ARCI

ANNUAL REPORT 2017-18

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ARCI

ARCI is an Autonomous R&D Centre of Department of Science and Technology (DST), Government of India, set-up with a mission to develop unique, novel and techno-commercially viable technologies in the area of advanced materials and subsequently transfer them to industries.

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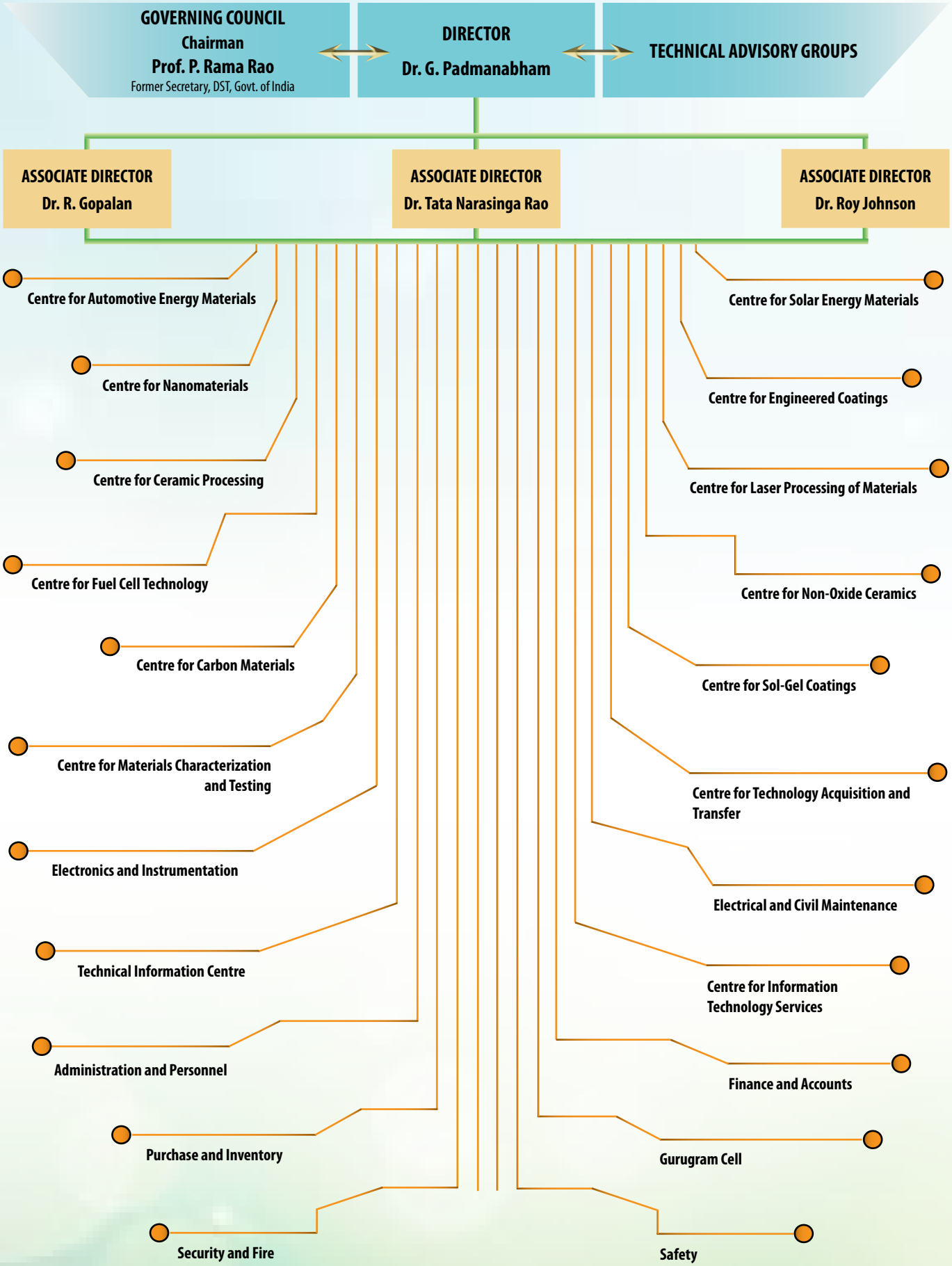
ORGANIZATIONAL STRUCTURE



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(as on March 31, 2018)

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Director's Report

I am glad to present the performance report of ARCI for the year 2017-18. Development of advanced materials, processes and systems to meet application requirements and directed basic research on topics of future relevance has been diligently continued during the year. Interaction with several industrial organizations and collaboration with other R&D and academic institutions have been intensified.

Substantial progress could be achieved under the DST sponsored Technical Research Centre on "Alternative Materials and Systems" with contributions from four divisions of ARCI. Lithium Ion Battery module were successfully on-road tested for e-cycle and e-scooter application. Fe-P based soft magnetic and Sr-Fe-O hexaferrite hard magnet material technologies moved to next stage of motor and alternator applications with successful prototype demonstration with the help of industry partner. Concerted effort in the areas of solar PV and solar thermal energy generation showed positive results. An efficiency of 16 % has been achieved in lab-scale perovskite solar cells (PSC) and 50mm x 50mm prototype module with power output of 70 mW. Solar absorber tubes with > 95% abs and 0.16 emittance was successfully developed by simple methods and field tested for medium temperature concentrated solar power (CSP) application. Self-cleaning coatings for dust mitigation in previously installed PV panels were field tested. In the fuel cell technology area, focus continued on R&D activities from the perspective of durability, cost, accelerated stress test and other related characterisation towards outreach and industrial acceptance. Continuous operation of 5 kW system for 24 hrs was demonstrated for stationary application. With improved catalysts and components , a 1.5 Nm^3 hydrogen generator has been developed.

Development of novel materials for different functionalities and strategic applications has been notable. First of them being smart carbon based TiO_2 nanostructured materials for visible light active self-clean textiles and paints which are suitable for indoor and outdoor applications. Lead-free copper alloys were developed for bimetallic bearing applications and successfully pilot produced at user company's facilities. Further modification in process was effected for improving the silica aerogel sheet products for thermal insulation applications leading to better industrial acceptance. The lab-scale process for synthesis of 2D transition metal sulphides has been upscaled to 2kg batch quantities. Oxide dispersion strengthened reduced ferritic martensitic steel powder were successfully supplied for conversion into plates use in fusion reactors.

Surface engineering and coating technologies are the areas in which the Centre continues to maintain its leadership through application development and equipment design & development. Cathodic Arc PVD technology could be successfully demonstrated for erosion resistance coatings on compressor blades in helicopter engines, solar selective absorber coatings and life enhancement of minting dies. New advanced lanthanum cerate coatings were shown to have enhanced performance of thermal barrier coatings against volcanic ash deposit resistance required for critical aeroengine applications. Pulsed electrodeposition technology was successfully used to develop Ni-W coatings to replace environmentally hazardous hard chrome coatings and industrial applications are under trials jointly with industrial partner. Equipment development also made good progress. Microarc oxidation coating systems were designed for academic research purposes. Advanced detonation coating system and the cold spray coating systems were further improved and data generated towards acceptance by the industry for commercialization. On the wet chemical Sol-Gel nanocomposite coatings front, hexavalent chrome-free, self-healing, corrosion protection coatings was a focus. Developed coatings have been successfully demonstrated on aluminum alloys 2024-T3, 6061-T6 and 70 75-T6. Durable ultra-hydrophobic surfaces could be generated using a combination of surface texturing and sol-gel coatings useful for antibacterial applications as well as for corrosion protection.

Ceramic processing group was successful in extending its capabilities in its thrust areas such as transparent ceramics and ceramic shaping technologies. Mid wave IR transparent Zinc Sulphide dome technology has been successfully transferred to industry for production. Magnesium aluminate spinel domes were also developed. Shaping capabilities were used to design and fabricate ceramic holders with grooved channels for energy efficient sanitary pad incinerators. The incinerators developed in collaboration with industry and National Environmental Engineering Research Institute (NEERI) has been field demonstrated. Similarly, porous zirconia thermally insulating sleeves were developed for reactor applications. Several specialized prototype developments were attempted using non-oxide ceramics such as SiC based

thrust bearing parts and channels for high temperature kiln furniture. Feasibility studies on 3-D printing of traditional and advanced ceramics based on extrusion shaping expertise at the Centre is also in progress.

On the advanced manufacturing side, main focus was on adopting metal additive manufacturing using selective laser melting. Stainless steel and nickel-based alloys were used to build parts and tools with special features like conformal cooling channels, metallic bipolar plates with external and internal flow fields for fuel cell stacks, nozzle guide vanes of gas turbines with cooling holes etc. Hybrid approaches such as additively building features on a wrought blank in similar and dissimilar material combinations was attempted. Laser micromachining was successfully adopted to fabricate control and shield grids for microwave generators and micro surface texturing carried out for attaining superhydrophobic surfaces. Surface texturing work progressed towards processing of actual components like thrust bearings and piston rings. Laser-arc hybrid welding has been demonstrated for single-pass welding of tube-fin high thickness joints for boiler applications. Repair and refurbishment of expensive components was continued with laser cladding technique successfully applied to a high strength steel component used in helicopter fan assembly. Surface hardening using lasers has been innovatively adopted to small and thin bearing components and low hardenable steel sheets used in automotive sector.

Ability to comprehensively characterize the materials synthesized or processed is a vital part for successful development and transfer of technologies or solutions. The Centre's capabilities in the areas of materials characterization and testing is enhanced by the partnership in setting up the national facility for 3D atom probe. An FE-SEM with EDS and EBSD units has been installed. The newly nanomechanical charcterisation work resulted in some exciting insights into the behavior of different coatings.

Activities related to IPR and marketing of technologies and capabilities have been intensively pursued. Apart from securing patents, patent analysis has been used to provide inputs for R & D planning, patent filing, publications / technical discussions. Outreach efforts include participation in 5 exhibitions, delivering invited lectures in appropriate fora and publishing articles in the media. In order to understand industry needs and evaluate their realisability vis-a-vis centre's capabilities in areas such as coatings, micromachining and additive manufacturing, working groups on aerospace, biomedical and sensor technology sectors have been constituted. Costing methodologies have been further refined through more than 50 projects/technologies costed this year.

Infrastructure has been enhanced towards alternative energy generation and energy saving measures. Roof top solar photovoltaic system for 90 kWp has been installed. An electro luminescence (EL) testing facility for solar modules has been established as part of quality assurance plan. A light sensitive inverter circuit for automatic switching of garden lights has been developed on a pilot scale as an energy saving measure. Efforts have been made to maintain the campus as green as possible by working on appropriate effluent treatment methods, afforestation and air quality monitoring.

Overall, the centre has successfully fulfilled its mandate in terms of technology transfers, product development and supplies, publications and patents, attracting external research funding from government and industry, academic collaborations and human resource development as indicated by the figures given in the table below. A conscious effort has been made to align the activities with the national missions like Make in India, Swastha Bharat and Swatch Bharat. The outcomes are listed in the next sections. In fact, the visiting Parliamentary Standing Committee on Science & Technology and Earth Sciences appreciated the Centre's efforts and advised to increase the outreach so that larger number of people can benefit from the technologies and products developed.

All the above mentioned has been possible due to dedicated efforts of all the scientists, technical and administrative staff at all levels and I am very thankful to one and all for their hard work and contributions to "our ARCI".

Performance Indicators

Parameters	***2017-18***
Papers in Refereed Journals	*135*
Chapters in Books	*16*
Papers in Conferences and Invited Lectures	*160*
No. of Ph.Ds. Produced	*5*
*Foreign Patent Applications (inventions awaiting grant)***	*6*
*Foreign Patents Granted***	*15#*
*Indian Patent Applications (awaiting grant)***	*72*
*Indian Patents Granted***	*38*

Parameters	***2017-18***
No. of Technologies/Designs and Other IP Commercialized	*18*
Number of Technology Leads Awaiting Transfer	*23*
Research Manpower Trained (other than PhDs)	*21*
Technical Manpower Trained	*96*
B. Tech/UG Projects Guided	*67*
M. Tech./M. Sc./M. Phil Projects Guided	*25*

*** Cumulative figures up to end of Financial Year*
 # includes same inventions granted in multiple countries

(G. Padmanabham)

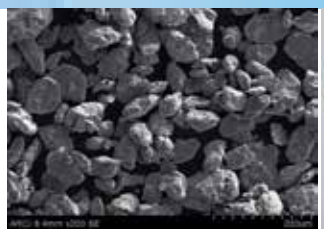
Contribution Towards National Missions

Make in India

- Oxide dispersion strengthened 9Cr reduced activation ferritic martensitic steel powders for subsequent conversion as backup plates in fusion reactors.
- Control and shield grids for microwave generators by ultrafast laser micromachining.
- Porous zirconia thermally insulating sleeves combined with good mechanical properties for reactor application.
- 30 kVA Micro Arc Oxidation coating systems with advanced safety features, ease of operation and ergonomics for academic research.
- Mid-wave IR transparent ceramic domes for strategic applications.

Electric Mobility

- Lithium Ion Battery modules of 48V, 720 Wh and 48V, 850 Wh capacity developed and used for on-road demonstration of e-cycle and e-scooter. The e-cycle has exhibited an on-road mileage of 25-30 km/charge with an average speed 25 km/h and the e-scooter has given a mileage of 55-60 km/charge with an average speed of 28 km/h.
- Indigenous Lithium Iron Phosphate (LFP) and Li-NMC cathode materials for fabrication of prismatic Lithium Ion Battery. The batteries showed good capacity retention.
- High performance porous carbon materials using bio-waste like jute stick and cotton fabric synthesised by a simple chemical activation process. The carbon materials exhibited excellent supercapacitor performance.
- Fe-P based soft magnetic alloys developed and demonstrated for automotive and EV applications. Hard ferrites with improved performance for automotive motor applications.

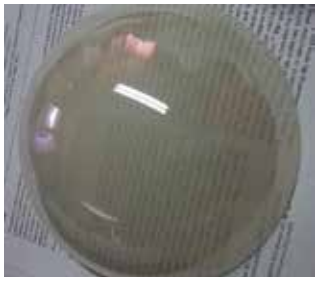


SEM image of as-milled ODS RAFM-9Cr steel powder

Control grid for pulsed microwave source fabricated using ultrafast laser

Porous zirconia thermally insulating sleeves

Exclusively designed and custom built 30 kVA MAO control system



MWIR transparent ceramic dome

850 Wh LIB Module

e-cycle

e-scooter

LFP-LTO pouch cell fabricated using indigenously developed materials

LIB device using indigenous carbon coated $LiFePO_4$

Development of Indigenous carbon materials using bio-wastes

Prototype claw pole alternator and claw pole rotor developed using soft magnetic material

Alternative Energy

- Super hydrophobic coatings with high transmittance for easy-to-clean property on solar PV panels.
- Prototype absorber tube for low and medium temperature solar thermal application.
- Demonstration of supercapacitor powered E-Bicycle with a driving range of 2 Km.
- With improved catalysts and components, a 1.5 Nm^3 hydrogen generator has been developed.
- Continuous 24 hour operation of 5 kW PEM Fuel cell for stationary application.
- Thermoelectric generator test rig for waste heat recovery for demonstration to automotive industry.

Environment Protection

- Energy efficient sanitary pad incinerators developed in collaboration with an industry and National Environmental Engineering Research Institute (NEERI) and field demonstrated. Product to be launched in market as "GreenDispo".
- Lead-free copper alloys used in internal combustion engine parts. Pilot production carried out by user industry.
- Novel pulsed electro deposition (PED) of nickel-tungsten alloy coatings. Know-how demonstration and transfer as replacement to environmentally hazardous hard chrome coatings.

Shape of water droplets on coated and uncoated PV panels

Solar selective absorber coatings on 4 m prototype receiver tubes

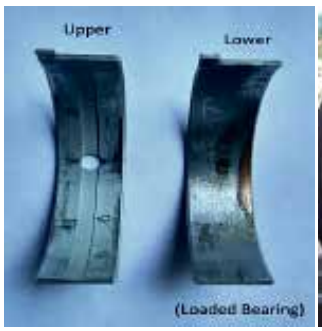
Supercapacitor powered E-bicycle

ECMR electrolyser system

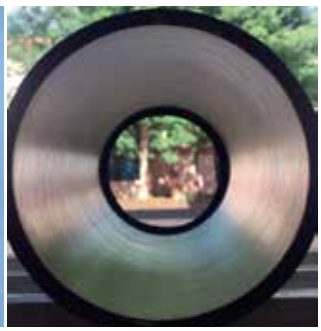
Prototypes of PEMFC system

Thermoelectric generator test rig

Energy efficient sanitary napkin incinerator



Half bearing made from lead-free copper alloy bimetal strip



PED coating inside engine cylinder liner

Research and Technology Highlights

Centre for Automotive Energy Materials

The Centre for Automotive Energy Materials (CAEM) located at Indian Institute of Technology Madras Research Park, Chennai. The primary objective of the Centre is to develop and demonstrate materials and components processing technology to Indian automotive industries as well as provide technical supports to their potential problems. The Centre has three main activities (i) development of materials and engineering the process technology of lithium-ion battery (LIB) for electric vehicle (EV) application, (ii) development of soft and hard magnetic materials for motors and alternators in automotive application and (iii) development of thermoelectric device for waste heat recovery in particular on automobile exhaust heat conversion into power

The major breakthrough in the LIB activity during the year was the development of LIB modules of 48V, 720 Wh and 48V, 850 Wh, and their on-road demonstration with e-cycle and e-scooter, respectively. The e-cycle has exhibited an on-road mileage of 25-30 km/charge with an average speed 25 km/h and the e-scooter has given a mileage of 55-60 km/charge with an average speed 28 km/h. In the magnetic materials program, the Fe-P based soft magnetic material and Sr-Fe-O hexaferrite hard magnet technologies have drawn a huge interest from a number of industries. Claw pole alternators and motors are some of the applications for which the magnet prototypes have been made. Industries after the in house tests on prototypes are seeking for more prototypes for performance evaluation before considering technology transfer. In the area of thermoelectric materials, a 300 W automotive exhaust thermoelectric generator (AETEG) has been fabricated and tested using an in-house developed test rig, simulating the typical 1.2 L diesel engine exhaust temperature, flow and pressure.

The above major activities are being executed currently through Technology Research Centre (TRC) project on Alternative Energy Materials and Systems from the Department of Science and Technology, where translation of these research results into technology and products are the main focus. In addition to the above, two more new activities have also been initiated under TRC project for the futuristic materials technology purpose, viz. Sodium-ion batteries for energy storage application and magneto caloric materials for room temperature magnetic refrigeration. During the last one year, the Centre has established additional facilities such as online thickness measurement system and particle size analyzer to support the ongoing programs.

Products Developed

720 Wh LIB Module

850 Wh LIB Module

Claw Pole Rotor

Magnets

TEG Test Rig

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Lithium-Ion Battery Modules for Electric Two-Wheelers

Electric vehicles will play a significant role in the reduction of greenhouse gas emitted by internal combustion engines, which is a major concern for global warming. In recent years lithium-ion batteries (LIBs) have been used widely in the hybrid electric vehicles, plug-in hybrid electric vehicles, and full electric vehicles (EVs). EV application requires LIBs with high energy and power density, excellent cyclic stability and cycle life. Moreover, safety of LIB is of utmost importance to cater its widespread use in EVs. After the recent announcement of the Government of India for switching of internal combustion engine vehicles to electric vehicles by 2030, there is a major requirement of LIB, which is one of the highest cost components in electric vehicle. There are a few electric two- and four-vehicles available in the market, which uses imported LIB pack. Currently there is no LIB manufacturer in India, and a cost reduction of about 20% is expected. In this context, the Centre has set-up a LIB pilot plant facility for fabrication of large format lithium-ion cells and testing facility. At CAEM, efforts are currently aimed to develop LIB module for e-cycle and e-scooter application. We have developed cylindrical and prismatic types of lithium ion cells ranging from 2-20 Ah using lithium iron phosphate (LFP) and graphite electrodes. Prismatic cells of 15 Ah and 18 Ah have been fabricated and their performance was evaluated (Fig. 1a). At 1C charge/discharge rate, the cells exhibited a capacity retention of > 80% after 1000 cycles with a Coulombic efficiency of about 99% (Fig. 1b). LIB module of 48V, 720 Wh and 48V, 850 Wh have been assembled using 15 and 18 Ah cells, respectively (Fig. 1c). The charge/discharge performances were carried out under static condition, and both the modules showed a capacity retention of >99% after 100 cycles. On-road demonstration of e-cycle has been carried out using the 720 Wh module, which gave a mileage of 25-30 km/charge with an average speed 25 km/h. In addition, the 850 Wh module was used for the on-road demonstration of e-scooter (Fig. 1d). It has exhibited a mileage of 60 km/charge with an average speed of 28 km/h (Table 1). Efforts are currently underway to improve the capacity retention at the cell level to >85% at 1C rate over 1500 cycles.

Table 1. Performance of e-cycle and e-scooter with ARCI LIB module

E-cycle Drive Tests (720 Wh module)	**Lab testing**	**On-road**	**Commercial e-cycle**
Mileage (km/per charge)	35-40	25-30	25
Top speed (km/h)	-	25	25
Current @ Top speed (A)	1.2	6	-
Current @ Average speed (A)	0.8	~2	-
E-scooter Drive Tests (850 Wh module)	**Lab testing**	**On-road**	**Commercial e-bike**
Mileage (km/per charge)	60-70	55-60	65
Top speed (km/h)	-	30	25
Current @ Top speed (A)	2	14	-
Current @ Average speed (A)	1	6	-

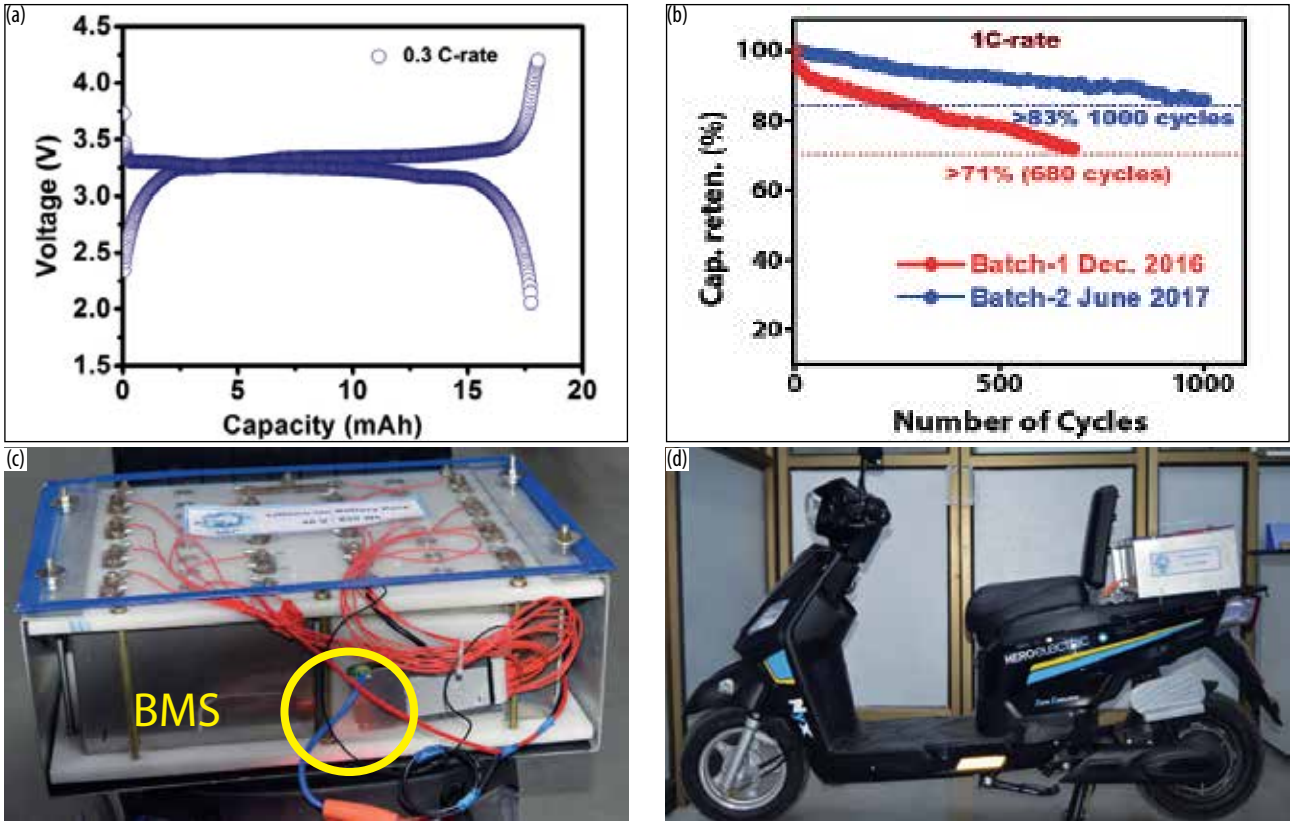


Fig. 1 (a) 3.2V, 18 Ah Li-ion prismatic cell and its charge/discharge characteristics at 0.3 C-rate (b) Cyclic performance of 18 Ah cell (c) 850 Wh battery pack with battery management system (BMS) (d) Demonstration of e-scooter with 850 Wh battery pack.

