
55	TS-01	Supply of Hafnium sponge VSSC	4,424,898	6,487,089		18,139,314	18,139,314	-7,227,327
		TOTAL (b)	69,139,524	112,931,131	18,345,724	67,323,102	85,668,826	96,401,829
	THRISSUR	:						
56	SP45	DST (NR)	-153,814	1,180		28,059	28,059	-180,693
57	SP51	DEITY (NR)	40,435	,		40,435	40,435	,
58	SP53	BRNS (RR)	-26,487	26,487			,	
59	SP54A	DEITY (NCP)	7,897			7,897	7,897	
60	SP54B	DST (NCP)	1,180			1,180	1,180	
61	SP55	BRNS (NR)	12,552	138,528		151,080	151,080	
62	SP56	BRNS (NR)	1,553,631	304,761		1,858,392	1,858,392	
63	SP57	SERB (NR)	64,191			64,191	64,191	
64	SP58	MEITY (KPM)	500,240			881,007	881,007	-380,767
65	SP59	BRNS (SNP)	154,794	636,730		730,376	730,376	61,148
66	SP60	DST (SNP)	-95,797	700,000		457,188	457,188	147,015
67	SP61	DST (AS)	1,566,261	1,566,863	1,765,528	799,424	2,564,952	568,172
68	SP62	ARMREB (AS)	1,833,084	1,048,812	1,598,255	1,237,862	2,836,117	45,779
69	SP63	MEITY (AS)	576,784	2,911,815		2,531,253	2,531,253	957,346
70	SP64	DST (SNP)	3,163,558	128,961	1,903,650	881,111	2,784,761	507,758
71	SP65	DIT (NCP)	21,977,916	14,887,000	3,785,923	7,573,889	11,359,812	25,505,104
72	SP66	CPRI (SEEMA)	4,465,349		3,485,107	1,088,216	4,573,323	-107,974
73	SP67	SERB (T Karthik)		3,575,864	1,284,365	771,248	2,055,613	1,520,251
74	SP68	MEITY (Rama)		15,000,000	146,895	1,628,300	1,775,195	13,224,805
75	SP69	DST (Stanly)		5865,487		758,921	758,921	51,065,66
76	SP70	MEITY (Seema)		8,252,000		1,708,363	1,708,363	6,543,637
77	SP71	MEITY (AS)		6,877,000		1,415,736	1,415,736	5,461,264
78	SP72	SERB (VK)		1,754,533		164,254	164,254	1,590,279

79	TS-31	DEBEL - TR	1,505,910	956,059	80,860	1,685,994	1,766,854	695,115
80	DISHA Ferroelectric Ceramic-Polymer Composite		20,032	542,393		522,635	522,635	39,790
81	JRF/PDF JRF Grant in aid		41,136	314,640		716	716	355,060
82	-	ICSEA 2019	58,197	109,180		5,611	5,611	161,766
		TOTAL (c)	37,267,049	65,598,293	14,050,583	26,993,338	41,043,921	61,821,421
		GRAND TOTAL (a+b+c)	138,546,291	253,717,152	40,455,143	128,262,718	168,717,861	223,545,582

## <u>Statement showing comments of statutory auditors on the accounts of</u> <u>C-MET for the year 2019-20 and C-MET's replies thereto.</u>

Sr.	<b>Brief Subject</b>	Auditor's Comments	C-MET Reply
No			
1.	a. Fixed Assets pertaining to projects:	At present, the fixed assets pertaining to projects are shown in the books as project expenses. As suggested project fixed assets are shown separately in the Balance Sheet. In respect of those assets, which relate to the projects that are completed and the fixed assets which are not likely to be returned to the sponsors, feasibility to dispose off such assets may be assessed.	Actual amount of Fixed Assets procured out of the projects is separately accounted for & indicated in the schedule. Also, individual head- wise expenditure is separately maintained and sent to Sponsoring Agency. In addition, project Fixed Assets register is also maintained. Ownership and title of project fixed assets rests with the project sponsoring agency. Fixed Assets pertaining to completed projects are disposed off as soon as
			sponsoring agency consents their disposal.
	b. Thrissur Centre expenditure	There are few expenses incurred by C-MET Thrissur section for major repairs of Rs.6,06,673/- which was supposed to be capitalised. Whereas the same is books as revenue expenditure on the basis of management representation letter issued by them.	Noted for information.
2.	Statutory Dues:	1. Income Tax Refunds of previous years to be followed up and if not receivable then it should be written off in next financial year.	The matter is being followed up by our internal auditors and accordingly non-recoverable amounts would be written off.
3.	Internal Audit:	Internal audit report of C-MET Thrissur is not submitted to us for verification.	This will be submitted to the auditors.

