ANNUAL PLAN

2020-2021

OF

CENTRE FOR MATERIALS FOR ELECTRONICS TECHNOLOGY (C-MET)

www.cmet.gov.in

Annual Plan 2020-21

Status of the Project

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 laboratories located at Pune, Hyderabad and Thrissur. C-MET's mission is to develop knowledge base in electronics 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.

Progress accomplished during 2018-2019

During the year 2018-2019, C-MET has implemented several sponsored projects and technical services in the following core programs viz.

- Integrated Electronics Packaging
- Nanomaterials, Thin & Thick films and Nano Composites
- Materials for Renewable Energy
- Ultra High Purity Materials and Compound Semiconductors
- E-Waste management
- NABL accredited RoHS facilities
- Microwave Dielectrics and Multilayer Ceramics
- Actuators and sensors
- Aerogel and Graphene based components / devices
- Plasmonic materials and devices

During the year, 8 projects were completed and 13 new projects were initiated and 19 projects are ongoing. The characterization and allied services were extended to outside organization on chargeable basis, overheads and assorted income from other sources revenue to the tune of Rs. 316.36 lakh was generated.

Summary of Unit wise Technical Progress

i) Pune Laboratory

Developmental activities at C-MET, Pune consist of **Electronics Packaging, Nanomaterials/ Nano composites/Sensors and Materials for Renewable Energy**. The salient features of the progress made during the year 2018-19 are as follows:

a) Electronics Packaging

- Fabricated and Supplied 10 Nos of Magnetic sensors (Mark 2.0) to BARC. Samples have been found acceptable by the end users. All Deliverables have been met and project has been completed successfully.
- Supplied Iteration 2, 3 and 4 samples to SAC, ISRO. Samples of Iteration 2 have been accepted. Samples of Iteration 3 have passed preliminary tests while Iteration 4 require minor improvement at cavity edges.
- First batch of PCR chip sensor tested at IITD for river water monitoring trials.
- Developed Electrolyte baths for binary Sn-Ag and Sn-Cu as well as ternary Sn-Ag-Cu systems for PCB applications. Industrial trials for Sn-Cu baths are in progress.
- Successfully fabricated and tested ReS_2 few layer continuous films. Films are now being supplied to other collaborators (BARC) for device fabrication.

b) Nanomaterials/ Nano composites and Sensors

- Glass nanocomposites for water purification have been prepared.
- Silicon nanoparticles were decorated on MoS_2 nano-sheets for water splitting and for electrode for the batteries.
- Copper sulfide nanoparticles sandwiched in MoS_2 nano-sheets for different applications.
- Developed layered nanostructured vanadium oxide for detection of ammonia with swift response.
- Study on engineering aspects of CO_2 sensor and O_2 sensor have been completed.
- Sulfonated semiconducting polymers and its polymer composites were developed for biological pH and amino acid monitoring. The paper-based pH monitoring colorimetric polymer strips were developed. The distinct color changes were observed with various pH and amino acidic conditions.
- In-Silico analysis of polymer-bio analyte interfaces has been carried out for Glucose monitoring (torsional angle change with analyte-polymer interactions) devices. Based on the theoretical outcomes, the semiconducting polymer and conducting inks were developed for flexible and wearable bio-sensor device fabrication. Optimization in device design and sensing capability is in progress.
- Semiconducting polymer-phytic acid-based polymer gel probe for pressure sensors has been synthesized. The lab made devices have shown the change in resistance (20 kΩ to 90 kΩ) with respect to the stress-strain developed on devices has been monitored for optimization.
- Polythiophene based on-skin flexible and wearable UV light sensors have been fabricated. The preliminary results show that the sensor devices are operating under 1 SUN light intensity (solar simulator) with measurable signal outputs (µA to mA) with respect to input light intensity (0.5 SUN to 1 SUN intensity).
- Silver powder with spherical morphology and particle size around 200-300 nm Specific surface area in the range of 1.63- 2.57 m^2/g and tap density of 1.4-1.5 g/cm^3 @ 50-100 g scale have been prepared.

Silver paste for Photovoltaic cells application with sheet resistance in the range of 4-5 (mΩ/sq) @ 20 g scale was achieved.