Development of Prototype Alternator for Demonstrating Fe-P Soft Magnetic Material Technology

A new type of soft magnet is being developed as a potential alternate to commercial Si steel. The new Fe-P alloy exhibits a high magnetic induction (>1.9 T) coupled with good electrical resistivity (>35 μΩ cm). The achieved properties are attributed to the engineered microstructure obtained by a two-step heat treatment process leading to the formation of Fe_3P nano-precipitates dispersed in α-Fe matrix. These ferromagnetic nano precipitates are exchange coupled with matrix phase yielding high induction without hindering the domain wall motion and at the same time acting as grain boundary scattering centres for enhancing the electrical resistivity. Such a good combination of physical properties makes them ideal candidates for application in motors and alternators, which are extensively used in automotive sector. A Memorandum of Understanding has been signed with and industry as per which ARCI shall provide the newly developed alloys and the industry shall develop the prototypes and test the performance. The first set of prototype alternator (prototype 1) was developed and the performance was evaluated. Based on the results, suitable analysis was carried out and necessity for increasing the magnetic induction was realized. A second batch of the alloys with slight chemistry modification to enhance the magnetic induction was undertaken. The second batch of the prototype alternator was manufactured using the modified alloy and the performance of the alternator was found to be better than the commercial standard alternator (Fig. 2). Currently more prototypes (~10 nos.) are being developed to check the repeatability and consistency of the alternator performance with the new material.

Development of a 300W Automotive Exhaust Thermoelectric Generator and its Performance Evaluation in In-house Built Test Rig

Among the major contributor to the greenhouse gas emissions to the environment, automobiles make substantial contribution to the extent of 16.4%. Though the advancement of electrical vehicle (EV) technology on one side is making a steady progress, expected to reach 56 million cars from the present 2 million by 2030, still it is far from making any fundamental change in the emission front from the transportation sector. Implementing new, innovative technologies for the conventional vehicles which can improve fuel efficiency can lower the emission to a greater extent. Several recent developments in the engine, transmission and few ancillary systems of the vehicles show promising results. Converting part of heat energy in the exhaust gas let out as waste into electricity by a thermoelectric generator (TEG) is one technology gaining significance in the recent past. This project aims to develop a 300 W TEG. The automotive TEG mainly consists of TE modules, a hot side heat exchanger and a heat sink to generate ΔT across the modules. Fig. 3a shows the photo image of the 300W TEGs developed. The hot side heat exchanger is made of SS with pin fin design with hot side surface suitable to hold 60 modules of 5W power rating. The two cold side heat sinks are with counter cross flow arrangement. The thermoelectric modules used are made of Bi_2Te_3 which can be used up to 320°C. Fig. 3b shows the 300 W TEG under testing in an in-house developed test rig simulating typical automobile exhaust condition using hot air. Fig. 3c shows the temperature distribution observed in the hot side surface of the heat exchangers, which is fairly uniform within ±15°C. Under the maximum achieved ΔT of 200°C, around 60% of the rated powers of the thermoelectric modules are produced.

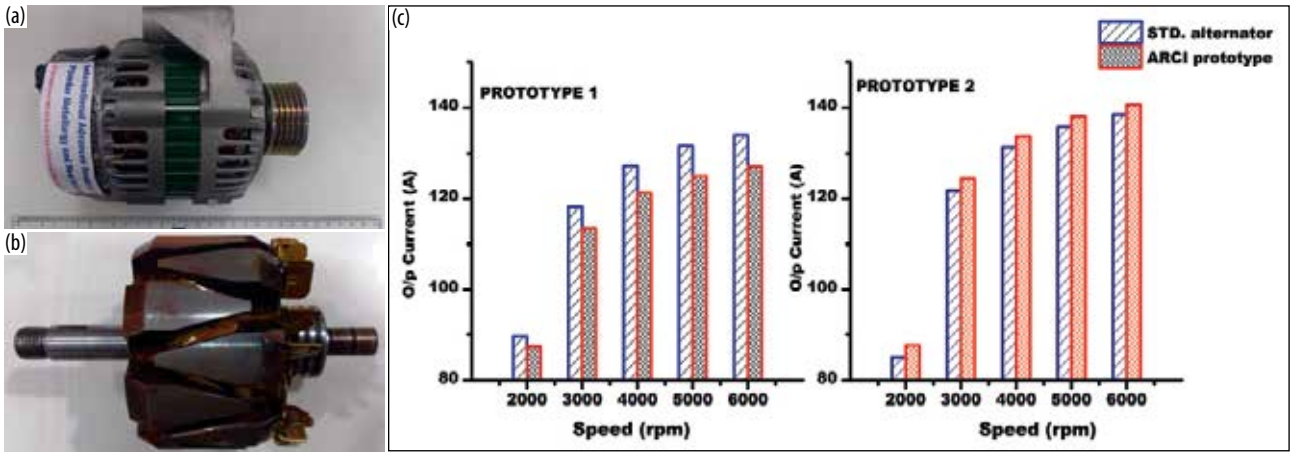


Fig. 2 (a) Prototype claw pole alternator developed for material testing and (b) the claw pole rotor made out of the developed soft magnetic material (c) ARCI machines showing lower o/p current compared to standard machines in 1st batch prototypes and with alloy modifications the ARCI machines performed better than standard machines in 2nd batch.

Fig. 3 (a) 300 W Automotive TEG (b) Automotive TEG under testing in TEG test rig (c) Hot side heat exchanger and the temperature distribution map during the testing

Up-scaling of In-house Developed Carbon Coated $LiNi_{1-x-y}Co_xMn_yO_2$: Electrochemical Characteristics of Pouch Cell

$LiNi_{1-x-y}Co_xMn_yO_2$ (LNMC) is being used as the cathode material for lithium ion batteries for electric vehicle application due to its capability to deliver high volumetric and gravimetric capacities and higher nominal voltage. However, because of the surface degradation, the cyclic stability of NMC are poor and there is a constant effort to modify its surface chemistry. In our recent investigation we have shown that the in-situ carbon coated LNMC have a superior electrochemical properties compared to pristine NMC. To have a better control over the morphology of LNMC and to upscale the synthesis, presently up to 250 g ethylene glycol pillared $NMC(OH)_2$ have been prepared using continuous stirred reactor (Fig. 4a). $C/LiNi_{1-x-y}Co_xMn_yO_2$ has been prepared by solid state reaction of $NMC(OH)_2$ and $Li(OH)_2$. With the controlled co-precipitation of the hydroxide, we were able to achieve the desired Nano/micro hierarchical structure of both $NMC(OH)_2$ and $LiNi_{1-x-y}Co_xMn_yO_2$and are given in Fig. 4b and Fig. 4c respectively. Lithium- ion 15 mA pouch cells are fabricated using in-house synthesized C/LNMC as cathode and superior graphite as anode. Galvanostatic charging/discharging at 0.5C for 100 cycles and at 1C for 100-1100 cycles are carried out. The cell delivered 13 mA and 12 mA at 0.5C and 1C, respectively. Only 20% reduction in the capacity is observed, even after 1100 cycles, as evident from the charging discharging curves at different cycles and capacity vs cycle cumber given in Fig. 4d.

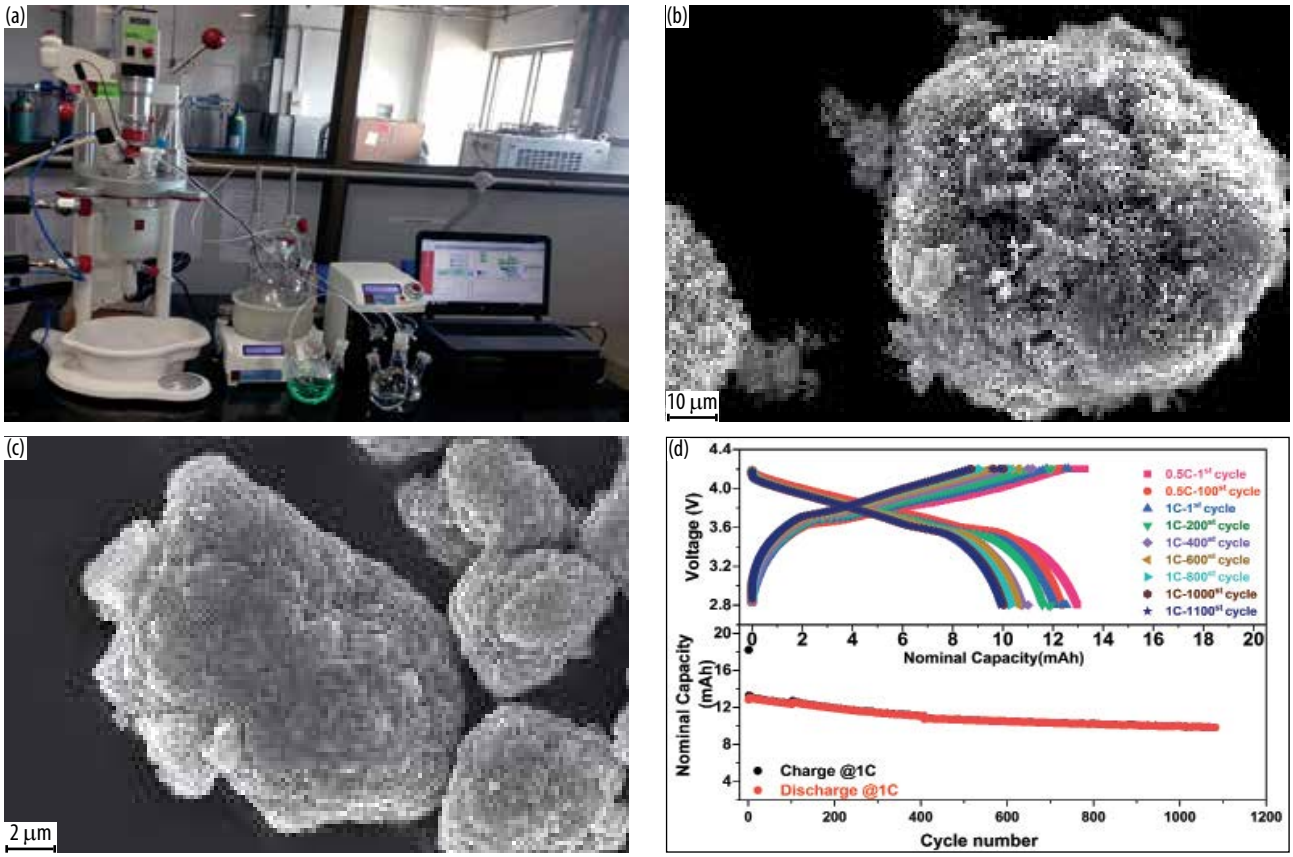


Fig. 4 (a) Continuous stirred reactor used to prepared $NMC(OH)_2$. SEM micrograph of (b) $NMC(OH)_2$ (c) LNMC showing the Nano/micro hierarchical structure (d) Charge discharge profiles of $LiNi_{1-x-y}CoxMn_{0y}O_2$ and C- $LiNi_{1-x-y}Co_xMn_yO_2$ with respect to graphite

Low-Cost Sodium-Ion Batteries: An Alternative to Lithium Ion Batteries for Large Scale Energy Storage Applications

Rechargeable sodium ion batteries (SIB) are considered as a viable alternative to LIBs for large-scale energy storage applications, and the development activities of electrodes/ electrolytes for SIB have been started at ARCI. In this regard, on the positive electrodes, layered P2-$Na_{0.67}(Mn_{0.5}Fe_{0.5})O_2$ (NMFO) has been prepared by co-precipitation followed by calcination at high temperature (~900°C) in air atmosphere. As an alternative to layered NMFO, poly-anions and mixed poly-anions, known for their stable cycling performance, have been developed using solid state and sol-gel techniques. The preliminary results of cathode materials are satisfactory and are given in Fig. 5. The choice for a stable anode material, i.e. negative electrode, is limited to hard carbon (HC) and $Na_2Ti_3O_7$ (NTO) owing to their low intercalation voltage (~0.1-0.3 V w.r.t. Na/Na^+) and high specific capacity. HC has been prepared from tamarinds seeds, whereas intercalation based layered oxide $Na_2Ti_3O_7$ (NTO), as an alternative, has been prepared from Na_2CO_3 and TiO_2 precursor materials via solid-state method at 800°C under Ar atmosphere.

Exploring Eco-friendly Magnetic Refrigerant Materials

Owing to its high efficiency and environmental friendliness, magnetic refrigeration technology based on magnetocaloric effect (MCE) is in much demand. We are exploring rare-earth free materials, which can exhibit huge magnetocaloric effect at low fields, which are suitable for refrigeration applications. Figure 6(a) shows the Transmission Electron Microscopy (TEM) image of x=0.3 of $Ni_{43}Mn_{46}Sn_{11}$ (FeB) x (x=0.3, 0.5) prepared by arc-melting, the alloys exhibit the cubic Heusler L21-type structure at room temperature. The magnetic entropy (ΔSM) was calculated from isothermal magnetization curves (x=0.3 and 0.5) using the Maxwell relation. A huge positive ΔS of 36 J/Kg-K at 203 K and 26 J/Kg-K at 230 K has been observed in $(FeB)_{0.3}$ and $(FeB)_{0.5}$ at a low magnetic field of 3T, respectively (Fig. 6 (b)). The magnetic entropy found in this work is higher than that of the values reported in the literature, which makes this system quite interesting from the point of view of fundamental aspects as well as applications.

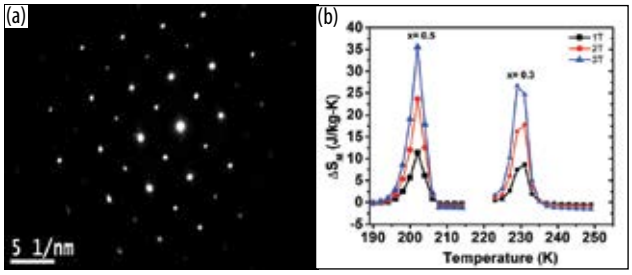


Fig. 6 (a) Transmission Electron Microscopy (TEM) image of x=0.3 of $Ni_{43}Mn_{46}Sn_{11}$ (FeB)x (b) Huge positive ΔS at 230 K observed in $(FeB)_{0.3}$ and $(FeB)_{0.5}$ at a low magnetic field of 3 T

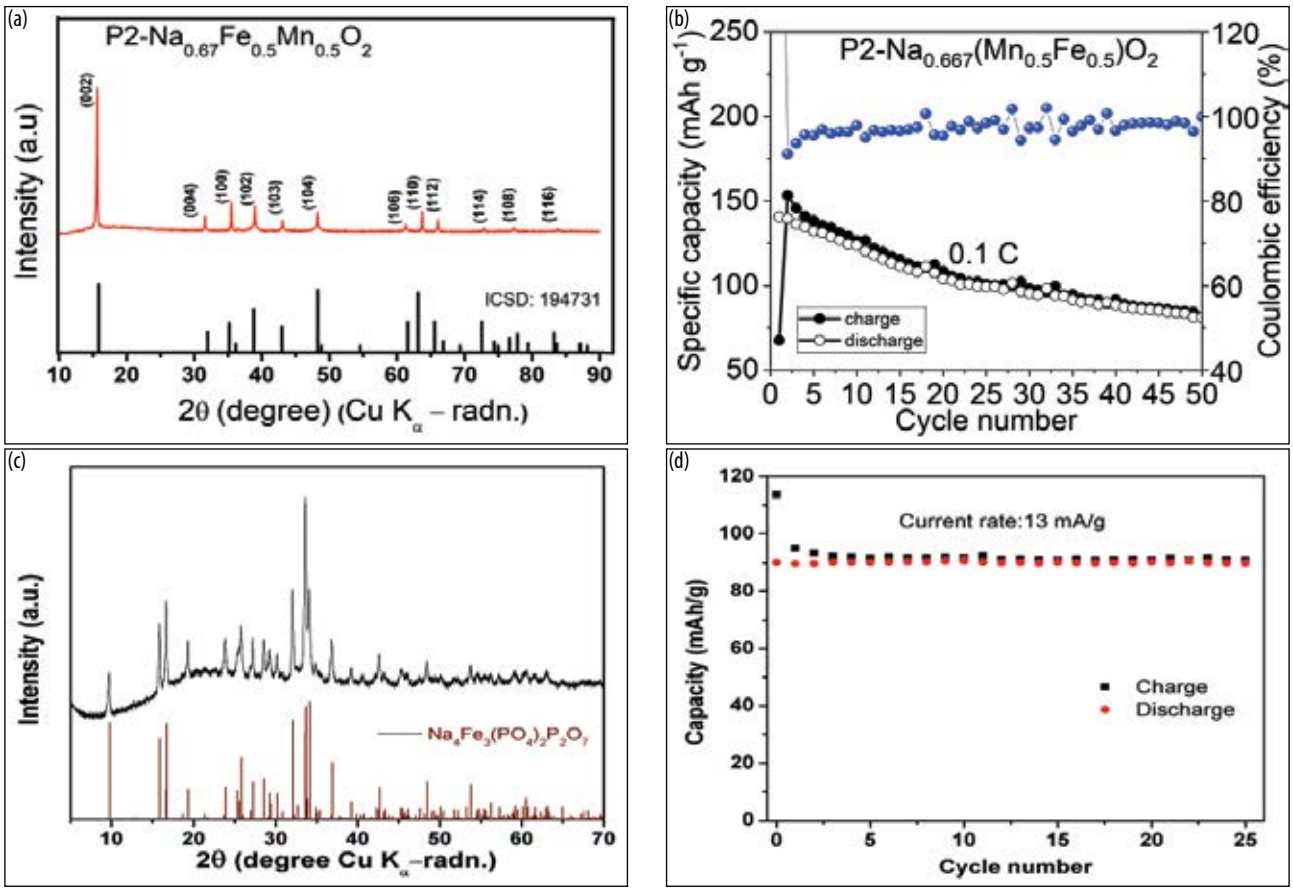
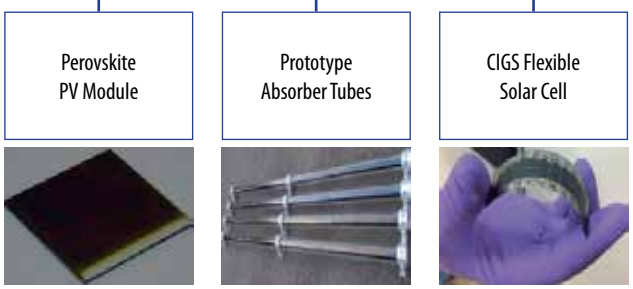


Fig. 5 XRD patterns of (a) P2-$Na_{0.67}(Mn_{0.5}Fe_{0.5})O_2$ and (c) $Na_4Fe_3(PO_4)_2P_2O_7$. Capacity vs. cycle number of (b) P2-$Na_{0.67}(Mn_{0.5}Fe_{0.5})O_2$ and (d) $Na_4Fe_3(PO_4)_2P_2O_7$.

Centre for Solar Energy Materials

Centre for Solar Energy Materials (CSEM) conducts cutting-edge research in materials, processes and components to develop innovative solar energy conversion technologies. Key research areas include absorber coatings for concentrated solar thermal power(CSP), CIGS thin film solar cells, and perovskite solar cells. Design and development of antireflective and easy to clean coatings for conventional and emerging PV technologies constitutes another major area of activity. We collaborate closely with small start-ups to leading renewable energy industries. State-of-the art characterization facilities available at CSEM assist our efforts to provide the service to industry for assessing the performance and operational stability of various photovoltaic and solar thermal components. PV modules based on direct band-gap CIGS thin film might one day offer performance and cost advantages compared to the traditional c-Si. Our CIGS pilot line operates on 'sputtering + selenization' concept to fabricate 300mm x 300mm size mini-modules on glass substrate. Development of CIGS absorber layer by non-vacuum ink-based route and pulsed electrodeposition method are also being explored as low-cost alternative to the established processes. Organometal halide perovskite solar cell (PSC) rapidly emerged as disruptive technology due to their high efficiency. A maximum efficiency of 16 % has been achieved in lab-scale PSCs and 50mm x 50mm prototype module with power output of 70 mW was demonstrated. Synthesis of earth abundant, non-toxic and intrinsically-stable perovskite is also actively carried out. Current efforts are being focused on the scale-up of PSC technology to 100mm x 100mm solar tiles for e-bike recharging station and smart window applications. Four meter long solar absorber tube with >95% absorption and 0.16 emittance was successfully developed by chemical oxidation method and is being tested in the field for medium temperature CSP application. Low-temperature and on-site curable self-cleaning coating with high transmittance and weather stability was developed for dust mitigation in previously installed PV panels. Apart from photovoltaic and solar thermal research the centre has been actively involved in visible light active photo catalytic materials and successfully developed a technology of smart carbon based TiO_2 nanostructured materials for visible light active self-clean textiles and paints which are suitable for indoor and outdoor applications.

PRODUCTS DEVELOPED



NEW FACILITIES ESTABLISHED

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Solar Selective Absorber Coatings for Low and Medium Temperature CSP Applications

Solar collectors play an important role for increasing energy efficiency in concentrated solar thermal power (CSP) such as solar dryer, solar desalination, stream generation for various industrial applications and power generation. Low and medium temperature solar collectors can be cost efficient compared to high-temperature collectors due to lower heat losses and use of low-cost materials. Coupled with Organic Rankine Cycle, the power generation cost can be comparable with fossil fuel. The overall objective of this technology is to develop a cost-efficient receiver coating with high absorbance (>0.95), low emission (<0.20) and high weather stability for solar thermal systems. We have adopted chemical oxidation and sol-gel process to develop this cost-effective absorber coating with 0.94-0.95 absorptance, 0.14-0.16 emittance, high corrosion resistance and good temperature stability at 300°C. At present we have developed and demonstrated prototype absorber tube (4m) for low and medium temperature solar thermal application. Now this technology is on the verge of transfer to the solar thermal power industry for industrial stream generation (Figure 1). Apart from that Cu-Ni-Mn-SiO_2 nanocomposite coating has been developed successfully with high optical properties (0.92 abs, 0.17 emission) by electrodeposition. An additional AR coating has further enhanced the absorbance of nanocomposite coating to 0.96. These coatings have shown a very good stability during thermal cycling upto 300°C.

Selective Absorber Coatings for High Temperature CSP Application

Spectrally selective receiver tube is the critical component in Concentrated Solar thermal Power (CSP).

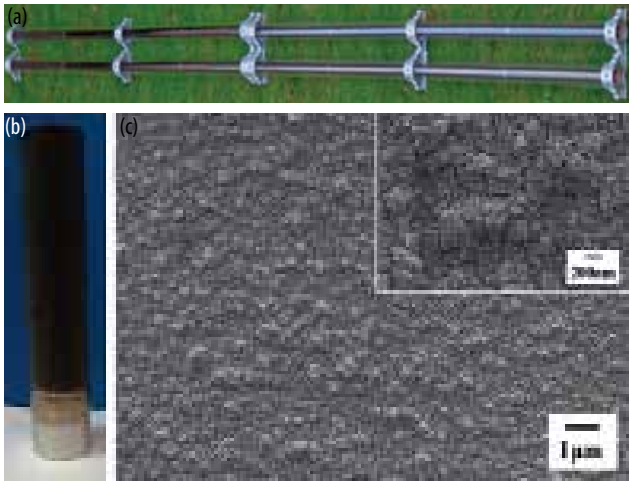


Fig. 1 (a) 2 and 3 layer absorber tandem solar selective absorber coatings on 4 m prototype receiver tubes developed by combination chemical and sol-gel process; (b) Image of 10 cm SS tube coated with Cu-Ni-Mn-SiO_2 nanocomposite by electrodeposition; (c) SEM image of the nanocomposite coating

To increase the overall efficiency of the thermal system, we need high thermally stable spectral selective coating which can be operated at ≤500°C and should function minimum of 25 years without any functional degradation. It should sustain the thermal fatigue over a long duration. Spinel structured materials are considered thermally stable at high temperatures (≤500°C). In addition, spinels are amenable to the substitution of a large number of transition metals, which can be chemically tailored to tune the optical properties of spectrally selective absorber coating.