### Steering and Executive Committee of C-MET (2019-2020) STEERING COMMITTEE

STEERING COMMITTEE		
Dr. V.K. Saraswat Chairman Former secretary, Defence R&D Member Niti Aayog, Room no.113, Niti Aayog building Parliament street, New Delhi - 110 001 Dr. K. Muraleedharan Director, CGCRI, 196, Raja S.C. Mullick Road, Kolkata – 700 032 West Bengal, India	<ul> <li>Shri. Arvind Kumar</li> <li>Group Coordinator (R&amp;D Electronics),</li> <li>Ministry of Electronics &amp; Information Technology</li> <li>Electronics Niketan, 6, CGO Complex,</li> <li>New Delhi - 110 003.</li> <li>Dr. Sandip Chatterjee,</li> <li>Director, Scientist F</li> <li>Ministry of Electronics &amp; Information</li> <li>Technology Electronics Niketan, 6, CGO</li> <li>Complex</li> </ul>	Member Nominee of GC
Shri. Arvind KumarMemberGroup Coordinator (R& D Electronics),Ministry of Electronics & InformationTechnology Electronics Niketan, 6, CGOComplex,New Delhi - 110 003	New Delhi - 110 003 Shri. Roop Kishore Deputy Secretary (Pers.), Personnel Division Ministry of Electronics & Information Technology Electronics Niketan, 6, CGO Complex, New Delhi - 110 003	Nominee of JSGC
Dr. Arun Kumar BhaduriMemberDistinguished Scientist and DirectorIndira Gandhi Centre for Atomic Research(IGCAR) Kalpakkam - 603102,Tamil Nadu	<b>Dr. B. B. Kale</b> Director (A) Centre for Materials for Electronics Technology Panchawati, Off Pashan Road, Pune - 411 008	Member
Shri P. SudhakarMemberOSD to DAE & Former CEO,ECIL ECIL admin. buildingElectronics Corporation of India Ltd(ECIL) Hyderabad - 500 062	<b>Dr. R. Ratheesh</b> Director Centre for Materials for Electronics Technology Hyderabad - 500 051	Member
Prof. (Dr.) Sanjay K. NayakMemberDirector GeneralCentral Institute of Plastics Eng.and Technology (CIPET)Chennai – 600 032	<b>Dr. N. Raghu</b> Director Centre for Materials for Electronics Technology Thrissur - 680 771	Member
Dr. Hemanth DarbariMemberDirector GeneralCentre for Development of Advanced ComputingPune University Campus, GaneshKhind, Pune - 411 008	<b>Dr. R. Prasada Rao</b> Programme Co-ordinator Centre for Materials for Electronics Technology Panchawati, Off Pashan Road, Pune - 411 008	Member
Dr. N. R. Munirathnam Member-Convener Director General Centre for Materials for Electronics Technology Panchawati, Off Pashan Road, Pune - 411 008	Shri G. B. Rao SFO Centre for Materials for Electronics Technology Panchawati, Off Pashan Road, Pune - 411 008	Member
EXECUTIVE COMMITTEE         Smt. Jyoti Arora       Chairman         Additional Secretary & Financial Advisor,       Ministry of Electronics & Information Technology         Electronics Niketan, 6, CGO Complex,       New Delhi-110 003.         Dr. N. R. Munirathnam       Co-Chairman         Director General       Centre for         Materials       for Electronics Technology         Panchawati, Off Pashan Road, Pune - 411 008	<b>Smt. Radha Jaisimha</b> Registrar Centre for Materials for Electronics Technology Panchawati, Off Pashan Road, Pune - 411 008	Member Secretary


Dr. Bharat B. Kale

Director (A), C-MET, Pune



**Dr. R. Ratheesh** Director, C-MET, Hyderabad



**Dr. N. Raghu** Director, C-MET, Thrissur

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