- EMI shielding of thick film paste in the range of 30-55 dB was achieved at 9 - 11 GHz frequency
- AlN nanoparticles with size 100 nm were prepared by using transferred arc thermal arc plasma for ISRO.

c) Materials for Renewable Energy and storage

- Prepared different morphology of nanomaterials viz., ZnO, TiO_2, Nb_2O_5 using solvothermal method by varying reaction parameters and used these nanomaterials for Dye Sensitized Solar Cell (DSSC) applications. The efficiencies of fabricated cells were in the range of 6-7%.
- Developed Sn_3O_4 based catalysts for the generation of hydrogen through water splitting and for environmental remediation.
- Hydrogen generation using nano catalyst like ZnO-TiO_2 composite, paper templated Cu@TiO_2 and Cu@ZnO under natural sunlight.
- $CdIn_2S_4$/C3N4 nanocomposite was prepared and used as photocatalyst for hydrogen production under natural sunlight.
- Fabrication of flexible electrodes using commercial LCO and Graphite on carbon cloth and carbon paper for Flexible Li-ion batteries has been initiated.
- SnO_2@C prepared as anode material for Li-ion battery for enhanced capacity.
- Nanoporous MoS_2 has been prepared as anode for Li-ion battery (Capacity: 200 $mAh^{-1}g^{-1}$)
- Layered MoS_2 has been prepared for Na-ion battery. (Capacity: 120 $mAh^{-1}g^{-1}$)
- Nanoporous carbon has been prepared from corn-silk for Na-ion battery.
- Nanoporous N-doped hard carbon has been synthesized for Na-ion battery (Capacity: 162 $mAh^{-1}g^{-1}$).
- LCO and NMC 111 as cathode materials have been synthesized for LIB.
- Battery pack of capacity 2000 mAh using indigenous LCO and LTO materials was made for mobile phone applications.
- V_2O_5 doped Carbon aerogel was prepared for flexible supercapacitor. Materials provided to VNIT, Nagpur for further evaluation.

ii) Hyderabad Laboratory

Developmental activities at C-MET, Hyderabad consist of **Ultra Pure & Special Materials (Metals, Alloys and Refractory Materials), Compound Semiconductors, MEMS based acoustic sensors, flexible electronics, E-waste and RoHS compliance.** The salient features of the progress made during the year 2018-19 are as follows:

a) Ultra-Pure & Special Materials (Metals, Alloys and Refractory Materials)

- 3.0 kg of UHP Tellurium & 5.3 kg of UHP Cadmium with 60 mm dia ingots were prepared, tested at NRC, Canada and delivered to SSPL/DRDO.

- One metre long Germanium (1 kg wt.) ingot was prepared for purification by inductive zone refining.
- Installation & commissioning of high vacuum unit completed successfully for zinc purification.
- Installation & commissioning of metal granulation system completed successfully for the conversion of Zinc ingot into granules.
- Vacuum distillation experiments @ 4 kg batch size with 50% yield (2 kg, 5N Zn) was carried out.
- Zone refining experiments of distilled Zinc was carried out and 1 kg of 7N pure Zn has been prepared.
- Converted 7N pure Zinc ingot into granules of <3 mm diameter.
- 20 kg of Hf sponge delivered to VSSC and received Rs. 49.00 lakhs of revenue.
- 122 kg of Hf oxide was prepared and more than 100 kL sodium nitrate effluent and other effluents were disposed off.
- Nearly 110 kg of Hf briquette and 78 kg of Hf tetra chloride were prepared. Two batches of Kroll reduction and vacuum distillations were conducted and 46 kg of reduced mass and 28 kg of Hf sponge were prepared.
- Hf yield improvement from 28-35% accomplished by recycling of residual coked briquette and Hf chloride.

b) Compound Semiconductors

- Process parameters for growing SiC single crystal boules were optimized using Design of Experiments (DoE).
- Characterization results at SSPL / DMRL revealed that grown SiC boule for experiment no-6 (DoE) is found to be of deliverable quality.
- 08 Nos. of 6H SiC single crystal bowls were grown as per DoE-6 process parameters for getting higher thickness.
- Targeted diameter (2 inch), polytypes area (100% against > 60%) by UV fluorescence characterization, Micropipe density (~20 cm^{-2} against ≤ 100 cm^{-2}) and FWHM (~ 50 arc-sec against ≤ 50 arc-sec) have been achieved.
- Clean room facility of Class 100000 is established and the same was inaugurated on 29th March 2019 jointly by Dr. Vikas Kumar, Director, DMRL and Dr. Seema Vinayak, Director, SSPL.

c) E-Waste management

- A demonstration plant for processing of 100 Kg PCB /day is established within 800 Sqm built up area.
- Installed and commissioned indigenously developed smelting furnace (FFRTF) and conducted seven demonstration trials. Processed nearly 115 kg of calcined PCBs and obtained 19.0 kg of Black copper.