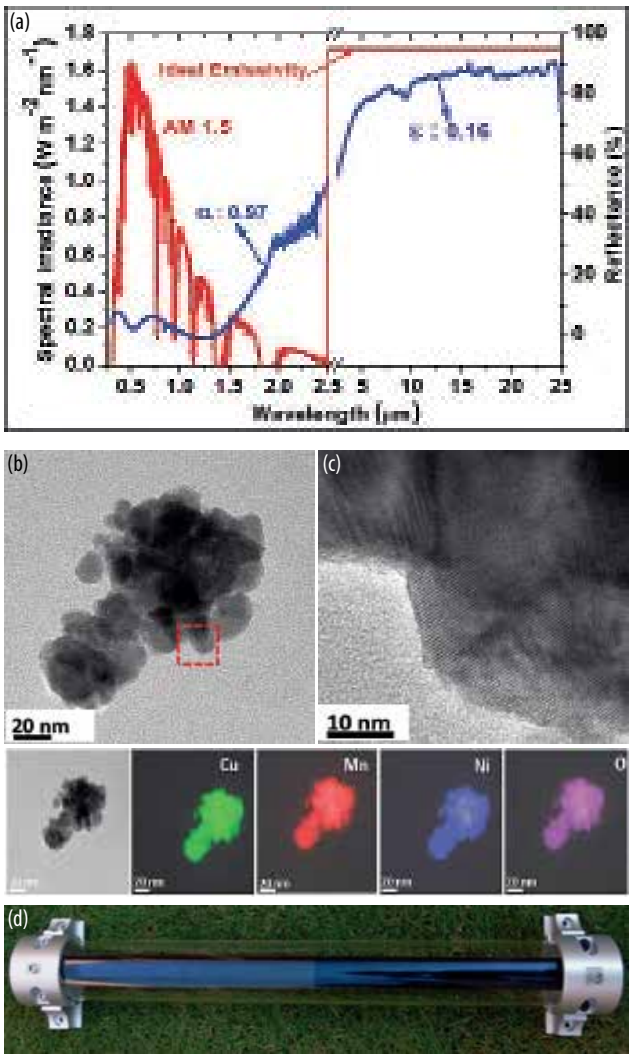


Fig. 2 (a) Optical properties of tandem spectrally selective absorber coating (b) TEM, (c) HR-TEM and elemental mapping micrographs of $CuxMnyNizO_4$ Spinel + CuO+ $MnNiO_3$ powder (d) Prototype Receiver Design comprising absorber tube with AR coated glass envelope

To attain high performance absorber coatings which are thermally stable for temperatures ≥500°C in air, we used transition metals like Mn, Cu and Ni since they are intrinsically more absorbing in nature. Vapor deposition techniques may lead to high cost for developing the absorber coatings; we adapted wet chemical method (Sol-gel) to develop coatings at room temperature to make it economically viable. The developed ternary transition metal oxide layer

comprises of nanocomposite particles made up of three crystalline phases such as $Cu_xMn_yNi_zO_4$ (Spinel), CuO, and $MnNiO_3$. Elemental mapping images illustrate that the formation of nanocomposite particle with uniform distribution of transition metals (Cu, Mn, Ni), aids to good optical properties (α=0.92, ε=0.14) and high temperature stability. We imparted SiO_2 antireflective layer on top of absorber to enhance the solar absorptance from 0.92 to 0.97. We successfully developed a high temperature resistant tandem layer with efficient manufacturability at low cost which is an attractive feature for concentrated solar power generation (CSP).

Smart Carbon Based TiO_2 Nanostructure Materials for Visible Light Self Cleaning Application

Titanium dioxide (TiO_2) is already the most promising photocatalytic material used in various practical applications, such as sterilization, deodorization, cleaning and super hydrophilic functionality by the strong oxidizing agents (holes and free radicals) thereof being generated after exposure to light. Conventional TiO_2 materials most preferably prepared from sol-gel, and other conventional methods are active (generating oxidizing species) only under the exposure to UV light because of its large band gap of 3.20 eV. Moreover, if a conventional TiO_2 material is illuminated with visible light (>400nm), oxidizing species cannot be formed because of no charge carrier formation. Incorporation of a few weight percent of transition metal or transition metal chloride or non metals (carbon, nitrogen, sulphur etc.) either in the bulk or at the surface of titanium dioxide leads to visible-light activation and suitable for indoor self-cleaning applications. In this regard, we have successfully developed a technology of smart carbon based TiO_2 nanostructured materials for visible light active self-cleaning textiles and paints which are suitable for indoor and outdoor applications. Now this technology is ready for transfer to the textile, paint and ceramic industries.

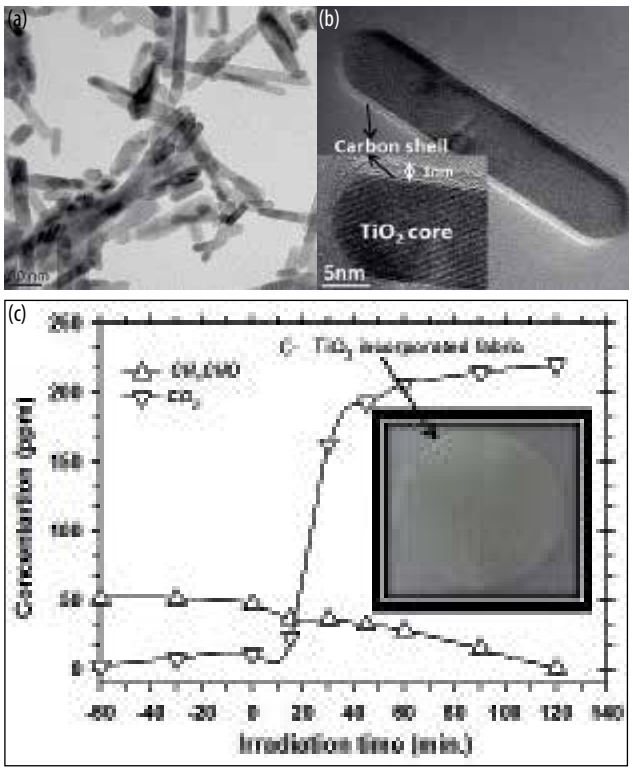


Fig. 3 (a) and (b) TEM and HR-TEM images of C- TiO_2 core-shell nanoparticles; (c) Visible light photocatalytic decomposition of acetaldehyde by C-TiO_2 incorporated fabric

Super-Hydrophobic Coatings with High Transmittance and Weather Stability for Dust Cleaning of PV Panels

Easy to clean technology is generally related to protect the solar devices from dust/dirt, corrosion and all sorts of weather conditions. PV panels employed in power generation are very important solar devices traditionally mounted outdoors on rooftops. Unfortunately, this type of outdoor placement of the devices is subjected to substantially constant weather and moisture exposure. The devices are preferably designed to use for many years with stable and reliable operation without failure due to moisture damage. A general challenge in finding the suitable protective coating material with easy to clean property for use with above mentioned devices is finding one protecting surface that has best-in-class qualities for the multifunctional properties desired in all sorts of environmental protections. Wet chemical process is used for synthesis of super hydrophobic sol. Room temperature curable super-hydrophobic

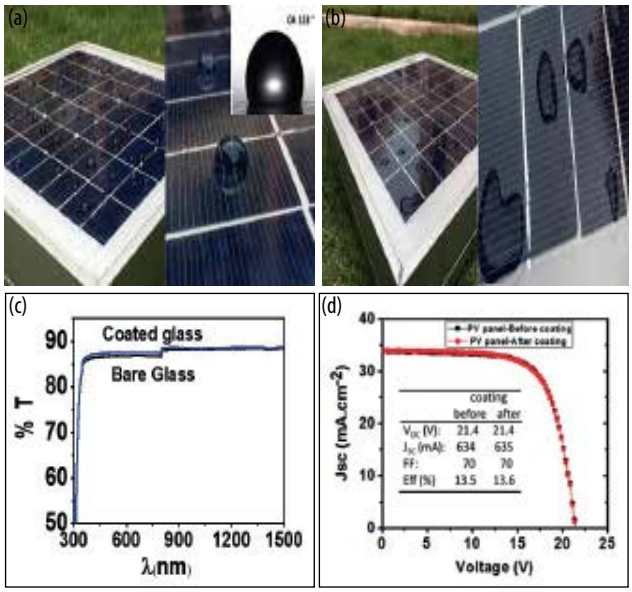


Fig. 4 (a-b) Shape of water droplets on coated and uncoated PV panels (c-d) Optical properties and efficiency of coated and uncoated PV modules

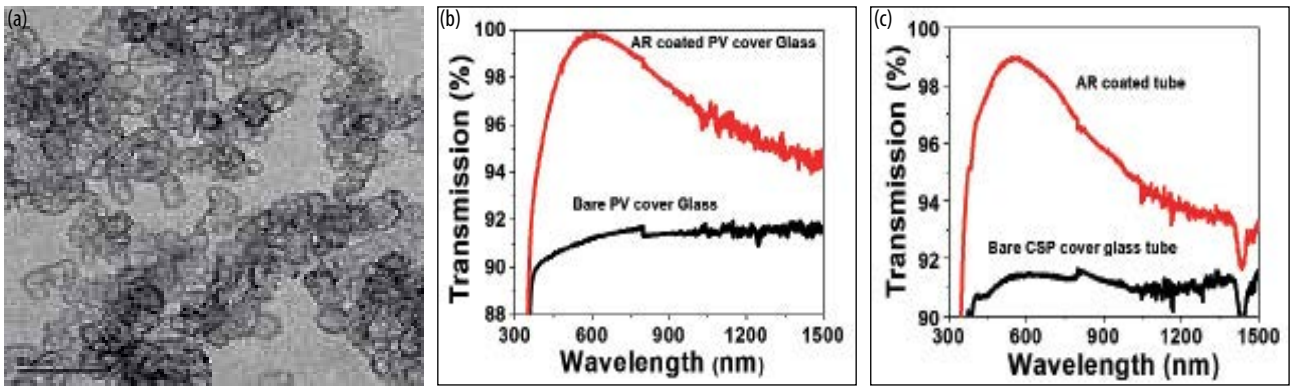


Fig. 5 (a) TEM image of Hollow MgF_2 nanoparticles; (b) and (c) Transmittances of AR coated PV glass and CSP glass tube

coatings are developed on PV cover glass by simple spray and wipe technique. The ultimate target was to attain super-hydrophobic coatings on PV panels existing in Solar power plants under operation. In this regard, a novel Superhydrophobic coating has been developed successfully with high transmittance, high weather stability and without loss in the PV module efficiency. Moreover, coating was applied on 250W PV panels (1x 2m (W x L)) for field demonstration.

Broad band Antireflective Coating for CSP and PV Applications

The development of broad-band anti-reflective coatings (BARCs) has attracted substantial research interest due to their high transmittance in a broad wavelength range (300–1500 nm) for diverse potential applications spanning photovoltaic systems, solar thermal collectors, optical and architectural glasses, windscreens, high power lasers, windows and video display panels. Due to their high refractive indices, optical elements like PV cover glass and CSP cover glass tubes suffer a reflection loss of about 8-9% in the visible spectrum of the solar radiation. Such reflection losses are undesirable and detrimental to the overall optical efficiency. Hence, broad-band anti-reflective coatings that transfer maximum incident light over a broad range of wavelengths can help to achieve competitive conversion efficiencies in solar cells or receiver tubes or other type of devices that require minimal reflection. The primary objective of this project work is to develop antireflective coatings with high optical performance in a broad solar wavelength range, high weather and thermal stabilities for concentrated solar thermal power (CSP) and photovoltaic (PV) applications. In this background, a novel type of broad band antireflective coating was successfully developed on soda lime and borosilicate glass substrates using novel mesoporous and hollow MgF_2 nanoparticles synthesized by hyothermal synthesis. The developed antireflective coatings exhibited an excellent optical performance (>95% average transmittance from 300 to 1500nm) along with high thermal and weather stabilities.

CIGS Thin-film Solar Cells

$Cu(In,Ga)Se_2$ chalcopyrite compound with an adjustable bandgap in the range of 1.05 – 1.65 eV is a promising absorber material for thin-film solar cell application. The main objective of the project was to build on existing key consortium competencies in thin-film PV materials, such as CIGS, in order to develop disruptive, high-performance, vacuum-based sputtering and solution-based (ink-based/ electrodeposition) non-vacuum processes for PV technologies for the Indian markets. The sputtering process involved deposition of CuGa/In on Mo sputtered glass by magnetron sputtering followed by selenization in order to achieve highly crystalline and CIGS layer. Device was fabricated by depositing the different layers including (Glass/Mo/CIGS/CdS/ZnO/ AZO). The main objective was to develop inexpensive and simple non-vacuum processing routes to produce high quality CIGS, cost-effectively. To achieve the milestone, two non-vacuum based routes were used. The first was an ink-based route where CIGS inks, precursors, and process chemistries to enable precursor based atmospheric processing was targeted. A precursor based homemade ink formulation in aqueous medium and printing parameters were optimized to achieve uniform pristine thin film on Molybdenum coated willow flex glass. Further, fine tuning of selenization process conditions using elemental Selenium as a precursor was adapted to produce quality CIGS thin film absorber layer. In order to obtain single $CIGSe_2$ chalcopyrite phase, inkjet printed precursor layer was selenized under Se rich atmosphere. Film thus obtained was highly crystalline and p-type in nature with compositional ratio of Cu/ (In+Ga)= 0.96 and Ga/Ga+In=0.25 which is desired for high photo activity. Further, CIGS films by non-vacuum inkjet route was used to fabricate complete solar cell, 100 nm CdS layer by chemical bath deposition followed by sputtering of i-ZnO and Aluminium doped ZnO layer on top was coated. Current density-voltage characteristics of the best solar cell under dark and standard AM 1.5 sun simulator illumination

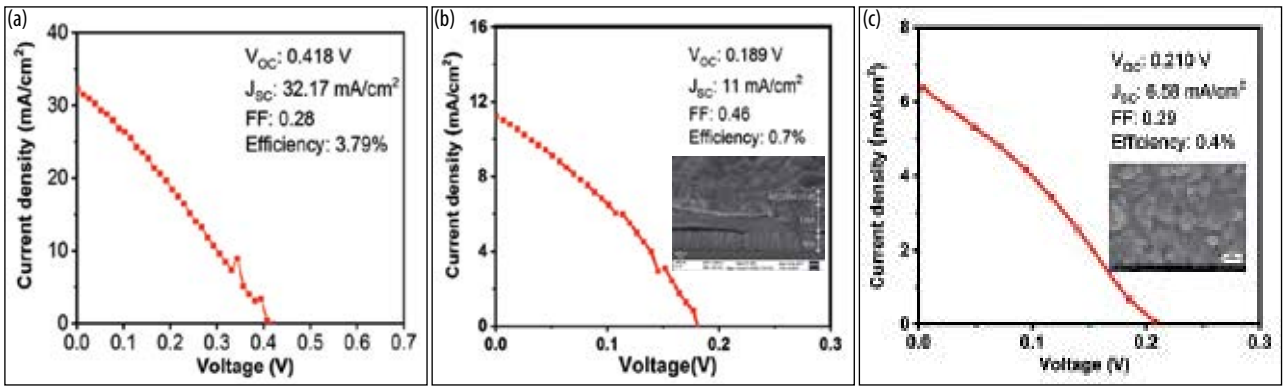


Fig. 6 I-V characteristics of (a) Sputtered, (b)Ink-jet printed and (c) Electrodeposited CIGS solar cells

display in figure 8(b). A maximum power conversion efficiency of 0.7% was achieved on active area of 6 mm x 4 mm, however average efficiency of 0.46% was achieved from total printed area of 12 mm x 20 mm. Low Voc of cell refers to quality of material, which can be improved by eliminating the secondary phases. In addition, a thick $MoSe_2$ formation and fine grain layer in $CIGSe_2$ absorber layer are responsible for low fill factor and performance of the cell.

The second was the electrodeposition route where CIGS layers were prepared in single-step as well as step-by-step approaches by direct current and pulse plating techniques. The as-deposited precursor films were further selenized under Ar atmosphere. In a novel attempt, pulse electrodeposition of Cu-Ga-Se and In were performed step-by-step on Mo coated willow glass and flexible Mo foils followed by selenization, yielded dense and stoichiometric chalcopyrite CIGS absorbers. Optimization of pulse parameters, duty cycle and deposition potential have played a major role in achieving single phase CIGS. The devices have resulted in a conversion efficiency of 0.4 % (Fig. 8(c)) indicating the active p-n junction formation. Further, efforts are underway to improve the composition, morphology and thickness of CIGS films to improve the efficiency of devices. Simultaneously, Cu/In layers are pulse electrodeposited to fabricate CIS absorbers for solar cells. In addition, fabrication of CIGS solar cell on Mo-coated glass by using completely non-vacuum routes for preparation of all the layers is another major focus. CIGS, CdS buffer layer and ZnO layers have been successfully optimized by room-temperature pulse electrodeposition route. The pn-junction formed by CIGS/CdS has indicated the junction's stable photoactivity during photoelectrochemical measurements. Further, device fabrication is being done.

Perovskite Solar Cells

Conventional solar cells based on crystalline silicon wafer and thin film absorber materials typically convert more than 20% of the incident solar light into useful electric energy. However, the intrinsic features of absorber materials and minimum thickness requirement for threshold light absorption results in opaque solar cell. In this context, 3rd generation solar cells based on custom synthesized organic and inorganic nanomaterials emerged as a preferred choice for the fabrication of transparent solar cells. Organometal metal halide perovskites with a generic formula of ABX_3 are found to possess direct band gap of 1.5 eV and high light absorption coefficient, critical parameters required for the high efficiency solar cells. Initial studies carried out in a sensitized solar cell configuration with methylammonium lead iodide ($MAPbI_3$) and iodine/iodide redox electrolyte have shown 3% power conversion efficiency and poor stability. Replacing the liquid electrolyte with small molecule organic hole transporting material (HTM) not only improved the efficiency but also helped in overcoming the dissolution of $MAPbI_3$ perovskite in corrosive electrolyte. High light absorption coefficient and optimum direct band gap of $MAPbI_3$ perovskite ensures that merely 300 nm thick film is sufficient to absorb most of the photons in 300 ~ 800 nm wavelength range solar spectrum. Composition engineering of perovskites through halide and cation replacement also opens up the possibility of multi color absorber layer. By carefully tuning the absorber layer and its interface with carrier selective contacts, one can manipulate the quantity of light needed for absorption and transmission into the PSCs. As a proof of concept, we partially replaced the iodine with bromine and obtained a semi-transparent $MAPbI_xBr_{1-x}$ absorber layer. Reflective Au metal cathode traditionally employed in high efficiency PSCs was replaced with dielectric-metal-dielectric (MoO_x/Au/MoO_x) stack. Lab-scale PSC was fabricated on FTO glass substrate using TiO_2 and spiro-OMeTAD used as electron and hole selective contacts, respectively.

Fig. 7 shows the typical transmittance curve of semi-transparent PSC prepared on 15mm x 15mm FTO glass substrate. Perovskite absorber and HTM layer thickness

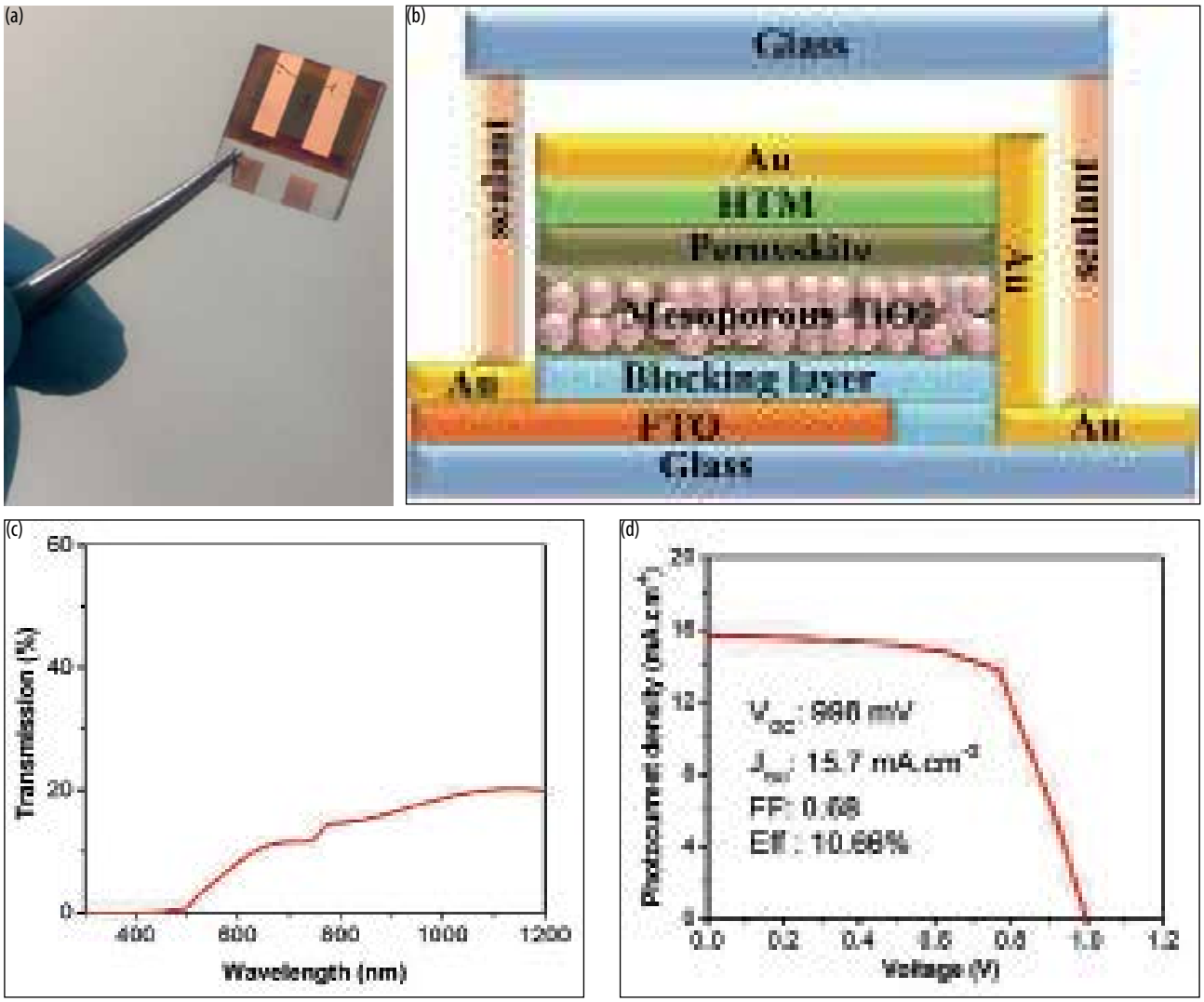


Fig. 7 (a) Schematic of PSC (b) Semi-transparent PSC (c) Transmittance and (d) Current-Voltage characteristics of semi-transparent PSCs

were optimized to maintain the balance between the absorption and transmission of incident solar light. The device shows the visible light transmission onset around 500 nm, gradually increases and stabilizes at 20 % for longer (> 900 nm) wavelength. Average visible light transmittance of device was estimated to be 13%. Metal cathode deposited in a DMD structure constructively improved the transmittance of PSCs as evident from the long wave length light transmittance. Slight yellow colour of HTM precursor solution, an indication of presence of reduced species in HTM also absorbs some of the photons in the visible range. Development of colourless HTM based on inorganic CuSCN is in progress and is expected to further improve the device transmittance in the visible range. The photovoltaic performance of semitransparent PSCs were measured under 1 sun condition (Fig. 7). Control device prepared using glove-box processed spiro-OMeTAD HTM shows 11.1 % power conversion efficiency. This may pave the way for the realization of all-air-processed high efficiency.Our study may lead to development of functional solar window which can generate electricity and allows light to pass through it for indoor illumination.

Although PSCs show promising photovoltaic performance, presence of lead (Pb) heavy metal raises environmental and safety concerns. Hence, a novel Pb-free perovskite with the inclusion of Cl ions into the perovskite structure was prepared. By incorporating Cl ions, the properties including stability, bandgap and charge carrier diffusion length are further tuned. The properties of the synthesized new material and its photovoltaic performance are studied in detail using of XRD, UV-vis spectrometer, FE-SEM, photovoltaic characterization and electrochemical impedance spectroscopy. The PSCs fabricated with novel Pb-free perovskite have shown short circuit current density of 12.8mA/cm^2 with an open circuit voltage of 939 mV, fill factor (FF) of 0.62 and power conversion efficiency (PCE) of 8.7% under 1 sun illumination. Interestingly, PSC made with Pb-free perovskite showed much better stability, when compared to solar cells prepared using conventional $MAPbI_3$ perovskite absorber. By further optimization of device architecture and film deposition techniques, PCE of new-Pb free PSCs are expected to increase 10%.

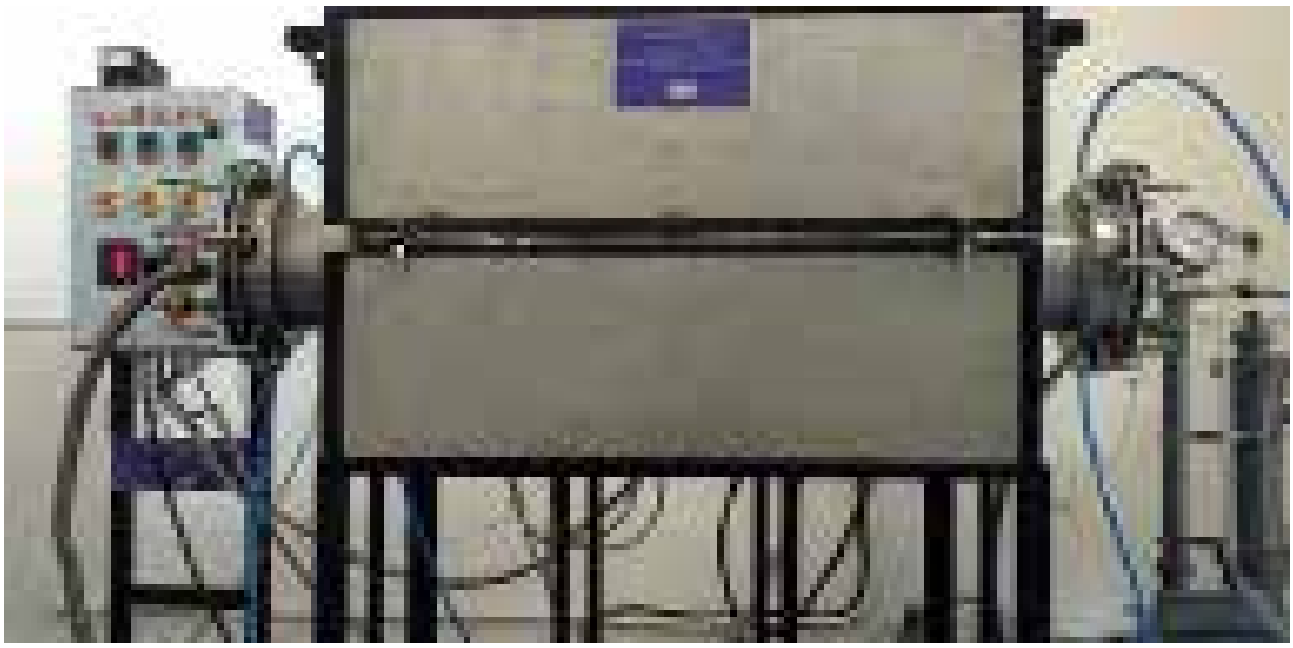
Centre for Nanomaterials

The major research activities being carried out are: (i) development and production of both anode (Lithium titanate) and cathode (Lithium iron phosphate) materials for Li ion battery, (ii) Super capacitors for electric vehicle applications, (iii) oxide dispersion strengthened steels for high temperature applications, (iv) Two dimensional transitional metal sulphides as additives to the lubricants and grease, and as catalysts in oil refineries and petrochemical industries, (v) Development of tungsten based jet wanes, (vii) Development of filters for fluoride removal and (viii) Solar hydrogen generation materials.

The Technology transfer for the production of Silica Aerogel flexible sheets for the thermal insulation application is nearing completion and the product shall be launched in the market by middle of 2019. Two technology transfers viz. (i) Development of lead free copper alloys for the bimetal bearings for automotive industry and (ii) Modified titania suspension for self cleaning textiles under visible light, are initiated.

Unique facilities like reactor for Large scale synthesis of 2D transition metal sulphides, Small scale flame spray pyrolysis reactor, Test facilities to evaluate supercapacitors and aerogel thermal insulation sheets were established during this year.

The overall performance of Centre for Nanomaterials during this year is encouraging and this is due to the concerted efforts of dedicated scientists, technical staff and students.



Scaled-up reactor setup at ARCI for the large scale production of 2D-TMS

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Silica Aerogel Flexible Sheets for Thermal Insulation Application

The technology of manufacturing silica aerogel based flexible sheets has been developed at ARCI for its use in high performance thermal insulation. The objective of commercialization of this indigenously developed world class product is to align to the 'Make in India' national initiative. This product possesses all the mechanical features and technological properties required for any ideal industrial thermal insulation material such as low thermal conductivity (0.04W/mK at RT), good thermal stability over a temperature range of -50 to 800°C, light weight (0.2 g/cc), good compressive strength, hydrophobic, fire, corrosion and chemical resistance, anti-fungal, low shrinkage, soundproof, non-toxic and eco-friendly. Tests carried out indicated superior insulation performance of Aerogel Flexible Rolls produced at ARCI (Fig. 1) as compared to commercial insulation materials. Thus this ARCI aerogel sheet can be used in various applications which can significantly reduce the heat losses, increase the process efficiency and conserve the energy. These sheets can be produced with a thickness of 5-25 mm for various insulation applications in refineries, power generation plants, furnaces, ovens, hot and cold storages.

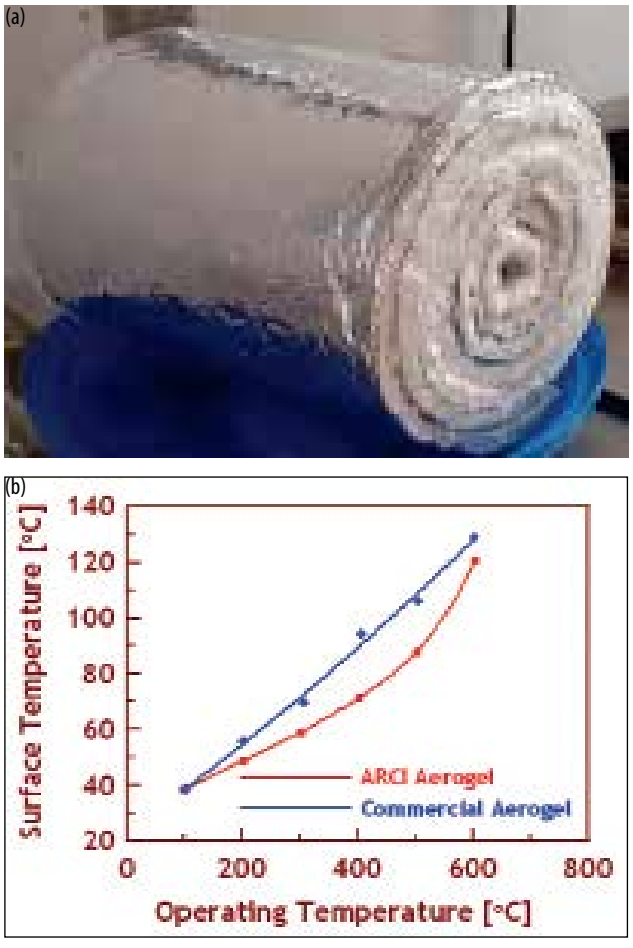


Fig. 1 (a) Aerogel Flexible Roll produced at ARCI (b) Graph showing the superior insulation performance of ARCI aerogel insulation sheet

Lead Free Copper Alloys for Bimetal Bearings

Lead containing Copper-tin alloys are being widely used for half bearings, piston pin bushes and cam bushes of internal combustion engines. The presence of lead improves the wear and the seizure resistance during mechanical operations. The new environmental regulations demand that the lead should not be used in these materials and hence there is a need for development of "Lead free copper alloys" for the above applications.

Two compositions i.e. Cu-Sn-Bi-5P and Cu-Sn-Bi-Ni were developed to have low friction coefficient and enhanced anti-seizure characteristics. The process for making bimetallic bearings involves loose powder sintering on the steel plate, cold rolling, annealing and finish rolling. All the above process parameters were optimised at ARCI and bimetal strips were produced by the industry (M/s. Bimetal Bearings Pvt. Ltd., Chennai) using the optimised parameters (Fig. 2). These strips exhibited yield Strength of 450 MPa, hardness of 119 HVN, wear resistance of 18μm/h and the fatigue strength of 110 MPa, which are superior to the lead containing copper alloys. The industry intends to use these materials for (i) main bearings and connecting rod bearings for heavy duty vehicles, (ii) cars and motor cycle bearings, (iii) transmission and hydraulic pump bushings, (iii) wear plates and (iii) camshaft bushings for medium size vehicles. Technology transfer is initiated.

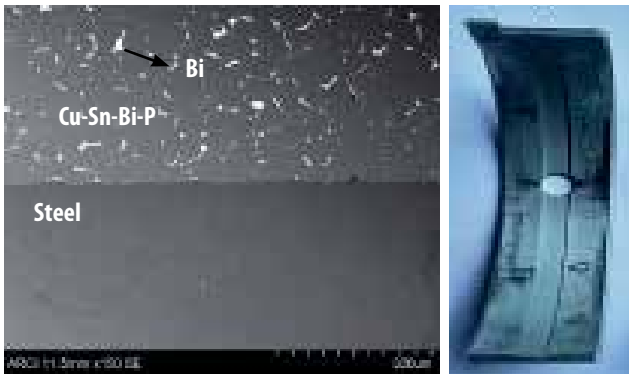


Fig. 2 Microstructure of the lead free copper alloy bimetal strip along with the photograph of the half bearing made from the strip

Development of Modified Titania Suspension for Self-cleaning Textiles under Visible Light

Self-cleaning property of visible light photocatalysts developed at ARCI has been evaluated for textile application using gas phase photocatalytic setup established at ARCI. Initially, composite (CNPs-TiO_2 composite) suspension is prepared by adding 10 wt% of CNPs in to 1 litre suspension of TiO_2 particles. The resulting

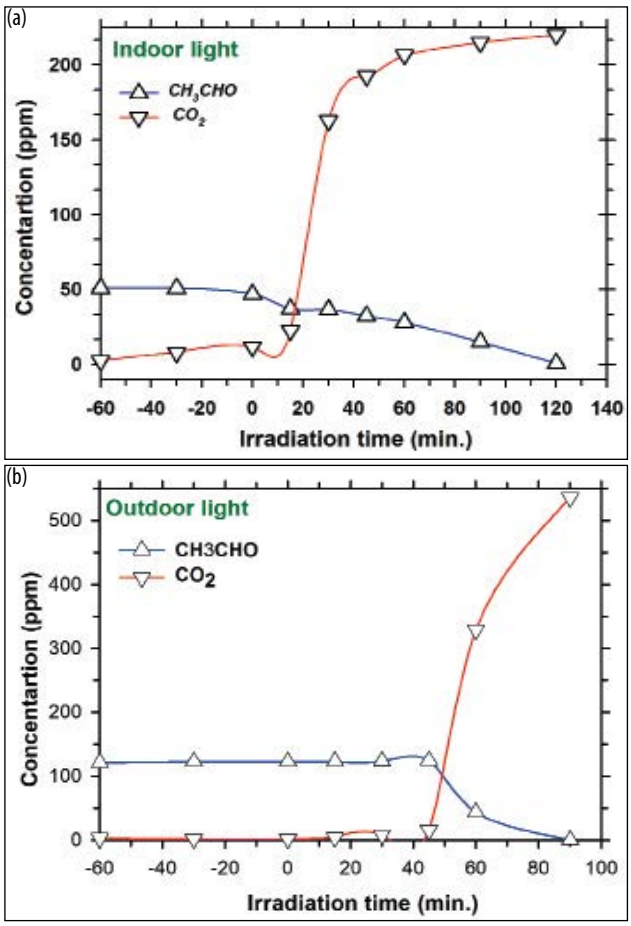


Fig. 3 Self-cleaning performance of modified titania coated fabric under (a) In-door and (b) Outdoor light illumination

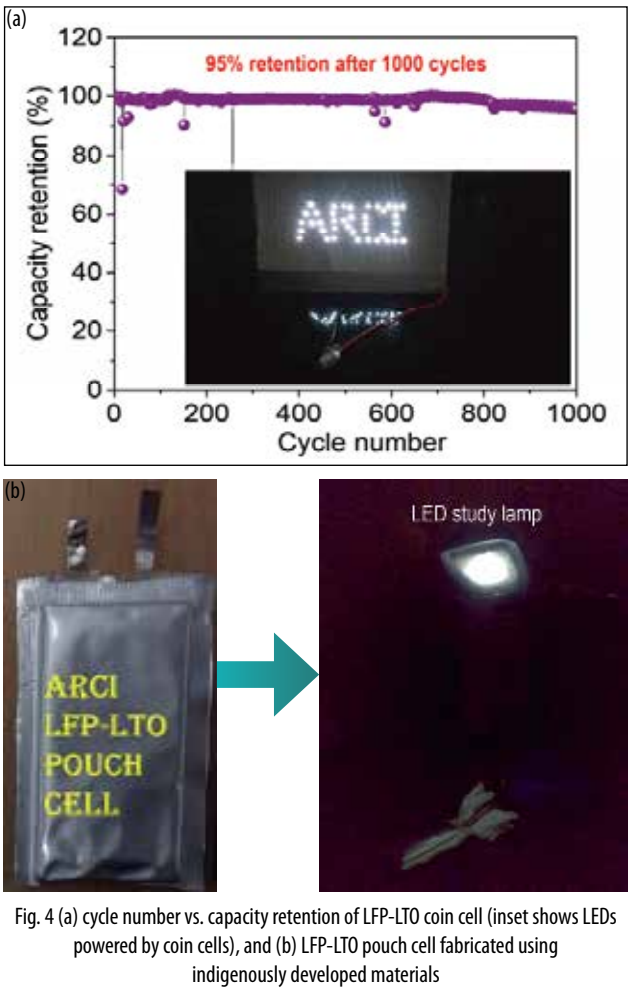


Fig. 4 (a) cycle number vs. capacity retention of LFP-LTO coin cell (inset shows LEDs powered by coin cells), and (b) LFP-LTO pouch cell fabricated using indigenously developed materials

suspension (CNPs-TiO_2 composite) was coated on fabric and then loaded into gas phase photocatalytic reactor followed by injection of acetaldehyde (CH_3CHO). After which the sample is illuminated with either indoor (blue LED) or outdoor (sun light) irradiation. To cut-off UV light from sun light, photocatalytic experiments were carried out by keeping UV cut-off filter on photocatalytic reactor. For comparison, the commercial TiO_2 coated fabric was also tested and the results are shown in Figure 3. Neither decrease in the concentration of CH_3CHO nor increase in the concentration of CO_2 is observed with commercial TiO_2 incorporated fabric under illumination of indoor and outdoor light, due to lack of visible-light absorption by TiO_2. In contrast, complete decomposition of acetaldehyde was observed for composite (TiO_2 with carbon nanoparticles) incorporated fabric under the illumination of indoor and outdoor light. The application of developed visible light active material could be extended to paint applications for the removal of VOCs.

Development of cathode (carbon coated $LiFePO_4$-C-LFP) and anode (lithium titanate-LTO) for lithium-ion battery Application

Synthesis of electroactive materials at large scale is necessary for a country like India, which depends largely on Asian countries mostly China for battery materials. Considering India's electric vehicle mission of deployment of 7 million EVs on road, materials synthesis as well as their electrochemical performance validation is of primary importance for ARCI. Keeping this in mind, the center focussed on the large scale synthesis of Lithium titanate (LTO) anode material by high energy Zoz milling process and Lithium iron phosphate (LFP) cathode material by flame spray pyrolysis (FSP). The LTO synthesis conditions by high energy ball milling such as amount of precursors loading, milling time and calination temperature were optimized. Bench mark studies revealed that the specific capacity of LTO synthesized by high energy Zoz milling (Zoz) process is higher than commercial grade LTO at high current rates. The as-synthesized LTO delivered a capacity of 150 mAh/g at 1C current rate and 125 mAh/g at 5C current rate when tested against Li metal in half cell configuration. Further, when it was tested as anode in combination with commercial grade $LiFePO_4$ as cathode to validate its efficiency, the full cell delivered a capacity retention of 95 % after 1000 charge-discharge cycles at 1C rate, two such cells connected in series (4V) were used to power LEDs [Fig. 4(a)].

The indigenously developed Lithium iron phosphate cathode by FSP method delivered an initial charge capacity of 146 mAh/g at C/10 rate and a reversible

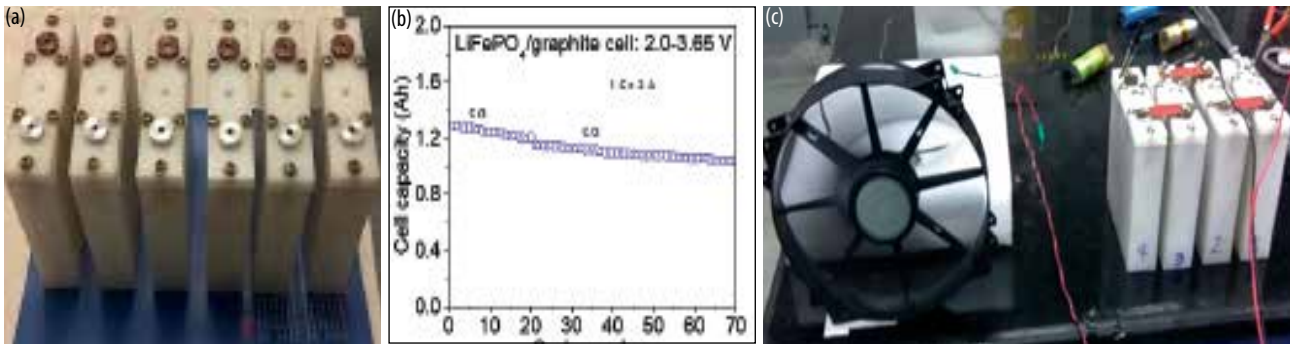


Fig. 5 (a) LIB device using indigenous carbon coated $LiFePO_4$ (b) performance evaluation of LIB device and (c) demonstration of LIB device connected in series for running DC fan

capacity of 110 mAh/g at 1C rate. The electrochemical performance in a full cell configuration is very significant for the development of lithium-ion battery chemistry. To validate the indigenously developed LFP-LTO chemistry, a pouch cell was fabricated using indigenously developed LFP as cathode and LTO as anode, and the performance optimization is being carried out to increase the capacity retention and cycle life in large format cells [Fig. 4 (b)].

Further, indigenously developed LFP cathode material has also been used for the fabrication of prismatic LIB cells using LIB pilot plant facility at CAEM Chennai. The full cell potential is the difference between potential of cathode and potential of anode materials vs. Lithium. The prismatic cells were made using LFP cathode and Graphite anode. The LFP having a potential of 3.45 V vs. Li and the Graphite having a potential of 0.2 V vs. Li would result in a cell potential of 3.2 V. Prismatic cells having a capacity of 2.8 Ah and a potential of 3.2 V were fabricated and four such cells were connected in series to get a potential of 12 V for the demonstration of 12 V DC motor fan (Fig. 5). The electrochemical performance of such prismatic cells was tested Galvano-statically within the potential window of 2-3.65V which shows promising capacity retention.

Oxide Dispersion Strengthened (ODS) Alloys

Oxide dispersion strengthened alloys are being considered as potential candidates for high temperature applications such as components in steam as well as gas turbines and nuclear reactors. The improved properties of these ODS alloys are due to the presence of uniformly distributed very fine (2-5 nm) Y-Ti-O complex oxide particles with high number density (2 x 1023/m^3). ARCI has embarked upon major programs to produce a variety of ODS steels (9, 14, 18 Cr, as well as austenitic steels and iron aluminides) for components of nuclear reactor, steam as well as gas turbines. The salient features of the developmental work are given below:

Development of oxide dispersion strengthened (ODS)-9Cr reduced activation ferritic/martensitic (RAFM) steel powders

ODS RAFM steels have been widely investigated due to their high irradiation resistance, high mechanical strength, reasonable ductility (about 15–20%) and low activation. ODS-9Cr RAFM steel powders of nominal composition (Fe-9Cr-0.12C-2W-0.2Ti-0.35Y2O3) were developed using inert gas atomisation followed by high energy ball milling. Figure 6 shows the SEM image of as-milled ODS RAFM-9Cr steel powder. ODS-9Cr RAFM steel powders were hot extruded into rods for microstructural and mechanical characterisation. Large scale production was demonstrated on pilot scale, about 150 kg of powder was supplied to Institute of Plasma Research, Gandhinagar for further processing into high thermal resistance plates (6 mm, 12 mm thickness).

Development of ODS austenitic steel for gas turbine blades

ODS austenitic steels (AODS) are considered to be a potential candidate for use as high pressure compressor and low pressure turbine blades of gas turbines replacing nickel-based super alloys for operational temperature of 650-750°C.

Fig. 6 SEM image of as-milled ODS RAFM-9Cr steel powder. Inset shows the extruded rods produced using the same powder

AODS of nominal composition Fe-18Cr-22Ni-1.6W-0.2Ti-0.35Y_2O_3 was produced by mechanical milling of pre-alloyed powders and nano yttria in a high energy horizontal ball mill (Simoloyer CM-08). The milled powders were upset-forged at 1050°C and subsequently hot-extruded at 1150°C with an extrusion ratio of 9 to get 16 mm diameter rod. The extruded rod was solution annealed at 1075°C for 1 hour and water quenched. The density of extruded and solution annealed sample is 99.6% of theoretical.

The XRD patterns of the material at various stages of processing are presented in Figure 7. It indicates that the milled powder contains austenite along with significant amount of ferrite phase, which eventually on extrusion, completely transformed into austenite phase. The EBSD grain orientation map [Figure 8 (a)] reveals that grain structure is equi-axed and randomly oriented with re-crystallized grains of average size of 340 nm. Annealing twins are also observed in some regions. The Transmission electron microscopy (TEM) done on extruded and solution annealed sample revealed dislocation sub-structure. The average dispersoid size is 7 nm [Figure 8 (b)]. The hardness of the as-milled powder and extruded and solution annealed sample was found to be 728 and 295 HVN respectively. Further work will involve measurement of tensile properties of the alloy from room temperature to 800°C.

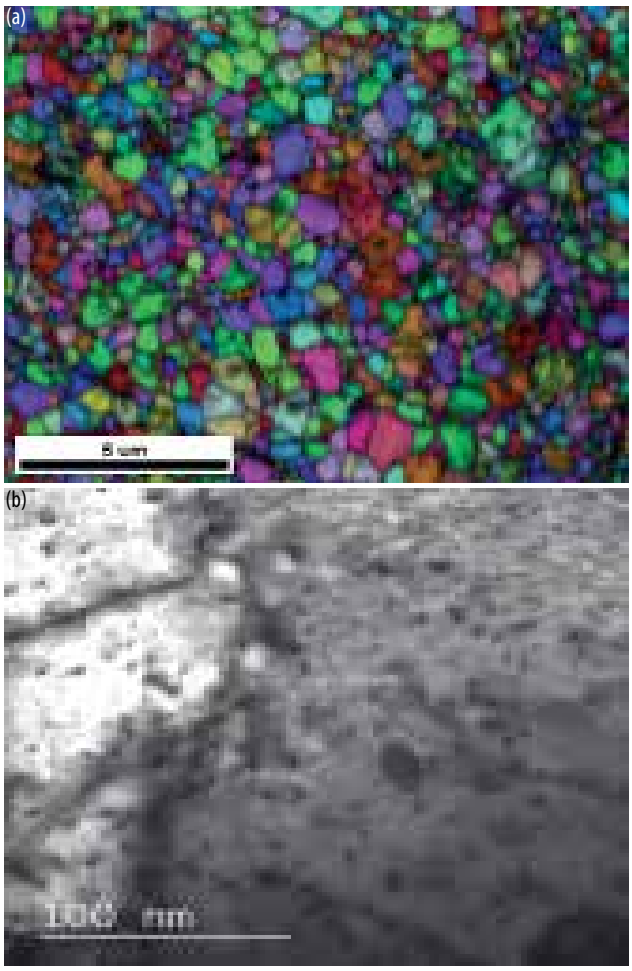


Fig. 8 (a) EBSD Grain Orientation Map; and (b) TEM image showing fine dispersoids

Tensile properties of oxide dispersed strengthened (ODS) Iron -Aluminides

Iron aluminides, particularly Fe_3Al are potential candidates for high temperature applications due to its light weight, low cost, good oxidation/ corrosion resistance and high strength at elevated temperature. However, their poor ductility at room temperature and inadequate creep resistance at elevated temperatures has hindered their commercial applicability. At ARCI, an attempt is underway to improve the room temperature ductility and high temperature creep resistance of Fe_3Al alloy by incorporating the oxide dispersion and fine grained structure. Elemental powders were milled in high energy horizontal ball mill and milled powder was extruded into rods by hot extrusion. The stress-strain behaviour of the ODS Fe_3Al at various temperatures (Figure 9) indicate that the material exhibited yield strength of 1250, 795 and 195 MPa at room temperature, 500 and 950°C respectively. The elongation of ODS-Fe_3Al

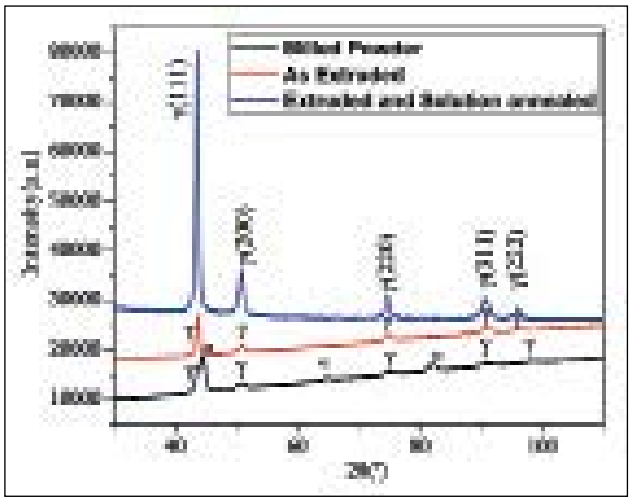


Fig. 7 XRD patterns of AODS steel at various stages of processing

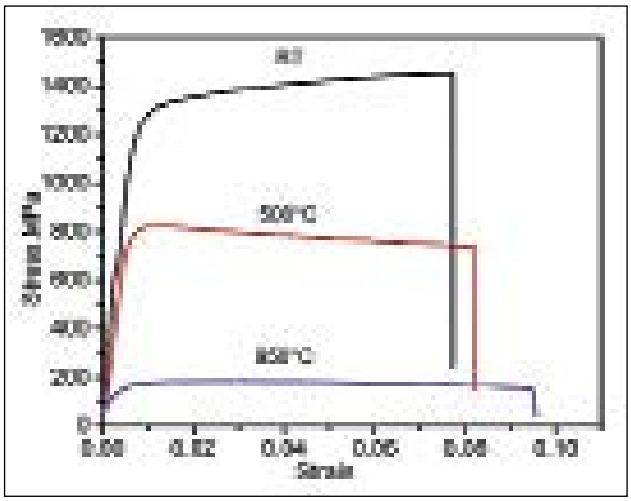


Fig. 9 Stress and strain behaviour of ODS Fe_3Al

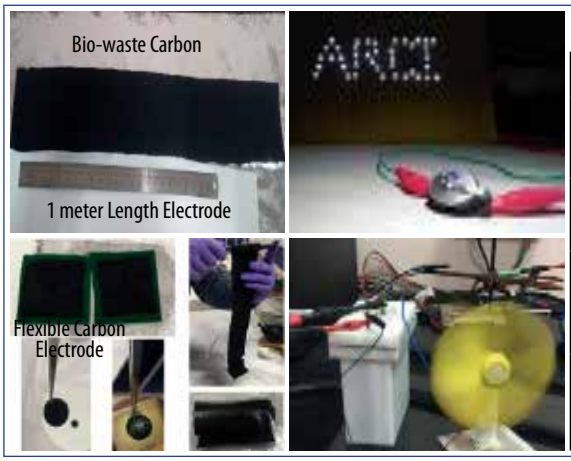
improved by 400%. These values are very high when compared to conventional Fe_3Al material.