- Scaled up electro-refining facility from 1 kg/day capacity to 5 kg/day capacity. Augmented DC rectifier to 500A, fabricated 0.6 KL of electrolytic tank and erected overhead circulation tank for electro refining of black copper.
- Gases evolved during clacination of PCBs like furans, dioxins, SOx, NOx, CO, CO_2 etc. have been analyzed at Vimta Labs, and found that all the pollutants are within the limits prescribed by CPCB.
- Established a wet chemical lab for sample preparation for the recovery of precious metals.
- Established 20 Litre volume of chemical reactor for anode mud processing.
- 54 kg of cathode copper, 24 g of gold and 40 g of silver have been processed.
- Pre-dispatch inspection conducted for TBRF at Italimpianti Orafi, Italy.
- Organized a National Workshop on E-Waste recycling and arranged expert lectures.

d) Re-cycling of Rare-earth from waste CFLs

- Acid leaching experimental set-up was up-graded from 0.5 kg batch to 1 kg batch level and prepared 0.6 kg of mixed rare earth oxides.
- Solvent extraction experiments using DEPHA was conducted on 50 kg per batch of mixed rare earth oxides for separating individual rare earth oxides.

e) NABL accredited facilities

- Around 1500 number of samples were analyzed during the year.
- Rs. ~24.52 lakhs revenue was generated from RoHS test facilities.

iii) Thrissur Laboratory

Developmental activities at C-MET, Thrissur consist of Microwave Dielectrics, Multilayer Ceramics, Actuators and Sensors, Nanomaterials & Thin films and Aerogel and graphene based supercapacitors. The salient features of the progress made during the year 2018-2019 are as follows:

a) Microwave Dielectrics & Packaging

- Prepared phase pure MD filler (Substituted analogues of CoZ type hexaferrite). Composite MD substrate and the antenna fabricated using the substrate showed miniaturization of 35% and bandwidth enhancement of 4%.
- Prepared phase pure Y-type hexaferrite (CoY) magneto-dielectric fillers. Antenna fabricated on MD composite substrate showed miniaturization of 30% and bandwidth enhancement of 4%.
- Developed polymer/ceramic composites based on PMN-PT and CCTO for embedded capacitor applications.

b) Actuators and Sensors

- The technology for thermal sensor based wearable device and an analysis system for the

early detection and screening of breast cancer was transferred to M/s Murata Business Engineering India Private Limited, Hyderabad, (ToT fee of Rs. 10.87 Lakhs + Taxes) on 22.01.2019 at C-MET, Thrissur.

- Developed Nano NTC compositions for low temperature applications (-100 ^{0}C to +50 ^{0}C)
- Developed submillimeter sized chip thermistors for weather balloon applications
- Influence of ST seed particle prepared using MSS were studied and the piezoelectric properties were evaluated.
- Optimized tape casting process with the addition of seed particles and alignment of <001> templates in PMN-PT matrix through tape casting process.

c) Aerogel, Graphene based Supercapacitors & other Energy materials

- Designed and fabricated a set of indigenous machines for fabrication of Aerogel supercapacitors (AGSC) of 0.47-50 F and demonstrated the process of making AGSC of 10F & 25F. AGSC thus fabricated were tested by several end users including IIT (Bombay), NAL (Bangalore), ECIL (Hyderabad), etc. and confirmed its electrical performances.
- Set-up a new facility of dehumidified clean room of Class 10,000 & RH<15% for sealing Aerogel supercapacitors under low humidity conditions.
- Fabricated 15 nos. of 300F aerogel supercapacitor packs of 350F (AGSC packs) and delivered to ECIL for conducting preliminary trials in VVPAT of EVM.
- Upscaled the preparation of aerogel carbon (AGC) in 2 kg/batch by adopting a new and cost-effective technique. Evaluated the physical properties of the AGC, thus produced and found suitable for use as supercapacitor electrodes. Around 250 nos. of Supercapacitors of values 5F, 15F, 25F & 35F were fabricated and delivered to IIT-Bombay for further testing and utilization in making Supercapacitor powerpacks.
- Developed Coin cell graphene supercapacitors having capacitance of 0.1F for electronic time fuse application for ARDE. Coin cell graphene supercapacitors with capacitance up to 0.8F have been developed.
- Developed graphene supercapacitors (<50F) having ESR as low as 40 mohm.

d) Plasmonic Materials and Devices

- Developed new and cost effective materials based on transparent conducting oxide thin films for plasmonic applications in near IR region. The films exhibited required carrier density (>10^{21}/cc) in the near Infra-red region.
- Developed titanium nitride films with carrier density (10^{22}/cc) for plasmonic applications in visible region.
- Initiated new project to develop plasmonic based portable biosensor to detect causative agents for food poison in collaboration with Rajiv Gandhi Centre for Biotechnology (RGCB), Govt of India, Thiruvananthapuram.