Development of Porous Carbon Materials for Super Capacitor Application

Supercapacitors (SCs) have been recognised as promising energy storage devices due to their fast charge-discharge time, very high power density and long life cycle period as compared than most widely used lithium ion batteries in the commercial applications. SCs are commercially available but widespread usage is restricted due to their high cost and low energy density. These drawbacks can be mitigated by developing a new class of high performance carbon electrodes produced from abundant, cheap and environmentally friendly resources with low processing costs. Although the activated carbon materials are extensively used as electrode material in supercapacitor but the specific capacitance and power density characteristics of these activated carbons are limited due to their intrinsically inappropriate porous structure, disordered carbon, low graphitic carbon content etc., which in turn restrict the pore accessibility and mobility of the electrolyte ions at high current rates. Therefore, carbon materials with high graphene/ graphitic nature and open mesoporous structure are essential to reduce transportation time and to increase the mobility of ions. Further, it is equally important to identify cost-effective carbon precursor having high carbon content and low ash content to synthesize porous carbon with high carbon yield. Hence, it is a great challenge to prepare graphene or graphite like structured carbon by a simple and cost effective process using economic carbon precursor suitable for supercapacitor application. Currently, ARCI focuses mainly on the development of large scale process to convert various bio-wastes into a high surface area porous carbon material with graphitic structure suitable for supercap application. ARCI successfully synthesized high performance porous carbon materials using bio-waste like jute stick and cotton fabric by a simple chemical activation process by maintaining appropriate ratio of biomass to KOH at optimized activation temperature. The resulting carbon materials exhibit very high surface area (2396 m^2/g), large pore volume and graphene like structured carbon (ID/IG ratio of 0.180) and delivers excellent supercapacitor performance in terms of capacitance, rate capability and cyclic stability in comparison to commercial activated carbon material (Fig. 10). In addition to material development, ARCI also focuses on the design and development of supercapacitor powered E-Bicycle equipped with supercapacitor module (51V, 71Wh) in which 18 commercial cells are connected in series by laser welding. ARCI in collaboration with Hulikkal Electro India Pvt Ltd., has successfully demonstrated supercapacitor powered E-Bicycle at ARCI Hyderabad campus with driving range of 2 km (Fig. 11).

Bulk Production of 2D-nanostructured Transition Metal Sulphides

Two-dimensional (2D) nanostructured transition metal sulphides (TMS) like tungsten disulphide (WS_2) and molybdenum disulphide are excellent multi-functional materials with a wide range of applications viz. as solid lubricant for aerospace and automotive sectors, as an electronic material, as a versatile catalyst for hydrogen evolution reaction (HER) and petrochemical refinement apart from being an electrode material for Li-ion batteries, supercapacitors, etc. In recent years, these grades of materials are also finding application in biomedical sector. In all these applications, the 2D nanostructured TMS, in powder form, is required in bulk quantity and reproducible quality (either high purity or doped version) for commercial exploitation of their unique properties.



Benchmark Study

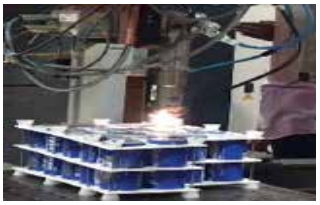
	Aqueous-IV			*Non-aqueous-2.7V*		
	Bio-waste Carbon	*Flexible Carbon*	*Maxwell*	*Bio-waste carbon*	*Flexible carbon*	*Maxwell*
Capacitance (F/g) @ 1A/g	*162*	*148*	*93*	*116*	*83*	*76*
Energy density (Wh/Kg)	*5.4*	*5.1*	*3.2*	*29*	*21*	*19*
Power density (W/Kg)	*249*	*249*	*235*	*675*	*674*	*670*

Fig. 10 Development of Indigenous carbon materials using bio-wastes and benchmark study of supercapacitor performance

Commercial Supercap

Specification:
V = 2.85 V
C = 3400 F
E= 3.85 Wh

Laser Welding



SC Module with CMS

Supercap E-Bike

Demo @ ARCI

Fig. 11 Design, development and demonstration of supercapacitor powered E-bicycle

An innovative technology was developed by ARCI between 2012-2015 for synthesizing these grades of materials by controlled gas-solid reaction in a specially designed reactor (patent filed). Different grades of 2D-WS_2 and MoS_2 nanosheet powders with an average thickness of about 10 nm (up to 8-10 layers) and lateral dimension between 40-500nm were synthesized by this ARCI method. The achievable yield using the lab scale reactor facility was about (20-50 gm per batch for 12h process duration (i.e., 50-100 gm per day). In view of the large-scale requirement for various commercial applications and as part of a project in this regard sponsored by Hindustan

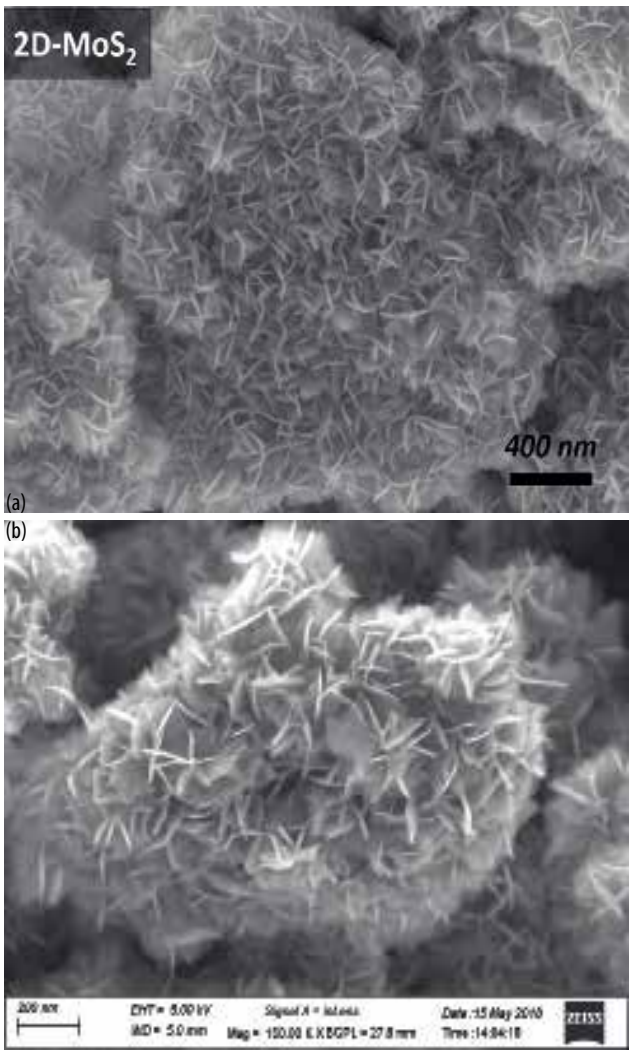


Fig. 12 2D-MoS_2 produced by (a) lab scale (b) scaled-up reactor setup at ARCI

Petroleum Corporation Limited (HPCL), a new scaled-up reactor has been designed with significantly enhanced production capability of about 2kg per day of 2D-WS_2 and MoS_2 nanosheet powders. Such higher capacity could be achieved with a modified reactor design, which enabled significant reduction in the synthesis temperature as well as batch run time. In addition, the large volume of the scaled-up reactor design also gives a provision to alter the reactant gas content considerably, maintaining certain critical amount necessary to produce various other grades of TMS apart from the 2D nanostructured variant.

The scaled-up reactor setup is currently operational at ARCI. Figure 12 (a) and (b) shows the morphology of 2D-MoS_2 nanosheet powder synthesized by lab-scale reactor and new scaled-up reactor, respectively. The grade of the product can be easily varied in the new scaled-up reactor with change in the various control parameters. This gives considerable advantage to the process as different grades of the 2D-TMS powders are required for various types of applications.

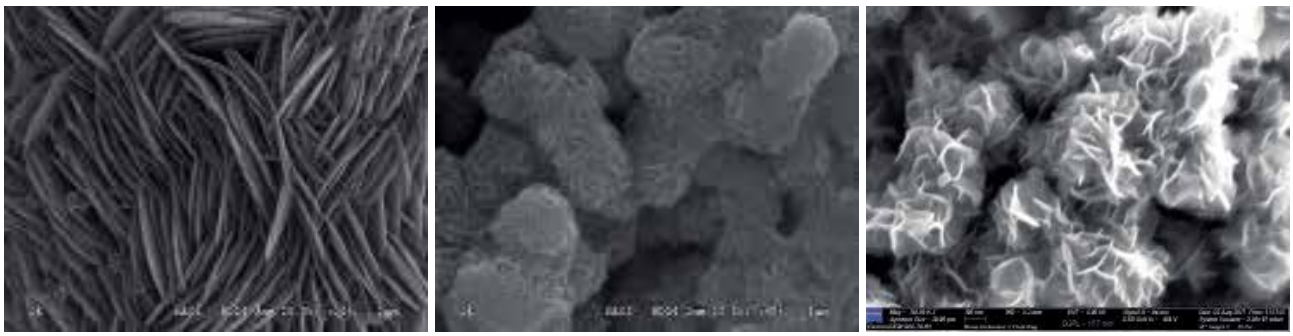


Fig. 13 FESEM photograph of the MoS_2 nanostructures used for electrode fabrication

Nano-structured Metal and Metal Composite (MoS_2) Electro Catalyst Electrode Development for Hydrogen Energy

Electrode material development for electrochemical water splitting into hydrogen and oxygen is highly desirable to attain independence from fossil fuels. Ideally, present day technology utilizes highly expensive and rare metal systems as platinum or its alloys as electrode material. This in turn hinders the commercialization of hydrogen based energy technology. Nanomaterials have ability to tune in the material properties by virtue of the size and surface control. Thus material nano-structuring has become an important criterion to achieve best desirable properties in any potential electro-catalyst material systems of sulfides/ carbides/phosphides for Hydrogen as well as oxygen evolution reaction.

ARCI is fabricating nanostructured electrodes (MoS_2, etc.) to achieve economically viable solution to generate hydrogen by electrolysis. Figure 13 shows nanostructure morphology of MoS_2 used in electrode fabrication. These films have shown excellent electrochemical properties when compared with Platinum counterparts. This has tremendous applications as alternative fuel for transport, mining, steel, jewellery and health sector industries We are utilizing the nanostructures for improving the electrolyzer performance.

Powders for Additive Manufacturing

During the last few years, digital manufacturing of metallic components directly from electronic data based on layer-by-layer fabrication has evolved from rapid prototyping to additive manufacturing (AM). In contrast to the conventional fabrication technologies, AM offers much more freedom in sophisticated material and thus module designing. In AM, the design of component is no longer restricted by the production methodology and additionally it offers many advantages. Since past to the present time, AM has evolved to a mature stage art methodology as well as capability and thus it is expected to find a significant place in the future of manufacturing. However, it is universally acknowledged that the quality of final AM component depends on the quality of the powder that one starts with. Additionally, the process yields in manufacturing of powders for AM are generally very low (<20%). At present nickel-based super alloy powders for AM are being produced by only few reputed international companies. ARCI, having the state of the art inert gas atomizer facility has embarked upon the development of powders for AM, Figure 14 (a) shows the morphology of the particles produced at ARCI (IN 718). Figure 14 (b) shows particle size distribution in comparison to the commercial powders. This suggests that the ARCI powder can be used for powder based AM. Component development using this powder is under progress.

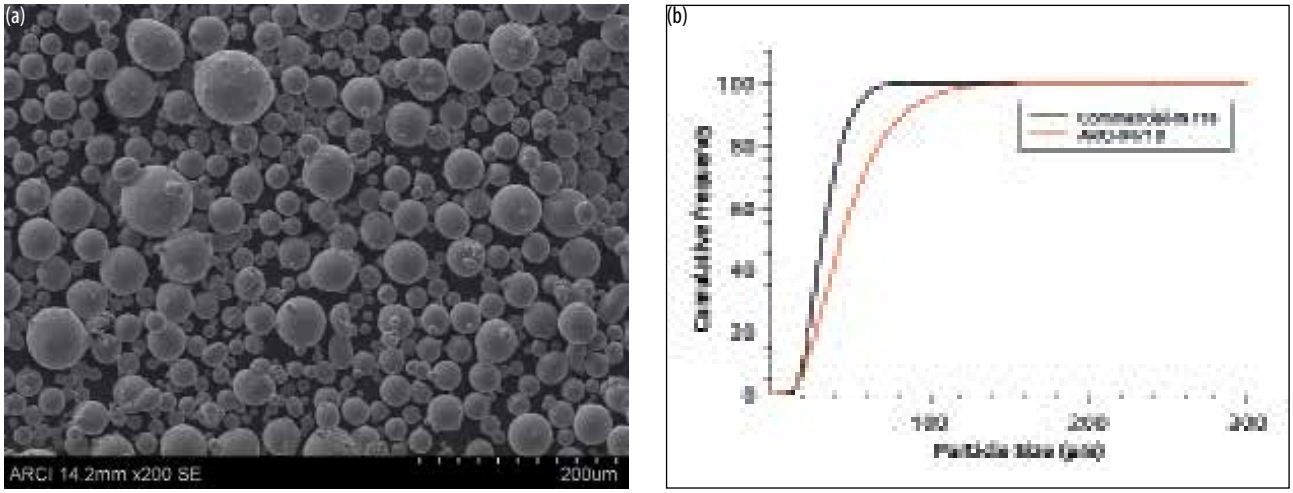


Fig. 14 (a) SEM morphology of IN718 powder produced at ARCI (b) particle size distribution of ARCI powder in comparison with the commercial powder

Centre for Engineered Coatings

Equipped with unique and advanced surface engineering infrastructure, sustained efforts were continued towards new application centric R&D of national relevance, realizing the objectives of various ongoing sponsored R&D projects and initiation of futuristic in-house R&D programs of industrial relevance.

Major Achievements include the design and development of advanced detonation spray coating (DSC) system with enhanced productivity; development of portable cold spray coating systems with multiple nozzle designs; Micro Arc Oxidation (MAO) coatings with simultaneous protection against wear, corrosion and fatigue; Cathodic arc PVD coatings for wear resistance application; solution precursor plasma spray coatings with enhanced Calcia-Alumina-Magnesia-Silica (CMAS) volcanic ash deposit resistance in TBC; Pulsed Electro Deposited (PED) coatings to replace environmentally hazardous hard chrome plating; and development of Thermal Barrier Coatings (TBC) for critical aero engine applications through electron beam PVD technology.

Based on promising results obtained the PED technology has been transferred to an industry and is now being implemented. A custom built MAO coating system has been fabricated for shipping to an academic institution for application development. Cold spray technology development activities at ARCI have now reached a final stage of commercialization. The technology for readiness in terms of documentation (working manual, complete engineering drawings) is also in final stages. A major initiative has been taken up to enhance the capabilities to understand nano mechanical behavior of various coatings.

Pulsed Electro Deposited (PED) Coatings Lab
Inset (a) PED coating inside engine cylinder liner (b) PED coating on engine exaust valves

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Advanced Nanomechanical Characterization (ANCC) for high performance coatings

The recently established joint demonstration center for advanced nanomechanical characterization (ANCC) in collaboration with Nanomechanics Inc, USA, is actively engaged in developing novel nanomechanical testing methodologies and next generation testing equipment. High speed mechanical property mapping is one of the key capabilities. Extensive mechanical property mapping studies (> 200000 indentation tests) have been carried out to understand the effect of thermal cycling on the local mechanical properties of plasma sprayed thermal barrier coatings (TBC) with different bond coat materials, NiCrAlY and NiCoCrAlY. The study enabled measurement of mechanical properties of thermally grown oxide (TGO) during thermal cycling, at the interface of the bond coat and the top coat for the very first time. While the TGO has been well studied microstructurally, its local mechanical properties have not been reported till date and the present work could provide significant insights for improving the thermal cycling life of the TBC as the TGO is one of the weakest links in the TBC system.

Development of Thermal Barrier Coating (TBC) using EBPVD System for Gas Turbine Applications

The coating formation mechanism in EBPVD process consists of accelerating the thermal electrons in an electron gun under high voltages leading to vaporization of ingot material and eventual condensation on the substrate. Compared to other vapour-based methods, EBPVD has many distinct characteristic advantages namely (a) higher deposition rate, (b) strong substrate-coating adhesion, (c) smoother surface finish and (d) columnar structure with controlled porosity. Towards capitalizing such advantages that are vitally useful for developing TBCs, focused R&D studies were conducted.

Owing to the high melting point, low thermal conductivity and favorable coefficient of thermal expansion suitable for coating nickel based super alloys, 8%-yttrium stabilized zirconia (YSZ) coatings are popularly being used in gas turbine engines. Therefore, the process parameters were optimized to deposit NiCoCrAlY bond coat of 60 µm thickness on nickel based super alloy followed by 160 µm thick columnar YSZ coatings through EBPVD route. Through the careful selection of process parameters, the coatings deposited were ensured to be uniform in terms of thickness even on the curved sample geometries by resorting to a specially designed multiple sample holder mechanism. The microstructural analysis indicates a good columnar growth, uniformly thick bond coat and top coat combination meeting the critical requirements of TBC (Fig.1). Further, the high temperature oxidation resistance and the thermal shock performance are being assessed through thermal cycling tests at elevated temperatures. The successful development of such TBCs are expected to pave the path for its application in gas turbine sector.

Development of Cathodic Arc Physical Vapor Deposition (CAPVD) Coatings for functional applications

Among the several PVD techniques, the cathodic arc PVD (CAPVD) is known for depositing coatings with great degree of homogeneity (in terms of thickness), high deposition rate, density close to bulk materials and good adhesion strength (due to high ion to neutral ratio). Towards capitalizing the aforementioned advantages, cathodic arc deposited coatings have been developed to cater to functional requirements of various industrial components:

(a) Erosion resistant coatings

Cathodic arc grown erosion resistant coatings (TiN, TiZrN & multi-layers of TiN/TiZrN) are highly popular in aerospace applications to enhance compressor blade life

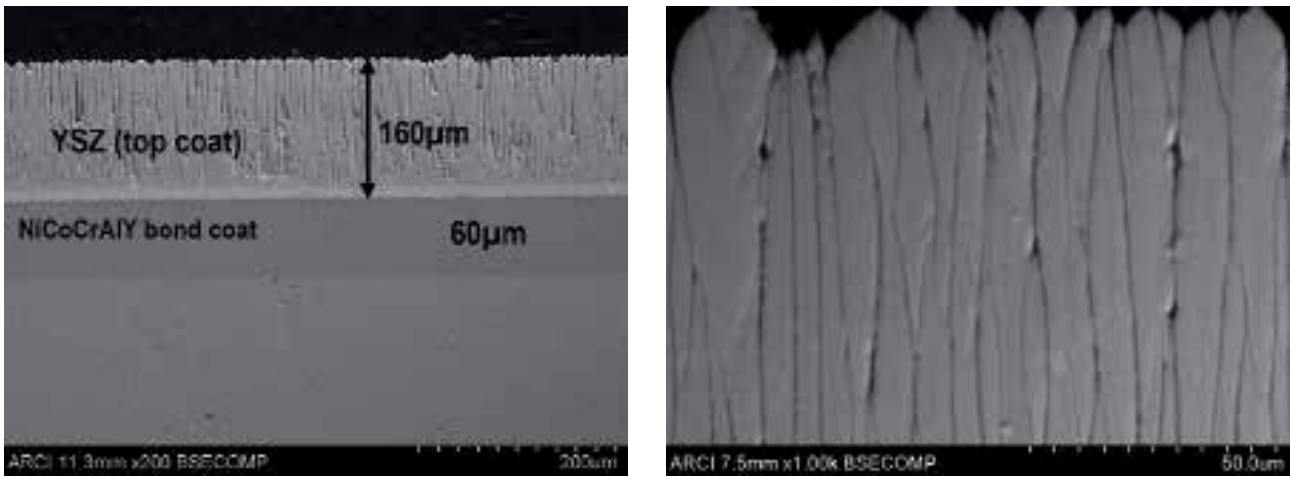

Fig. 1 TBC coating architecture illustrating NiCoCrAlY bond coat and YSZ top coat deposited by EBPVD route while the top coat columnar structure with optimum inter-columnar porosity is the key factor for development of TBCs

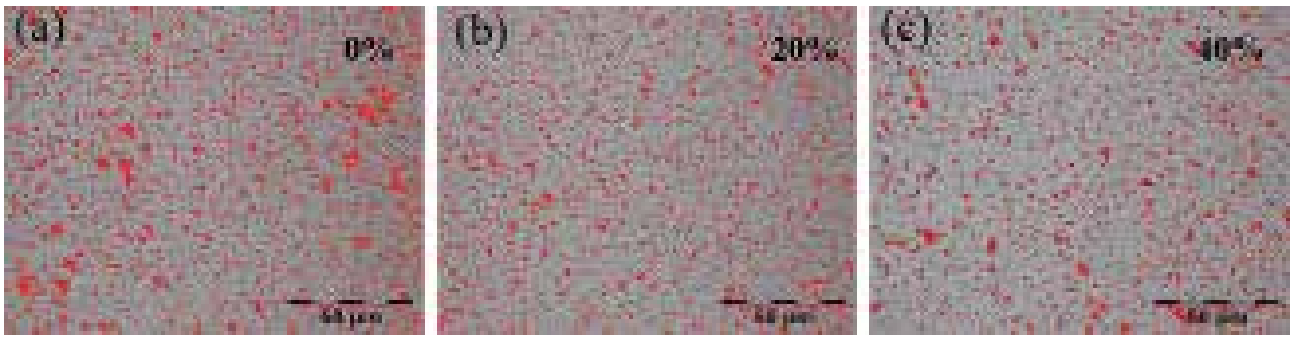

Fig. 2 Optical image of a TiN coatings representing the reduced droplets/damage area with pulsed bias duty cycle

by many folds. Though the coatings impart significant life enhancement, the droplet (defect) density is deemed to limit the eventual life of the component (Fig. 2). Therefore, an attempt was made to develop relatively thicker (15 µm) multi-layer TiN coatings with minimized defect and residual stresses using pulsed bias for erosion resistant applications. The effect of pulsed biasing parameters (duty cycle and magnitude of the voltage) and coating configuration on physical, mechanical and erosion properties of the TiN coatings were studied systematically. The erosion resistance property was studied using % area damage measurement technique. i.e. the progress in physical damage to the coating with the erodent flux. The TiN coatings grown using – 500 V pulsed bias with 40% duty cycle have shown the best erosion resistant properties with nearly 50% enhancement compared to conventionally grown ones. These coatings were found to have the lowest residual stress with good adhesion and mechanical hardness. The coatings were also grown in multi-layer structure to further minimize stresses in the coatings. The two repeating layers in the multi-layer structure were selected in such a way that, they exhibit different elastic modulus. In the present study TiN grown at two different nitrogen partial pressures were used to achieve desired modulus values (TiNE-450: Modulus 450 GPa & TiNE-350: Modulus 350 GPa). The 15 µm thicker multi-layered TiNE-450/TiNE-350 pulsed bias grown coatings have shown the best properties.

(b) Solar selective coatings for solar thermal power generation

In the concentrating solar power (CSP) technology, heat is generated using concentrated solar energy through a photothermal process which in turn is used to generate electricity. Most of these plants make use of Heat Collection Elements (HCE's) like copper or stainless-steel tubes for harnessing sunlight. As such, bare steel tubes have low absorptivity: $\alpha = 0.36$ and high emissivity: $\varepsilon = 0.14$, therefore needs a suitable surface modification to enhance the optical properties. The best possible way of according surface functionalization is by depositing spectrally selective coatings.

The use of CAPVD technique for solar selective applications has gained interest due to several advantages such as high coating-substrate adhesion, homogeneity in thickness and composition of the coating, high deposition rate and non-toxicity. Accordingly, a multi-layer solar selective coating incorporated with two absorbing layers and two anti-reflection layers (SS/Cr/G-CrTiAlN/TiAlN/AlSiN/AlSiO) was proposed for flat plate collectors and developed successfully (Fig. 3). This coating proved to exhibit absorption (α) of 0.96 and an emissivity (ε) of 0.10 on SS 304 plates. Though Cr/G-CrTiAlN/TiAlN/AlSiN/AlSiO coating exhibited best optical properties, upscaling and reproducibility was challenging due to the presence of the gradient layer (G-CrTiAlN). Attempts were made to avoid the gradient layer while maintaining the optical properties and enhancing the physical properties. A novel spectrally selective multilayer (ML) coating (Cr/ML(CrN/AlTiN)/AlSiN/AlSiO) was deposited on SS 316 substrates via Cathodic Arc Physical Vapour Deposition (CAPVD) technique. The composition and thickness of the constituent layers were optimized to achieve high absorptivity ($\alpha = 0.93 – 0.96$) and low emissivity ($\varepsilon = 0.10 – 0.12$). The developed coatings were studied systematically for their thermal, environmental (corrosion), mechanical and physical stability. The thermal stability tests were carried out using a thermal cycling test in the open atmosphere. Over a period, the

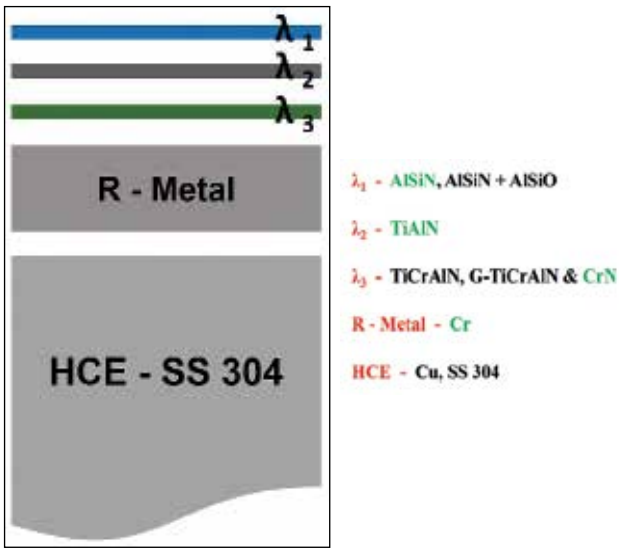

Fig. 3 Schematic of a basic solar selective coatings developed at ARCI

absorptance was found to decrease slightly from 0.96 to 0.93. In case of the corrosion studies, a similar decrease was observed beyond 175 hrs. In addition to above, the coatings were also subjected to scratch resistance and wettability measurements. The adhesion strength of the coatings is found to be in the range 6 - 10 N and exhibits a reasonable hydrophobic nature (104°). These results indicate that Cr/ML(CrN/AlTiN)/AlSiN/AlSiO coatings not only exhibit state-of-the-art solar selective properties but are also able to withstand harsh environments and may prove to be a more economical solution relating to Concentrated Solar Power (CSP) systems.

(c) Superhard coatings for improved cutting tool performance

Superhard nanocomposite (NC) coatings of the type nanocrystalline-AlTiN/a-Si_3N_4 with hardness in the range of 40 GPa are very well known to outperform conventional PVD coatings such as TiN (24 GPa), TiAlN (30 GPa) or AlTiN (26 GPa). It was observed that multi-layered TiN/NC coatings with optimized hardness and toughness performed better than individual softer TiN or hard and brittle nanocomposite coatings. To take this observation forward, an attempt has been made to compare the performance of TiN/NC coatings with other coatings, namely, AlTiN and multi-layered TiN/AlTiN/NC. Accordingly, the WC-Co turning inserts have been deposited with PVD coatings of monolayer AlTiN and mulati-layered TiN/NC (30 GPa) and TiN/AlTiN/NC (30 GPa) and further tested at potential user machine for conducting real time performance assessment (Fig. 4). The results obtained indicate that uncoated WC-Co insert, having low hardness, is unable to resist abrasion and therefore wears out in shorter time. Being harder than WC-Co, AlTiN is able to resist abrasive wear to a moderate extent. Owing to the presence of alternate layers of TiN and nanocomposite, the multi-layer TiN/NC coating with optimized hardness value and high toughness showed best performance during milling which is on par with the commercially available state-of-the-art AlTiCN coatings. Based on the results obtained, the need for tailoring the coating architecture for specific cutting tool application has been realized and further studies in this direction have been initiated.

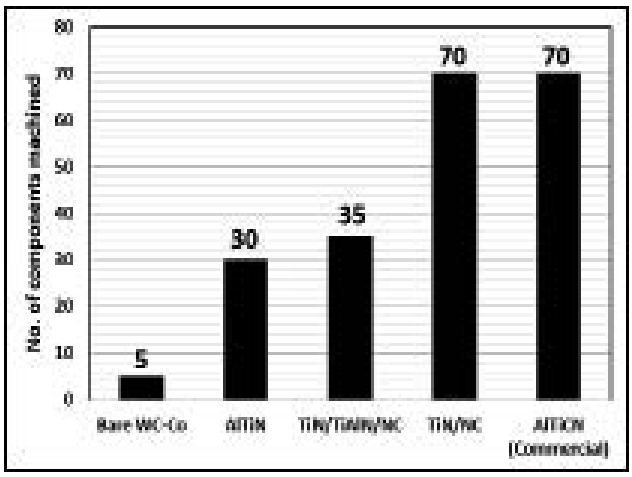

Fig. 4 Turning performance of PVD coatings in comparison with uncoated inserts

Improvements in Gas Turbine Performance via Novel Plasma Spray Coatings for Protection Against Ingested Species

The DST-EPSRC sponsored joint project involves ARCI, India and University of Cambridge & Cranfield University, UK in which ARCI works towards the development of novel protective coatings by conventional atmospheric plasma spray (APS) and Solution Precursor Plasma Spray (SPPS) technique which also envisages the development of futuristic TBC materials and processes. The main objective is to design high performance thermal barrier materials to counter sintering effects within the top coat (promoted by the ingested species from CMAS volcanic ash) and identify means to improve their thermo-mechanical stability for its use in gas turbines of aero-engines and IGTs.

Considering the performance requirements and also the compatibility issues with the standard bond coat, novel top coat microstructures were developed to overcome the CMAS infiltration through hybrid composite and layered architecture (Fig. 5). Accordingly, advanced ceramic materials based on zirconates and cerates were chosen and synthesized as standalone and with doped systems to meet the performance requirements desired for futuristic TBCs.

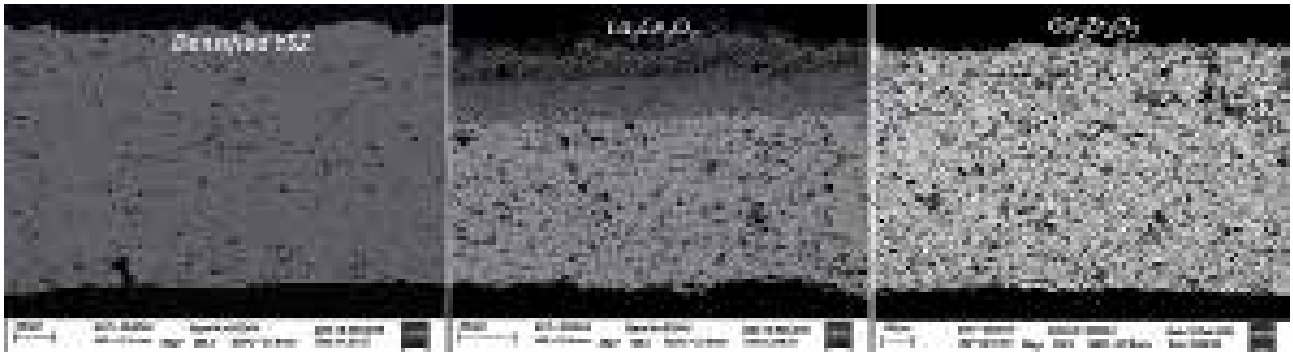

Fig. 5 Cross-sectional microstructure of infiltrated TBCs indicating the level of ingestion of volcanic ash species

The standard gadolinium zirconates were considered as the benchmark due to their enhanced CMAS resistance and was compared with indigenously synthesized lanthanum cerates doped with various rare earth oxides. Simultaneously, SPPS coatings were generated with composite and layered microstructural features and compared with the conventional APS coatings. The performance benefits of doped cerates against ingestion of volcanic ash or CMAS could be seen clearly with the formation of arresting reaction layer, similar to the features observed in the standard gadolinium zirconate coatings. Additionally, the thermal cyclic life of the double layered coatings designed in conjunction with the conventional YSZ was found to be satisfactory. The above detailed studies allow the realization of futuristic thermal barrier materials which can potentially result in higher efficiency for the next generation gas turbines operating at elevated temperatures.

Development of Tungsten Coating Technology for First Wall Application in Fusion Grade Tokamak such as First Wall of ITER, TBM and DEMO

The objective of the project is to develop high performance tungsten coatings for first wall applications for diverters in plasma facing components (PFC) to withstand high temperature, erosion and thermal shock. Atmospheric plasma spray parameters have been optimized to deposit thick coatings (~500 µm) with low porosity and oxide contents, as desired for the proposed applications. The coatings were demonstrated on SS316LN, Cu and RAFM steel substrates. The process parameter optimization studies were carried out in understanding the role of each parameter as well as the extent of influence on the quality of coatings. Based on the optimization studies, W coatings were deposited on test mockups to assess their performance under the influence of simulated heat flux conditions exposed in cyclic mode (Fig. 6). Based on the satisfactory performance of W coatings on various substrate materials including the CuCrZr which survived for more than 1000 cycles, it was concluded that the W coatings developed at ARCI were qualified for further evaluation. A demonstration of W coating deposition on larger components was also made with the existing facility at ARCI and can provide necessary technological support during the installation of ITER in India.

Technology Transfer of Pulse Electrodepositon Process Know-how

In accordance with Government of India's prestigious "Make in India" program, Hyderabad based M/s. HEW proposed to establish "Advanced Surface Finishing Labs" with techno-scientific assistance and support from ARCI. The demonstrated research outcome at the centre has led to the transfer of process know-how related to the electrodeposition of Ni-based alloy. As mutually agreed, CEC has provided assistance in design, fabrication and establishment of a pilot scale plant with additional process steps to meet the HEW requirements. Utilizing the pilot plot, the Ni-W coatings were deposited on industrial components such as automotive engine valves, cylinder liners, large area plates that are currently under user evaluation.

Design, Development and Transfer of MAO Technological Systems

In order to popularize the micro arc oxidation (MAO) technology and simultaneously extend the benefits to academic institutions in terms of scholar training and research purposes, design and transfer of R&D scale systems has been initiated. In continuation to one such supply to M/s. Annamalai University before, after analyzing the project requirements of NIT-Tiruchirappalli, a custom built 30 kVA MAO system with advanced safety features, ease and ergonomical operation was designed, fabricated, inspected, thoroughly tested at ARCI. Unlike before, for enabling ready use of exciting technology, the project was accepted on turnkey basis. In addition, towards extending application base of MAO coatings with enhanced structural integrity, unique technological solution for simultaneous protection of wear, corrosion and fatigue has been developed at ARCI.

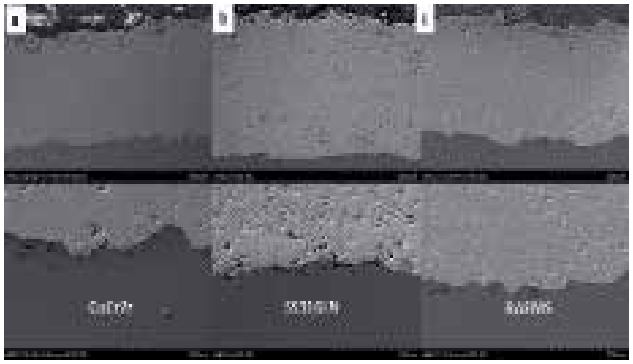

Fig.6 Cross-sectional microstructure of W coating deposited on various substrates as per the project requirements

Fig. 7 Technology know-how transfer agreement signing between ARCI and HEW

Fig. 8 Exclusively designed and custom built MAO control system being supplied to NIT-Tiruchirappalli in operation during its testing at ARCI

Development of Superconducting Cavity by Cold Spray Technique

Towards developing dense, thick superconducting Niobium coating on copper cavity by cold spray technique, spray grade niobium was deposited on copper substrates and heat treated at different temperatures. All the samples were tested for oxygen content and superconductivity performance. ARCI cold sprayed samples were compared with the standard Niobium samples of global origin. The effect of oxygen content and inter-splat boundary fraction on the superconductivity of cold sprayed niobium is being investigated. Critical temperature for superconductivity of cold sprayed samples were estimated between 8.4 to 8.6 K as against 9.25 K of bulk niobium.

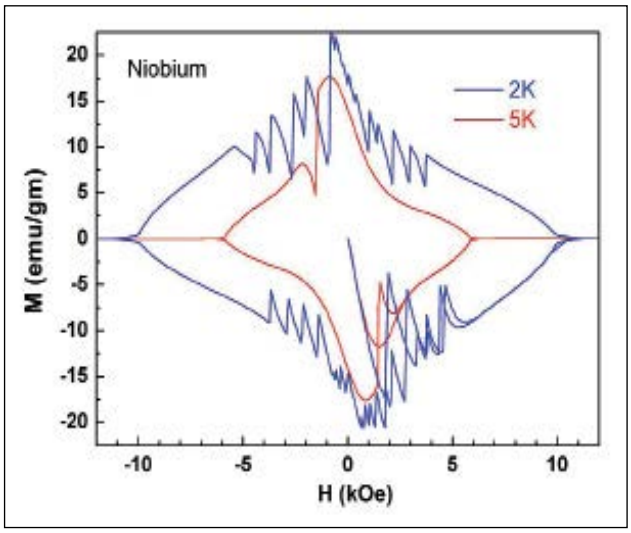

Fig. 9 DC magnetization plot of niobium heat treated at 1250°C.

Development of High Entropy Alloy Coatings as Potential Bond Coat Materials for High Temperature Turbine Engine Applications

Towards developing novel, dense Al and Mn based high entropy alloy (HEA) coatings on SS and super alloy substrates, Al and Mn based HEA powders were cold spray deposited on SS and Super alloy substrates at different process conditions. The initial phases have been successfully retained in the cold sprayed coatings since cold spray is a low temperature variant of thermal spraying. Accordingly, the SEM microstructure which is shown in the image reveals that the HEA coating is dense and very well bonded with the substrate. The XRD analysis reveals the phase retention during deposition process which is unlikely in the case of conventional thermal spray techniques such as plasma spray and HVOF spray.

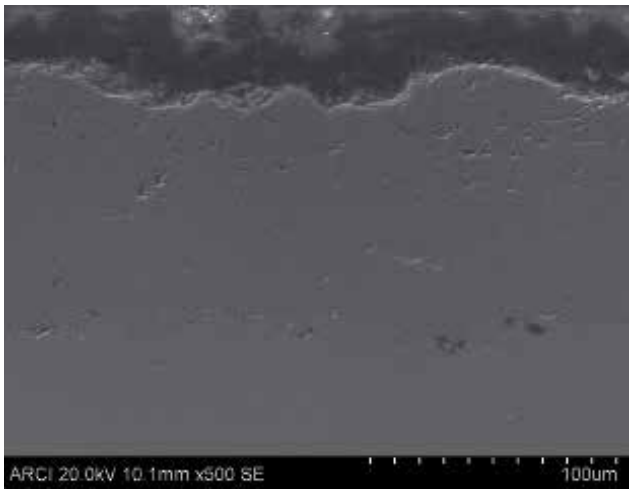

Fig. 10 Dense microstructure of high entropy alloy (HEA) coatings deposited using cold spray technology with high degree of phase retention in the coating

Centre for Ceramic Processing

Centre for Ceramic Processing has been successful in its efforts to fulfil commitments on technology demonstration and transfer and also supply of deliverables to companies from various industry sectors in line with ARCI's mandate and has also initiated various ongoing/new research programs. The Centre has upgraded its Hot isostatic pressing technology for broadband Zinc Sulphide having close to theoretical transmission and has demonstrated and transferred the same to a company. During the period, the Centre has also developed ceramic holders with grooved channels for energy efficient sanitary pad incinerators in collaboration with M/s Sowbal Aerothermics and National Environmental Engineering Research Institute (NEERI) and has demonstrated the same for ecofriendly and energy efficient incineration. The Centre is also planning to launch the device "GreenDispo" in the market in line with Swachh Bharat Mission (SBM).

Development of know-how and delivery of porous zirconia thermally insulating sleeves with excellent thermal conductivity of 0.7 W.m/K combined with a flexural strength of 70 MPa and sodium beta alumina ceramics for Na-S batteries were successfully completed. Feasibility studies on 3-D printing of traditional and advanced ceramics based on extrusion shaping expertise at the Centre is also in progress. A new program on the development of porous magnesia and Magneto Rheological Polishing of optical components is also initiated as a part of international collaboration.

Ceramic holders with grooved channels and Sanitary Napkin Incinerators

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Energy Efficient Air Heaters and Eco-friendly Sanitary Napkin Incinerators

With ever increasing use of sanitary napkins due to enhanced awareness, volume of associated waste will increase manifold in years to come posing big challenge to safe disposal. A research programme is being persuaded at ARCI jointly in collaboration with CSIR-National Environmental Engineering Research Institute (CSIR-NEERI), Nagpur and M/s. Sowbal Aerothermics Hyderabad. Slip casting slurry having optimum viscosity with specially engineered ceramic formulations were developed and formed into ceramic plates with grooves that channelize the heat in one direction. This results in lower ignition time, increased heater temperature, increased life expectancy in combination with reduced power consumption. These developments with cleaner energy system design related expertise of CSIR-NEERI along with long-standing experience and innovative approaches of M/s. Sowbal Aerothermics in thermal engineering have resulted in the development of GreenDispo demonstrating 1000±50°C which is mandatory to minimize hazardous emissions as recommended by WHO and Indian Waste Management Rule 2016. GreenDispo currently designed with the power rating of 800 Watts &1000 Watts and a unit size of about 2-3 Cubic feet volume. Prototypes tested at CSIR-NEERI have shown the particulate matter and CO in the range of 20-35 mg/m^3 and 68-95 ppm, respectively. Further, the reliability in performance was also established through field trials by installing the device at a few colleges and public places.

Fig. 1 GreenDispo prototypes undergoing testing at CSIR-NEERI, Nagpur

Synthesis of 1-butyl-3-methylimidazolium tetrafluoroborate (BMIM-BF4): A Room Temperature Ionic Liquid

1-butyl-3-methylimidazolium tetrafluoroborate (BMIM-BF4) room temperature ionic liquid (RTIL), because of its zero or no vapour pressure, is used as a helper catalyst to perform electrochemical reduction of CO_2 (ECR) to CO and also in various similar applications. BMIM-BF4 has already demonstrated a faradaic efficiency of >95%, including a selectivity of 100%, and current density of > 140 mA/cm^2 at over-potentials below 1 V in the ECR of CO_2 to CO. This article reports the cost-effective route for the synthesis of BMIM-BF4 developed as a part of the programme on artificial photosynthesis being persuaded at ARCI. The various reaction steps and processing conditions such as temperature, pressure, reflexing etc. are optimized for the synthesis of BIMIM-BF4 from 1-methylimidazolium, 1-bromo-butane and sodium tetraborate. BMIM-BF4 formation is confirmed by NMR and mass spectroscopy and a typical H1-NMR spectrum recorded for BMIM-BF4 is shown in Fig. 2.

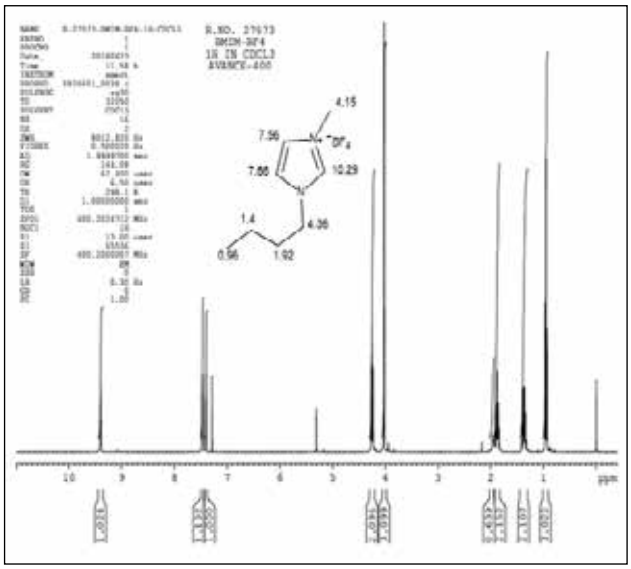

Fig. 2 H1-NMR spectrum of BMIM-BF4 RTIL synthesized at ARCI, Hyderabad

Sodium Beta Alumina Ceramics for Na-S Battery Applications

In the recent times, a renewed interest has been shown across the globe on the Sodium Beta Alumina (NBA), a well-known Na+ conductor due to many reasons like escalating demand for mobile energy requirements. NBA being already well identified as the candidate material especially due to increase in the demand for Li and its sources are already diminishing. ARCI has undertaken a sponsored R&D and developed the NBA ceramic formulations with selected additives. XRD patterns of the Sodium Beta Alumina powder is shown in Fig. 3. The powder formulations were granulated and Cold Isostatically Pressed (CIP) in to the one end closed tubes. The one end closed tubes are sintered to final dimensions of 30 mm diameter and height of 50 mm and a wall thickness of 2 - 3mm with a sintered density of 95-96%. Rate of heating and peak temperature of sintering are found to be very critical in achieving the crack and defect-free samples with required ionic conductivity values. The ionic conductivity of the sintered NBA specimen was found to be 0.02 S/cm. The samples are being integrated and the fabrication of Na-S battery is in progress at user's facility.

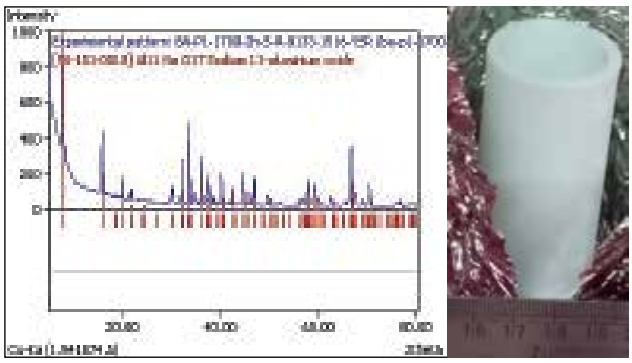

Fig. 3 The powder XRD pattern showing the formation of the desired phase of Sodium Beta Alumina and the one end closed sintered tube

Chemically Stable Polycrystalline Ceramics for Molten Sodium Environment

Magnesium Oxide (MgO) due to its inherent high melting point, good chemical stability, moderate strength and environmental compatibility is being explored for applications under extreme chemical environments. In this ongoing project, commercially available magnesium oxide with purity >99% was used. The powder was characterized for their particle size distribution and shown a range of particle sizes from 200-900nm with an average particle size of 444 nm. In order to improve the processability, powders were subjected to surface passivation under controlled thermal treatment conditions in order to retain the activity. The passivated powder was initially blended with polyvinylpyrolidine (2 wt %) as a binder in ethanol and compacted into disks of 30 mm in diameter and 10 mm in height. Samples were subjected to sintering under controlled rate at 1550°C and the sintered samples were subjected to density, SEM, elastic modulus and dilatometric analysis. A density of 97% of theoretical density was achieved with uniform distribution of porosity as revealed by SEM studies (Fig. 4). Dilatometric analysis of the sintered sample resulted with CTE of 15.3×10^{-6}/°C from RT to 600°C. Sodium compatibility studies have indicated the chemical stability with no change in chemistry. Studies are in progress to establish the durability under sodium melt.