Research Performance Indicators during 2018-19

S.No	Activity	Total (actual)
1.	Research publications in peer-reviewed journals	62
2.	Conference presentations	21
3.	Invited talks	76
4.	Awards and Honors	15
5.	Patents awarded	03
6.	Patents Applied	01
7.	Fellowships/visits (Abroad)	05
8.	International/ National conferences organized (Workshop)	02
9.	Books / Book Chapters	02
10.	Technologies ready for transfer	02
11.	Technology transferred	02

Likely Expenditure for 2019-20

S.No.	Head of Accounts	2019-20 (Rs. in lakhs)	
		Budgetary Estimates	Tentative Sanction
1.	Grant-in-aid (Salaries)	2010.00	1900.00
2.	Grant-in-aid (Capital Assets)	1740.00	600.00
3.	Grant-in-aid (General/Revenue)	700.00	500.00
	Total	4450.00	3000.00
Budgetary support		4450.00	3000.00

S.No.	Description	Targets for 2019-20 (Rs. in lakhs)
1.	IR	425.00
2.	EBR	2700.00
Total		3125.00

Projects planned for 2020-2021

C-MET will continue its program on development of advanced electronic materials and technology through intra-inter laboratory research integration. Based on their importance and role in the future electronics technology vis-à-vis C-MET's capability to execute them and produce the desired end-results, it is proposed to implement programs viz.

1. Integrated Electronics Packaging.

2. Nanomaterials, Thick films and Nano Composites.
3. Materials for Renewable Energy and Sensors.
4. Ultra High Purity Materials and Compound Semiconductors.
5. E-Waste management.
6. NABL accredited RoHS facilities.
7. Microwave Dielectrics and Multilayer Ceramics
8. Actuators and sensors
9. Aerogel and Graphene based Supercapacitors
10. Plasmonic materials and devices

C-MET has prepared plan to execute the projects during 2020-2021 are given below.

C-MET, Pune

It is proposed to initiate/continue the development work on:

- Development of PCR, fluidic and electronic substrate in LTCC for river water monitoring
- Development of Micro Solid Oxide Fuel Cells (µ-SOFC) in Low Temperature Co-fired Ceramic (LTCC) Technology.
- Development of low cost LTCC based optoelectronic packages using 3-D printing Technology for optical packaging applications.
- Development of LTCC based micro coolers for Electronic cooling applications
- Submission of Phase-2 project on CVD of 2D materials
- Digitalization of in-house developed NOx sensors.
- Development of radiation shielding materials based on metal/polymer nanocomposites.
- Development of Sensors required for smart parking.
- Synthesis of novel heterostructures of anionic and cationic poly-electrolyte and polymer composites for bio medical sensing applications
- Development of polymer, metal oxide and its composite based additive manufacturing for 3D printing technology: Application in bio-sensing and energy storage devices
- Development of electrolyte (bio analyte) gated thin film transistor (TFT) based signal amplifiers for biomedical diagnosis.
- Development of materials and sensors including RFID for smart applications.
- Screen printable conductive/resistive/dielectric inks for flexible and stretchable substrates.
- Q-dot glass with band gap from UV to IR will be designed for water purification.
- Optimization of solid polymer/ionic liquids electrolyte for flexible battery
- NMC 811 and LFP as cathode materials for LIB and cylindical 18650 type fabrication facility
- Flexible supercapacitor prototype
- Fabrication of Na-ion cell using Tin oxide half cell and Na-ion cell full cell

- Fabrication of Li-air battery half cell using Pt catalyst
- Fabrication and design of Reserve battery with BEL
- Optimization of process parameters for flexible full cell using liquid electrolyte
- Fabrication of Power pack battery for mobile cell using indigenous LCO and Graphite materials
- Preparation of Organic LED materials
- Recovery of active materials from spent Li-Ion battery
- Implementation of Centre of Excellence in Rechargeable Battery.
- Thermoelectric cooling device using Bi_2Te_3
- AlN thin film sensors for UV detection