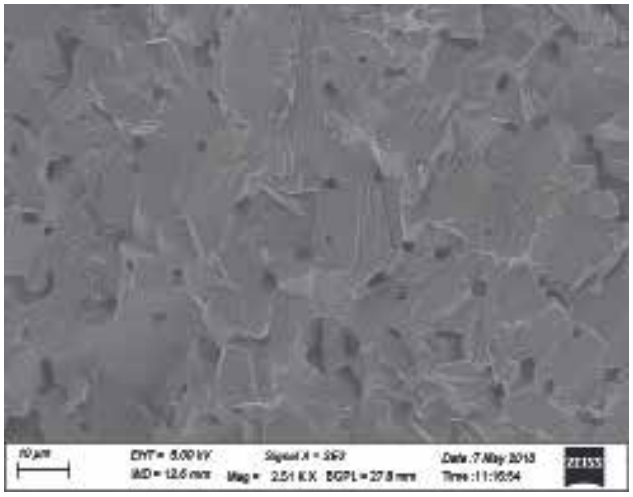

Fig. 4 SEM micrograph showing the uniform distribution of pores

Hot Isostatic Pressing of Polycrystalline Zinc Sulphide (ZnS) Ceramics

Chemical Vapour Deposition of ZnS based on reaction between metallic Zn and hydrogen sulphide results in the formation of Zn-H as the by-product affecting the broad band transmission with characteristics absorption band appearing at 6.5 μm. In an attempt to eliminate the Zn-H, the CVD Zinc sulphide (ZnS) was subjected to heat treatment under vacuum and Hot Isostatic Pressing (HIP). The temperature was limited to 9750C in both cases in view of the crystallographic transformation of cubic to hexagonal phase which is not desirable for optical properties. The samples have shown identical densities of 4.086 and 4.079 g/cc, respectively with significantly low transmission values of 30% in case of vacuum sintered samples in comparison to the >70 % transmission observed with isostatically pressed samples. The poor transmission of the vacuum sintered samples can be attributed to presence of residual pores formed as a result of evolution of hydrogen from Zn-H as revealed by the microstructures (Fig. 5(a) represented by arrows). Though both the specimens exhibited similar grain sizes the morphology of grains was different with significant twinning (Fig. 5(b), represented by arrows) in case of isostatically pressed specimens. Under HIP condition the simultaneous application of temperature and a pressure of 135 MPa have resulted in the closure of residual pores and enhancing transmission values to 70%.

Fig. 5 Microstructure of ZnS samples (a) Vacuum sintered and (b) HIPed under identical temperature

Centre for Laser Processing of Materials

The centre has been conducting R&D in the areas of micro-processing, surface engineering, repair & refurbishment, materials joining and drilling with the help of an array of laser processing systems available at the centre. In the current year, the centre made two major acquisitions, a powder bed selective laser melting (SLM) metal additive manufacturing system and a 10 kW fibre coupled diode laser for surface engineering and materials joining to cover a wider range of applications. As in the past years, emphasis has been on development of processes and application development for various industrial sectors. A first attempt has been made to model the laser hardening and cladding processes.

A major thrust was given to develop capabilities in the area of "Additive Manufacturing", keeping in view the extensive related capabilities at ARCI in the areas such as laser materials processing, powder production, special heat treatments, metallurgical characterization and mechanical characterization (including creep, fatigue and nanomechanical characterization) in order to take this futuristic technology towards applications. Aerospace, repair of components, special tooling and biomedical devices have been chosen as application areas.

Major projects in the area of micromachining using ultrafast laser processing system for surface texturing has been pursued. In the area of laser hardening, substantial effort has been put on development of novel and innovative methods of hardening bearing components for increased capacity and performance. Laser clad deposition technology was demonstrated for repair of aerospace components. Laser cladding of thermal power plant components technology was transferred to an industry. Feasibility of laser MIG hybrid welding of thick sections for power plant applications in plate-plate and plate-tube configurations has been demonstrated as a precursor to major R&D programme to be taken up in the near future towards the Advanced Ultra Supercritical Technology. Laser brazing technique has been continued on joining of Aluminium alloys to Steel.

Several industry tie-ups and collaborations with academic institutions through IMPRINT, DST/SERB advanced manufacturing technology programmes have been pursued.

Overall, it has been a fairly successful year for the centre in terms of technology transfer, application development, enhancement of capabilities and facilities and introduction of new and advanced technology areas into its portfolio. Highlights of the same are presented in the following sections.

Laser based metal additive manufacturing system

10 kW fiber coupled diode laser

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Development of Laser Surface Texturing Technology for Automotive Applications

Laser surface texturing process involves creation of microfeatures e.g., tiny dimples, usually distributed in a certain pattern, covering only a fraction of the surface of the material that is being treated. The process offers several advantages for tribological applications, including improved load capacity, wear resistance, lubrication lifetime, and reduced friction coefficient. The most familiar and earliest commercial application of surface texturing is that of cylinder liner honing. In a diesel engine, up to 60 % of the mechanical losses result from friction between piston rings and cylinder walls. It's possible to achieve 10 % or more reduction in friction using a surface textured piston ring/cylinder liner. It has been estimated that 10% reduction in friction loss can lead to a decrease in fuel consumption up to 3 % with corresponding decrease in CO_2 emission.

In the present study, surface modification of gray cast iron, using femtosecond laser irradiation, is adopted in order to establish an optimal geometrical pattern with dimples, grooves and cross-hatch features and dimensions, to improve wear and friction behavior. The surface texturing was done using an ultrafast laser with pulse duration of 100 fs and wavelength of 800 nm. The effect of range of process parameters such as pulse energy, scan velocity and textured density on the performance characteristics of laser textured samples was investigated. The textured surfaces show a significant reduction in friction coefficient and improvement in wear resistance. Among various patterns tried, the pattern with 55% texture density gave the best results.

Additive Manufacturing using Powder Bed Selective Laser Melting System

Additive manufacturing and 3D printing are now perceived as the future of manufacturing technology. It gives immense flexibility to the designers to conceive designs with advantages such as light weighting, multiple parts consolidation into single part and fast realization of new components by going through quick iterations. Additionally, in some cases tooling is eliminated, which usually takes a long time. While plastic rapid prototyping has been around for quite some time, metal additive manufacturing technology is showing signs of commercial acceptability only in the recent past. Various techniques of metal additive manufacturing such as the selective laser melting, direct metal deposition, laser engineered net shaping are being developed world over. In the selective laser melting, a fine laser beam spot is rastered on a powder bed as per the profile required resulting in melting and solidification of the powder that is exposed to the laser energy. In the process, layer of particulate profile is realized. In order to realise an actual component, the design is sliced into distinct layers and the laser beam is made to move on the powder bed as per the layer requirement. Once a layer is formed the bed is moved down by a certain height and a fresh layer of powder is spread. The laser beam scans the fresh layer as per the geometry of that particular layer. Like this, the whole component is built layer by layer. Among the various metal additive manufacturing techniques, powder bed SLM method is capable of achieving the nearest net shapes with good surface finish. Very small dimensions also are possible to be built. However, in order to achieve the required features with out

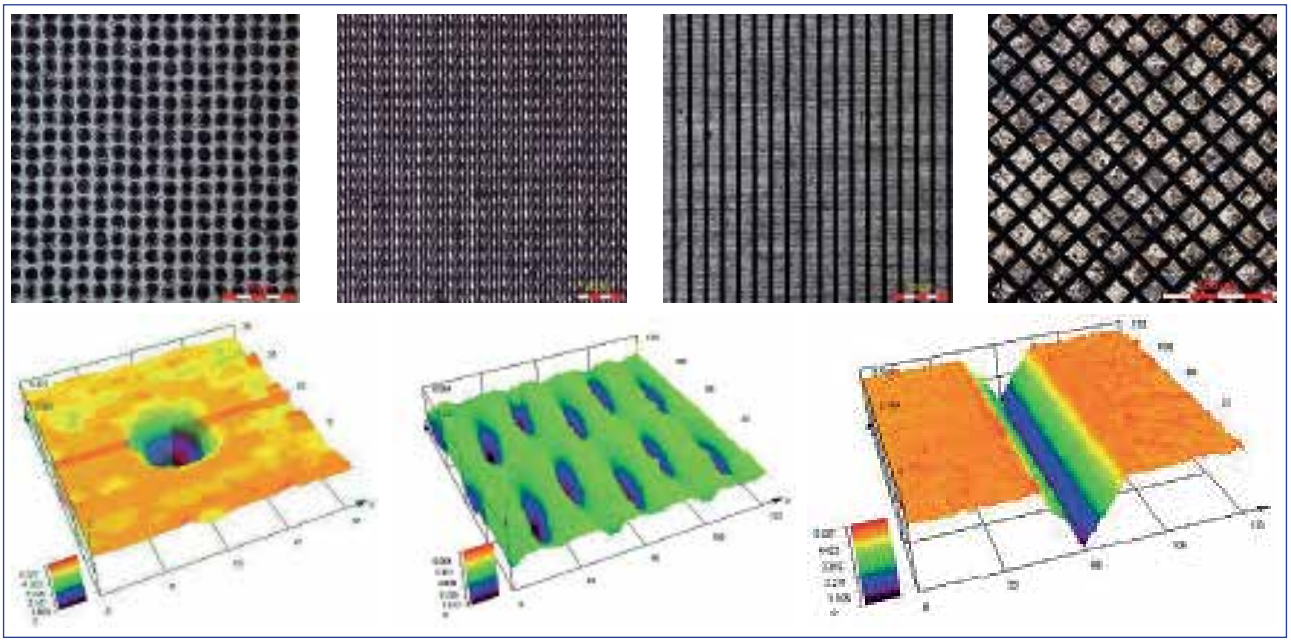

Fig. 1 Optical micrographs, 2D and 3D profile of laser surface textured samples with different geometries; dimples, ellipse, grooves and cross-hatches

defects and deviations a systematic understanding of the process behavior under different conditions is essential. Similarly, understanding the consequent metallurgy and subsequent post treatments to obtain homogenous properties in the built structure are very crucial to application of this technology to actual components. At the same time, it is appropriate to mention that, due to the limited layer thickness build up possible, the process is very long and a small component may take several hours to be completed. So, methods of improving the build rate or improving productivity are to be addressed. In the above backdrop extensive experiments have been carried out at the Centre using the newly established Selective Laser Melting (SLM) machining SLM 280HL jointly with M/s. SLM International GmbH.

Hybrid Additive Manufacturing: Conformal Cooling Channel for Pressure Die Casting (PDC) Tools

Cooling channels close and conforming to the PDC tool surface contours can improve the heat transfer efficiency and thereby resulting in improved tool life. Although additive manufacturing gives greater design freedom, building of conformal cooling channels with overhanging features (circular cross section) is a challenge as it requires sacrificial support structures to build and subsequent support removal. Generally, PDC tool inserts are of length around 300 mm and diameter of around 30 mm, building of such long components take very long build time. In an effort to solve both issues, attempts have been made using laser assisted metal powder bed SLM 280 HL system.

Possible use of self-supporting drop shape cross-section design for conformal cooling channel and also reduced total build time by adopting AM on conventional CNC machined blank (about 75% of length) of the insert. The art of matching and building the top insert portion with complicated and twisted cooling channel by additive manufacturing has been developed and adopted to build a model insert shown in Figure 2.

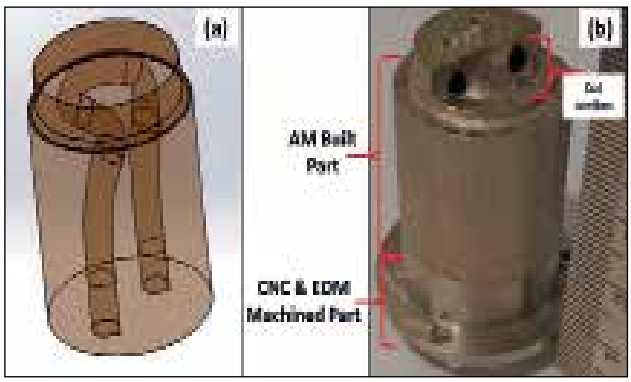

Fig. 2 (a) CAD model of the insert with drop shape cross-section conformal cooling channel and (b) photograph of hybrid manufactured model insert with top cut section showing drop shape conformal cooling channel

Dissimilar Materials Additive Manufacturing

Dissimilar material structures offer advantage of combining good properties of two different materials such as mechanical property (stainless steel) with the heat conductivity (copper). Structures used in industrial applications, such as heat exchangers, have specific requirements. Other potential applications are in electronics and cryogenics.

Difference in the physical properties of the two metals, including the melting point, thermal conductivity and thermal expansivity, make defect-free dissimilar metal building difficult. Hence, building dissimilar material structures is a challenge and using such concept in additive manufacturing leads to a kind of hybrid additive manufacturing or rebuilding the part with different material. Attempts have been made to build stainless steel features on a copper block and stainless steel on Inconel. Initial experiments showed good metal joining properties with respect to interface structure, porosity and strength. Copper-Steel joint

Fig. 3 Photographs of as built dissimilar metal parts

showed tensile strength better than copper substrate. Similarly, Inconel-Steel joint (Steel as AM portion) showed necking and breaking on steel side showing joint has better strength than the steel AM part.

Mesoporous Structures using Different Materials

Additive manufacturing of lightweight structure was explored by building mesoporous structures. Ni-based superalloy - IN718 powder was used to build the structures by selective laser melting process. Reduction in mass is observed to be 76.75%, 73.17% and 37.39% in honeycombs with interconnected holes (Fig. 4). It has also been inferred that the increase in unit cell size will reduce the mass of the structure. Another structure attempted was a body centred periodic cellular lattice structure (BCPL) [Fig.5], which had a calculated section modulus of 0.01mm^3 (for circle and triangle struts) and 0.1 mm^3 (hexagon). Test coupon of 10x10x20 mm^3 built shown in the figures as per ISO 13314:2011 (E) standard for evaluating compression behaviour. It has been inferred that there is no bending failure occurring, which justifies high resistance to bending failure.

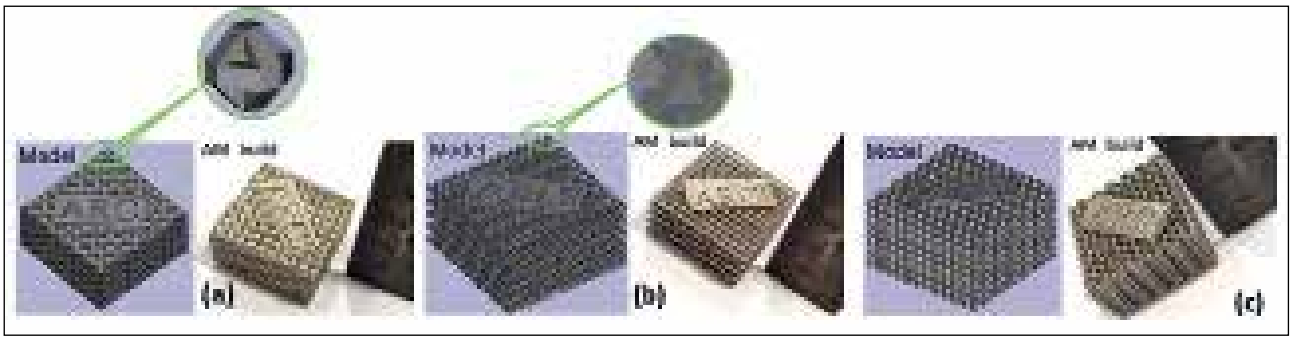

Fig. 4 3D models and as built photographs of lightweight structures with different unit cells (a) G-struct 10, (b) DSM tetra and (c) Honey comb with interconnected holes

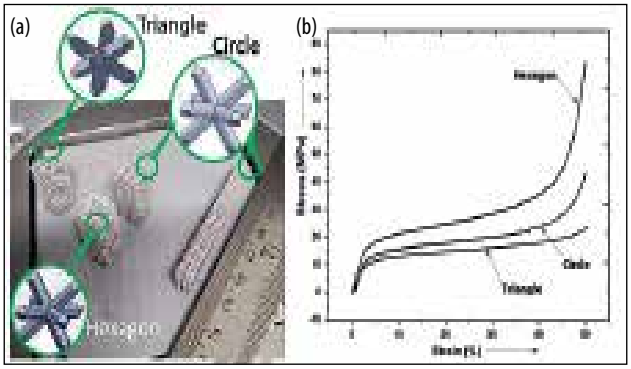

Fig. 5 BCPL structures with different strut shapes (a) photograph of as built structures and (b) compression test behaviour plot

In-house development of Powders for Additive manufacturing

Superalloy IN 718 powders suitable for AM with respect to alloy composition, particle size distribution, morphology (spherical) and flowability have been produced using a gas atomizer available at ARCI. Ingots have been sourced from M/s. Midhani Ltd. Hyderabad. The powders were used in additive manufacturing by powder bed and direct metal deposition (DMD) processes. The powder bed-built specimens showed 99.5% density.

Laser Clad Deposition for Refurbishment and Surface Engineering

Laser cladding is a technique in which powder is fed into the focus of laser beam resulting in melting of the powders and deposition on a surface to be coated. The surface also undergoes some melting due to the laser energy, resulting in a shallow melt pool. Due to the mixing of the deposited molten metal onto a shallow molten metal pool, a metallurgical bond is created at the interface. Due to the highly precise energy deposition and powder feeding, the base metal dilution can be controlled to less than 2%. At the same time, it gives an advantage depositing the material in a localized manner at minimal heat input. Consequently, the distortions and heat affected zones are minimal in this process.

Refurbishment of High Strength Steels using Laser Cladding Technique

High strength low alloy steels are commonly used in automotive, energy and general engineering sectors for various power transmission gears shafts, connecting rods propeller shafts, and heavy forgings such as rotors, shafts, disc etc. Such components can be damaged during operation due to wear at the contact areas and refurbishment of such components using laser cladding can save the replacement cost. In the present work, repair of low alloy high strength steel in hardened and tempered condition was studied using laser cladding process. A comprehensive study was carried out utilizing equivalent AISI4340 steel powder on hardened and tempered AISI4340 steel component. Samples were analyzed for microstructure, mechanical properties, interfacial strength and wear behavior and compared with that of the substrate. Anisotropy in the microstructure of clad and substrate could be removed after suitable heat treatment. Mechanical properties, interfacial strength and wear properties are found to be on par with that of the substrate.

Laser-clad Coating Technology for Life Enhancement of Boiler Parts Used in Thermal Power Plants

ARCI has developed a unique laser coating technology that can enhance high temperature erosion-corrosion

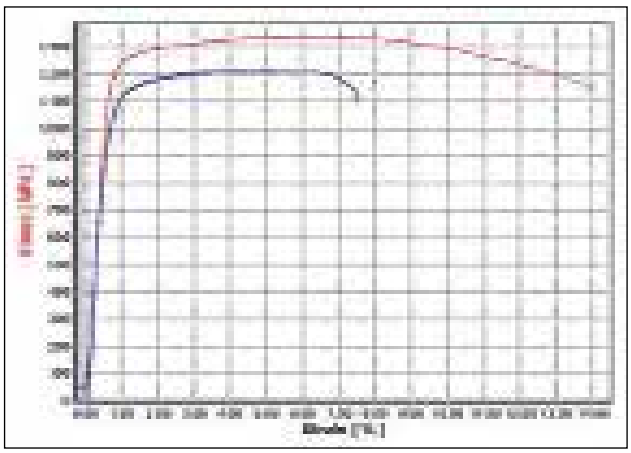

Fig. 6 Micro tensile result of laser clad and substrate material from a used component

Fig. 7 Stainless steel boiler parts used in coal-based critical/super critical thermal power plants effected by Erosion-corrosion

resistance coating on stainless steel boiler parts such as nozzle, spreader etc used in coal-based critical/super critical thermal power plants. The technology involved development of a unique laser clad-coating of metal-matrix composite materials on stainless steel boiler parts that leads to significant reduction in downtime maintenance schedules and thereby enhance economics. Direct plant testing of a part of a nozzle tip has proven that the coating developed could enhance the life by two-to-three times as compared to uncoated counterpart and also superior in performance with conventionally weld-surfaced counterpart. A know-how technology transfer agreement has been signed with a private entrepreneur and is under process of transfer. The developed technology can be adopted on any suitable high-power laser system integrated with a Robot/CNC workstation and appropriate powder feeding and nozzle subsystems. The unique features of the technology are the design of coating materials and process adaptation with optimum deposition efficiency that leads to excellent metallurgical bonding of the coating with boiler steels and can provide high temperature erosion and corrosion resistance. The process methodology is adopted in a way to provide precise coating in appropriate wear-pattern designs at the required regions of the parts/components.

Surface Engineering using Transformation Hardening

Laser beam of certain intensity, when irradiated over the surface of a hardenable steel, will locally raise the temperature above austenitisation temperature and cools rapidly as the beam moves away. Consequently, the heated and cooled area undergoes a martensitic transformation resulting in hardening. The size, depth and hardness of the treated zone is dependent on the metallurgy of the steel used, beam intensity, scan speed, spot size and laser wavelength. Depending on the required area of coverage, laser is scanned on the surface and hardening achieved either in a single pass or multiple passes. Two challenging tasks of hardening very low carbon steels and thin sections have been attempted. Due to the limited layer thickness, heat build up is possible.

Laser Surface Re-engineering Technology for Auto-body Structural Components

A unique surface re-engineering technology applicable for steel sheets usable for structural and auto-body parts has been developed and jointly patented with Tata Steel Ltd, India. Microstructurally tailored blanks (MTB) and/or sheet metal parts are fabricated by employing laser surface treatment (patterning) at specific custom-designed areas with different patterns. For example, regions requiring higher crash worthiness, without affecting the formability. A prototype B-Pillar of auto-body has been produced with excellent results in terms of improvement in crashworthiness. The technology can be useful replacing high cost HS/AHS steels with surface re-engineered cheap HR/CRCA steels.

Fig.8 A prototype B-Pillar of auto-body

Laser Surface Treatment Technology for Bearing Elements

A novel method of processing steel bearing components to enhance load bearing capacity and life with imparting of a superior surface at the required contact regions has been developed. The process utilizes robot-integrated diode laser system with appropriate setups, prior-treatments and processing optimization methods. Various bottlenecks in terms of surface texture, surface topology, microstructure-control, distortion and tolerance controls of the components have been solved. Comparative analysis of various properties of the laser treated surface with other conventional ones showed vast improvement with reduction in post-process machining requirements. The process developed is uniquely applicable for thin-sectioned bearing parts wherein load bearing capacity is higher with life enhancement. The fatigue testing of bearing elements as per standard with testing of laser treated rollers as well as bearing life test is underway.

Materials Joining by Laser Brazing

Laser brazing is a technique where in the braze material in the form of a wire is fed into the focal point of laser beam, which melts it and deposits in the joint area. Due to high intensity and precise control of the power using lasers, melting of the substrates can be avoided and clean braze joints can be made at very high speeds. Since melting of base metals can be avoided or controlled, the process can be very useful in joining of dissimilar metals. Special brazing heads are commercially available for precision wire feeding and seam tracking. With this it is possible to form brazed joints of three dimensional contours as well. Technology development has been undertaken for joining similar and dissimilar combinations of various steels (D, DD, EDD, DP etc) and aluminum alloys (3xxx, 5xxx, 6xxx) used in automotive. Special tools and methods such as wire-feed based seam-tracking (that facilitate in drastic reduction in fixturing and edge-preparation setups), special flux-added brazing/welding precursors were tried and tested to produce defect-free continuous seams adoptable to different joint contours of parts. Maximum load bearing capacity of joints varied in the range of 230 – 265 N/mm, depending on the Al-Steel combination used with processing speeds up to 5 m/min. As per fatigue and corrosion testing analysis, the joints were found to be acceptable. Few prototype components (sheet-to-sheet, profile-to-sheet) have been demonstrated successfully. Development of few actual automotive auto-body parts is underway.