C-MET, Hyderabad

It is proposed to initiate/continue the developmental work on:

- Development of technology for recovery of Lithium from spent Li-ion batteries
- Six inch Semi Insulating (SI) SiC Single Crystals Processing Technology
- Continuous Preparation of Hf sponge at pilot plant scale and fine-tuning of process parameters
- Development of beta gallium oxide single crystals substrates for LED applications
- Development of ultra-high pure silicon carbide (SiC) powder for single crystal growth.
- Recovery of metals from waste solar PV modules
- Development of ZnTe single crystals for Terahertz applications
- Development of Fe-Al-Si flaky powders for microwave absorber applications
- Development of antennas for NaViC system
- Augmentation and setting up of 1 T/day E-waste processing facility with PSU
- Development of rare earth free permanent magnetic materials
- Development of HfO_2 doped gate oxide materials
- Edge defined Sapphire single crystal growth for LED applications
- Development of Carbide derived Carbon for Energy Storage Applications
- Development of MEMS bionic sensors
- Development of Si_3N_4 based high speed RADOMES

C-MET, Thrissur

It is proposed to initiate/continue the developmental work on.

- Development of Supercapacitor based power module (SCPM) for application in EVM-VVPAT
- Development of Aerogel supercapacitor bank for application in electric vehicles

- Dev. of high energy density Li-ion hybrid capacitors with graphite/carbon aerogel electrodes through safe pre-lithiation method
- Development of Polybutadiene/ ceramic composite laminates and Substrate Integrated Waveguides (SIW) for microwave and millimetre wave circuit applications
- Training of Industrial people and support for commercialization of thermal sensor based monitoring system for the early detection and screening of breast cancer
- Automated production process for wireless thermography wearable device and multicentric clinical trials for early detection and mass screening of breast cancer.
- Technical Service : Supply of thermal sensors and calibration of sensors
- Development of Nano NTC composition based sub- millimeter sized thermal sensors for low temperature applications
- Development of Thermal Tomography for the Detection of breast cancer and to predict the Size and Location of the Cancerous Tissue
- High capacitance (50F to 200F) graphene supercapacitors for storage of power from Renewable energy sources
- Development of supercapacitor bank for electronic time fuse application
- Graphene Supercapacitor Modules for Long Life and High Power UPS/Solar Inverters
- ToT of digital Thermometer and graphene supercapacitors
- Development of polymer/ceramic composites with high dielectric constant for embedded capacitor applications
- Development of transparent conducting oxide based plasmonic materials and devices
- Development of TCO based portable biosensor with reusable TCO based chips to detect virions of chikungunya and dengue in blood
- Development of lead free based piezoactuators
- Development and supply of piezo-micro actuator
- Development of 2D transition metal carbide materials for energy storage/electronics applications
- Development of ceramic dielectric thin film capacitor for HEV applications
- Piezo MEMS Energy harvester
- Development of ultrasound probe for medical imaging

Budget Estimates, Budget sanctioned & Actual Expenditure for 2018-19, Budget & Revised Estimates for 2019-20 and Proposed Estimates for 2020-21							
							(Rs. in lakhs)
S. No.	**Head of Accounts**	**2018-2019**		**2019- 2020**			**2020- 2021**
		Budget Estimates	**Actual Expenditure**	**Budget Estimates**	**BE approved by MeitY**	**Actual Expenditure** (as on 30-11-2019)	**Proposed Estimates**
1.	Grant-in-aid (Salaries)	1710.00	1538.59	2010.00	1900.00	1207.62	2310.00
2.	Grant-in-aid (Capital Assets)	1590.00	570.26	1740.00	600.00	268.25	2090.00
3.	Grant-in-aid (General/ Revenue)	670.00	419.83	700.00	500.00	335.39	600.00
	Total	3970.00	2528.68	4450.00	3000.00	1811.26	
Budgetary support		3970.00	2471.00	4450.00	3000.00	3000.00	5000.00

						(Rs. in lakhs)
S. No.	**Description**	**Targets for**				
		2018-2019		**2019-2020**		**2020-2021**
		Target	**Actual**	**Target**	**Actual** (As on 31-12-2019)	
1.	**IR**	360.00	316.36	425.00	470.08	450.00
2.	**EBR**	2400.00	1292.20	2700.00	2414.31	2950.00
Total		2700.00	1608.56	3125.00	2884.31	3400.00

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