Fig. 9 Ditode Laser System (10kW)

Fig. 10 Laser weld-brazed Profile-to-Sheet (Al-Steel)

Adaptive Process Control for Uniform Laser Hardening of Complex Geometries using Iterative Numerical Simulation

Laser surface hardening, when applied to complex geometries poses challenge in terms of obtaining uniform hardness throughout the hardened area due to variable heat sink effects. In this work an iterative numerical approach was used to estimate the required modulation in laser power to achieve a uniform surface temperature throughout the process zone. Firstly, a transient thermal model for the laser-material interaction was developed for a rectangular spot of 5 mm x 8 mm. The temperature dependent material properties were used to bring in non-linear effects in the analysis so as to predict the hardened zone dimensions more precisely. The numerical model was validated by carrying out laser hardening experiments using 6kW diode Laser. The validated numerical model was used with an iterative technique aided by the conditional looping to achieve uniform surface temperature during laser hardening of the complex geometry with variable heat sink. The developed iterative approach can be effectively used on any geometry with variable heat sink to obtain constant surface temperature throughout the process zone.

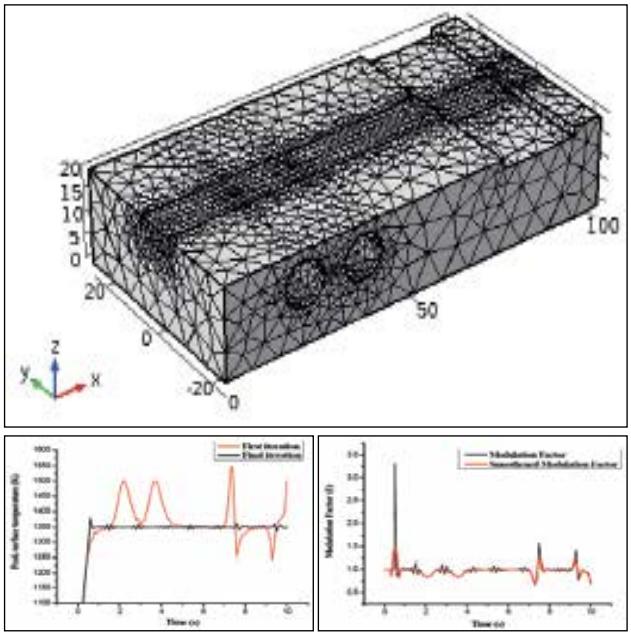

Fig. 11 Laser hardening process modelling: (a) Geometry used for simulation (b) Surface temperature after first and 20th iteration (c) Power modulation required for achieving uniform surface treatment

Centre for Fuel Cell Technology

Centre for Fuel Cell Technology (CFCT) continues to be at the forefront of Polymer Electrolyte Membrane Fuel Cells (PEMFC) technology development in the country. During the year, the Centre mainly focussed on the outreach of its technologies to companies from various industry sectors as well as addressingsome of the greyareas of these technologies.The Centre is focussing on R&D activities from the perspective of durability, long time operation, accelerated stress test and other related characterisation.Looking at the importance of hydrogen infrastructure, CFCT has taken a major initiative in the electrolysis mode of hydrogen generation withdepolarizers to reduce the power consumption. With improved catalysts and component, a 1.5 Nm^3 hydrogen generator is in place. Related Balance of Plant (BoP) components are being developed in collaboration with an Industrial partner. In terms of energy storage both Zn-Ni and Zn-Air batteries are being made by addressing the complicated catlyst reactions as well system development.

In addition to fuel cell technology demonstration, CFCT is also engaged in all R & D activities related to fuel cells viz., durable electrocatalysts, modeling, electrolysers for hydrogen generation, metallic bipolar plates for transport application of fuel cells, energy storage using Zn based batteries, hydrogen storage using Alane, and supercapacitors using carbon derived from agricultural wastes. All these projects are funded by National funding agencies like Department of Science and Technology, DRDO, GAIL India, M/s. Flash Forge etc. The Centre has also augmented additional facilities, among which the notable ones are ultrasonic nozzle free catalyst coater for the development of catalyst coated membranes, optical profilometer, and I-scan pressure map.

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Polymer Electrolyte Membrane Fuel Cell Prototype Development

Polymer Electrolyte Membrane Fuel Cells (PEMFC) for stationary application is one of the major programs at CFCT. During the year 2017-2018, CFCT has been able to successfully feed a power grid with 10 kW of power through a regenerative load. The 10 kW power was generated by engaging two 5 kW stacks in series as well a single module of 10 kW capacity. The thermal management has been balanced to an extent wherein the continuous operation of the system for more than 8 hrs between a single start-stop could be comfortably achieved.

In the absence of accelerated methods to test fuel cells, the only option to ascertain the life of the fuel cell systems is to operate them continuously. This is possible only when the hydrogen is available continuously. The various challenges that need to be addressed are continuous operation of the system with many start-stops, due to control monitoring system and inverters. To achieve these objectives and control the heat generated from the stack, heat exchangers are used. Cross flow heat exchangers are being used as a medium between PEMFC stack and coolant reservoirs. Experiments were carried for thermal management with combinations of inner loop design between PEMFC Stack, Heat Exchanger and Coolant reservoirs.

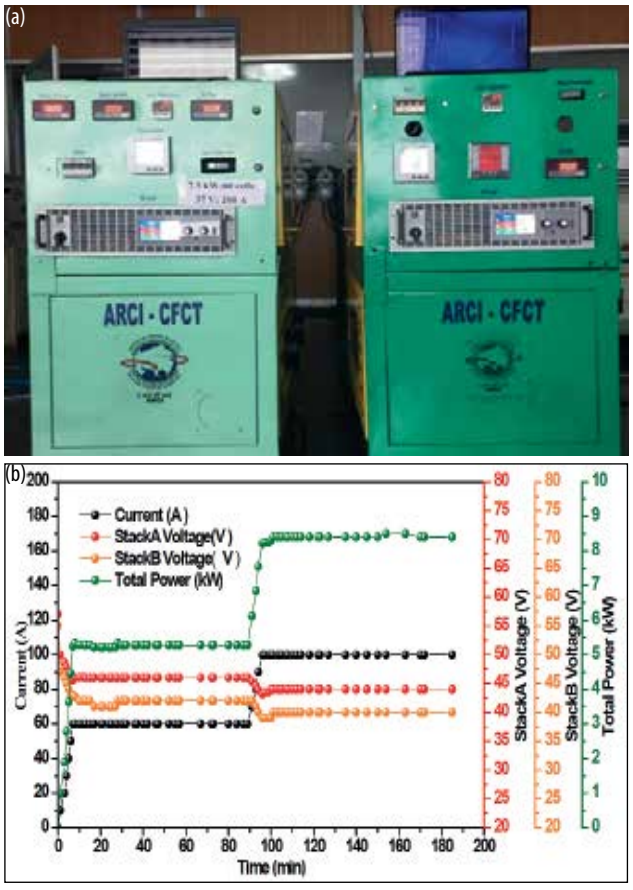

Fig. 1 (a) Prototypes of PEMFC system (b) performance schematic

Development of Next Generation Electrolyser Stack for Hydrogen Production (1.5 Nm^3/hr) through Electrochemical Methanol Reformer (ECMR)

The development of improved Membrane Electrode Assembly (MEA) for ECMR cells was addressed through modifications of the electrode structure by altering various process variables. Various electrode preparation parameters were optimized by evaluating the MEA performance in ECMR single cell with 30 sq.cm electrode area. The single cell with optimized electrode condition was tested for about 200 hrs, continuously. Further, the improved electrode area was scaled up to 770 sq.cm and a short stack of 4 cells was assembled and tested continuously. The operating current density of electrolyser stack was increased and the corresponding hydrogen production rate was increased to 33% when compared to GEN 1 electrolyser stack. Further, attempt has also been made to develop Next Generation (GEN 2) electrolyser stack with improved electrodes (770 Sq.cm) of 32 cells. The developed GEN 2 stack was tested with all the BoP components (power supply, reactant feed system, reactant concentration monitoring system). It delivered hydrogen at the rate of 1.5 Nm^3/hr with an energy consumption of 1.4 kWhr/Nm^3. The performance of GEN 2 Stack was tested for about 50 hrs and obtained stable performance and delivered about 75 Nm^3 of hydrogen. Currently, the development of 2.5 Nm^3/hr hydrogen production capacity stack with modular type is in progress.

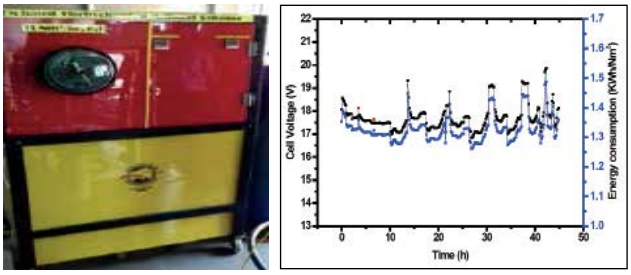

Fig. 2 ECMR electrolyser system with performance

Design and Development of Metallic Flow Field Plates for PEM Fuel Cells

At CFCT, a detailed study of Metallic Bipolar Plate (MBPP) formability and reactants flow analysis, along with its performance in a fuel cell has been carried out by experimentally and using ANSYS - CFD (Computational Fluid Dynamics), respectively. The scale-up design has been optimized from 30 cm^2 to 150 cm^2. The flow volume of reactants in MBPPs has been created and velocity profile has been analyzed using ANSYS - CFD. MBPPs for fuel, oxidant and coolant were also made by Additive manufacturing by Selective Laser Melting Process at Centre for Laser Processing of Materials (CLPM). They were tested for their viability for application in fuel cells.

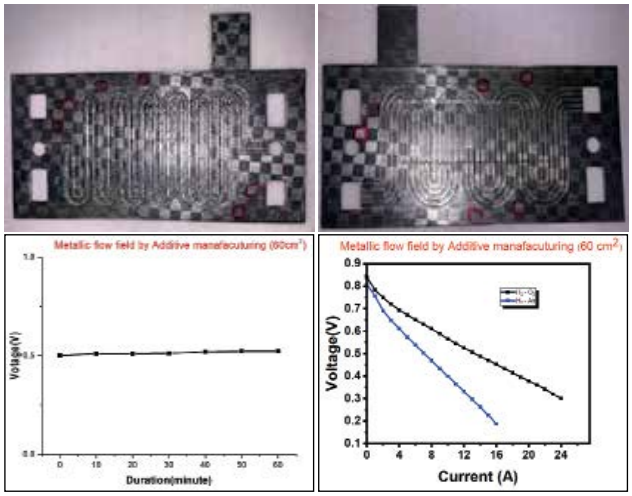

Fig. 3 SS plates made by Additive manufacturing and performance

Studies in terms of operating conditions, Surface resistance, weight loss, contact angle, roughness etc., are in progress. The Prototype of Metallic Flow Field Plates formed by hydroforming were supplied by M/s. Flash Forge Private Limited, Mumbai and are being evaluated in terms of quality based on channel depth, width, uniformity, flexibility, suitability for fuel cells etc.

Rechargeable Alkaline Electrochemical Cells based on Zinc

The growing need to develop low cost, safe batteries suitable to power electronic devices, for storage of renewable energy and automotive applications has led to research on rechargeable Zinc based electrochemical cells such as Zn-Air and Nickel-Zinc batteries. The electrochemical performance of zinc air battery depends on the physical and electrochemical characteristics of the cathode materials. Air electrode of zinc air battery should exhibit good conductivity, high active sites for oxygen adsorption, excellent ORR and OER catalytic activity and structural stability for longer cycle life. Ionomer assisted non-noble metal oxide based catalysts of Co and Mn were synthesized with superior electrocatalytic activity towards ORR and OER under alkaline conditions. The ORR and OER current densities were found to be 5 $mAcm^{-2}$ and 25 $mAcm^{-2}$, respectively. Notably, integrating this hybrid electrocatalyst into a rechargeable zinc-air battery shows 100 cycles of charge-discharge with low voltage polarization value of 0.75V@10$mAcm^{-2}$, which is superior to Pt/C catalyst. These new findings will give a new way for rational design of highly active bifunctional ORR and OER catalysts.

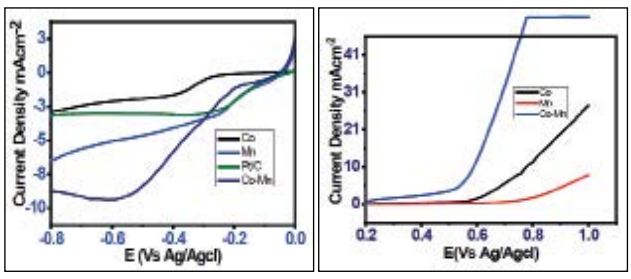

Fig. 4 ORR and OER characteristics of Co and Mn based catalysts

Further, a freely air breathing Zn/air cell of six cells that could be discharged with current density of 3 $mAcm^{-2}$ was assembled and a maximum capacity of 30 Wh was achieved. The charging voltage for six cell stack was around 12.6 to 13.4 V at charging current of 500 mA and the discharging voltage is around 6.4 V at discharging current of 500 mA.

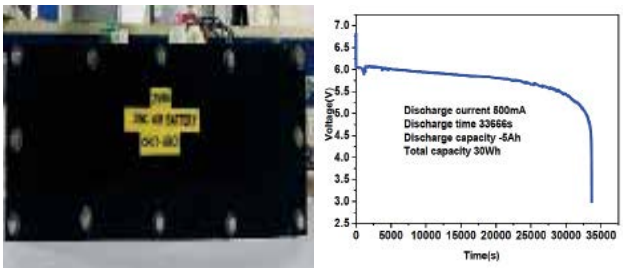

Fig. 5 25Wh Zn-Air battery and its discharge characteristics

Development of Alkaline Zinc-Nickel Battery for transport application is in progress with modified electrode technology. The resultant cell improved the capacity by three times to 330 mAh at the single cell level, showing cyclic stability of over 400 cycles. The Life cycle assessment Cell (550 cycles) and its post mortem analysis carried out showed that the capacity degradation was due to formation of gamma phase NiOOH which is irreversible. Further scaling this electrode technology upto 150 sq.cm is under progress.

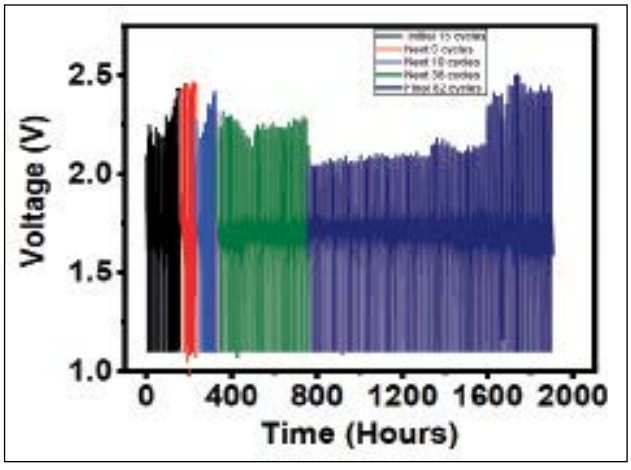

Fig. 6 Ni-Zn battery cycle life

Catalyst Development-Pt-less Electro-Catalyst for Oxygen Reduction Reaction

Reduction of Pt content in the catalyst is the major bottle neck in the commercialization of Fuel Cells (FC). CFCT is involved in a project aimed at reducing Pt in the catalyst layer. Inter metallics is one of the solutions. For this purpose, PtNi was loaded over functionalised acetylene

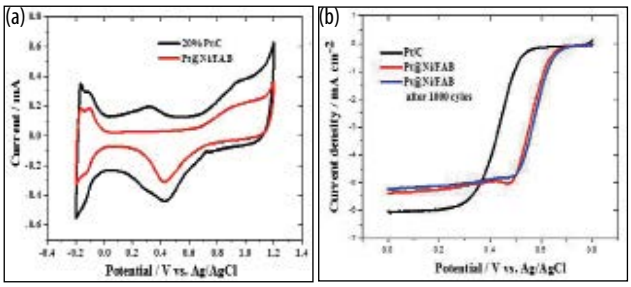

Fig. 7 ((a), (b)) Cyclic voltammograms at 50 mV/sec and ORR polarization curves at 10 mV/sec with 1600 rpm in 0.1 M HClO4 solution respectively

black and the results obtained were highly promising with enhanced ORR activity as shown in Fig. 7.

The durability of the conventional catalyst support carbon for Platinum (Pt) electro catalyst is still a challenging issue in the usage of PEMFC in transport applications. The support carbon corrosion is accelerated at higher potentials produced due to the air-fuel boundary formation at the anode. This carbon corrosion at high potential of 1.2 V leads to dissolution, detachment or agglomeration of Pt particles at the cathode which ultimately lowers the electrochemical surface area of catalyst and eventually degrades the performance over a period of time. CFCT has identified a corrosion resistant alternative support such as Zirconium carbide and modified carbon. The same has improved the conductivity of carbide supports as well. These electrocatalysts were tested electrochemically with various protocols to estimate for its ECSA loss. The ECSA loss for Pt/FAB was 28% and for Pt/ZrC+FABit was only 15%. Both the electrocatalysts meet the DOE target of less than 40% ECSA loss.

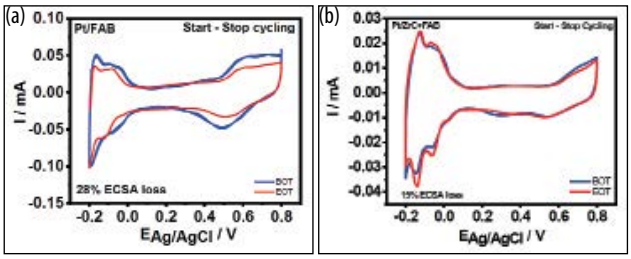

Fig. 8 Start-stop protocol tests for (a) Pt/FAB (b) Pt/ZrC+FAB

An alternative catalyst-support material with highly oxidation-resistant properties, some conducting oxides such as sub-stoichiometric titanium oxide of the general formula $Tin2n^{-1}$, which is known as Magneli phase, is an attractive material because of its high electric conductivity. Ti_4O_7 phase exhibits the highest electrical conductivity of 103 S cm^{-1} at room temperature, which is comparable to that of graphitized carbon.

The Ti_4O_7 supported Pt-electrocatalyst with the Pt mass loading of 20% (mass fraction) was prepared by conventional impregnation – reduction method. The

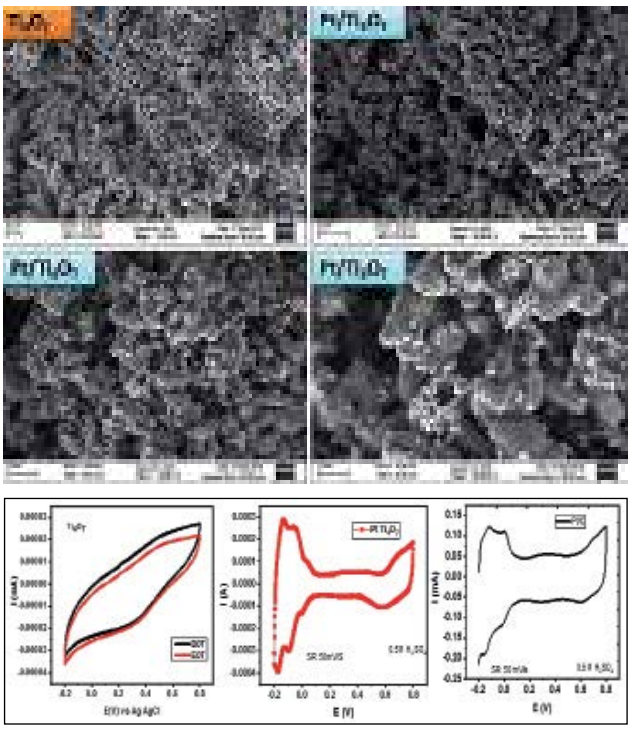

Fig. 9 Pt/Ti40$_7$ catalyst morphology and its electrochemical characterization

confirmation of the Pt was done by the XRD analysis. There is clear indication of impregnation of Pt on Ti_4O_7. The surface morphology was studied by scanning electron microscopy (SEM) analysis of Ti_4O_7, Pt/ Ti_4O_7. There was irregular spherical morphology formed, and the platinum is impregnated on the Ti_4O_7. In order to investigate the electrochemical stability of the supports a potential of 1.2 v (vs RHE) was applied to the support covered working electrode for 25 cycles in 0.5 mol/L H_2SO_4 aqueous solution to measure the corrosion currents and the CV curves recorded. Typical hydrogen and oxygen adsorption/desorption behavior can be clearly detected on both Pt/C, Pt/Ti_4O_7 catalysts and no additional current peak is observed, indicating that the Pt/Ti_4O_7 is electrochemically inert.

Development of Polymer Electrolyte Membranes

CFCT has been engaged in development of both anion and cation conducting membranes for PEM fuel cells, ECMR, hydrogen purification and alkaline electrochemical cells. For enabling low cost, effective on-site hydrogen production attempts are in progress in developing the alternative ion exchange membranes.

• Proton exchange membrane for electrochemical methanol reformation

A composite membrane synthesized using low cost partially fluorinated polymers like Polyvinylidene fluoride and inorganic zirconium phosphate nano particles has been developed. The membrane conductivity and other characterizations were carried out and tested for ECMR.

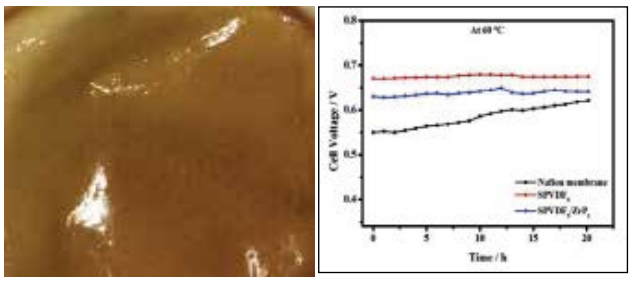

Fig. 10 1PEM for ECMR electrolyser and its performance

- **Anion exchange membrane (AEM) for alkaline methanol electrolysis**

Anion exchange membrane based on poly(phenylene oxide) and graphene oxide have been synthesized with a view to use in alkaline methanol electrolysis cells.

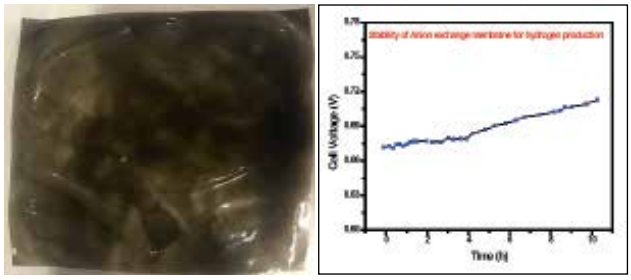

Fig. 11 AEM for ECMR electrolyser and its performance

Modelling of PEMFC for Impurity Tolerance as well for HT–PEMFC

There is a potent requirement of understanding the underlying electro-chemical and physio-chemical processes in most electrochemical devices both qualitatively and quantitatively. Electrochemical modelling of these systems can help us quantify the adverse effect in presence of such impurities in advance and help take precautionary and/or other remedial steps during experimentation. The performance with pure H_2 and H_2 containing various concentrations of CO (1-16%) is simulated and compared with experimental data. Fig. 12 shows experimental (data points) and simulated (line) performance of fuel cell at (A) different temperature (B) different CO concentrations at 150˚C.

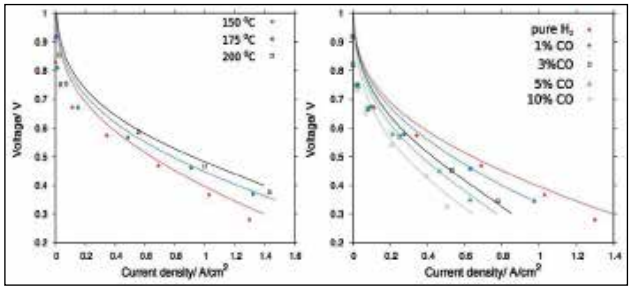

Fig. 12 Modelling of HTPEMFC with CO contaminant and experimental validation

Supercapacitor

Supercapacitors (SCs) are considered as an emerging energy storage system due to their attractive properties such as high power density, high cyclic life, short charging time, and so on. The hierarchical porous carbon aerogels were synthesized by single step carbonization of the tamarind seed kernel. The effect of carbonization temperature (500ºC - 800ºC) on the surface area and pore size distribution was studied. Figure 13 a shows the change in surface area with increase in temperature, which indicates that the surface area increases with increase in temperature upto 700ºC. The CAG-700 has high specific surface area of 2645 $m^2 g^{-1}$, a pore volume of 1.72 $cm^3 g^{-1}$, and showed a high specific capacitance value of 191 F g^{-1} at 0.5 A g^{-1} in 6 M KOH.

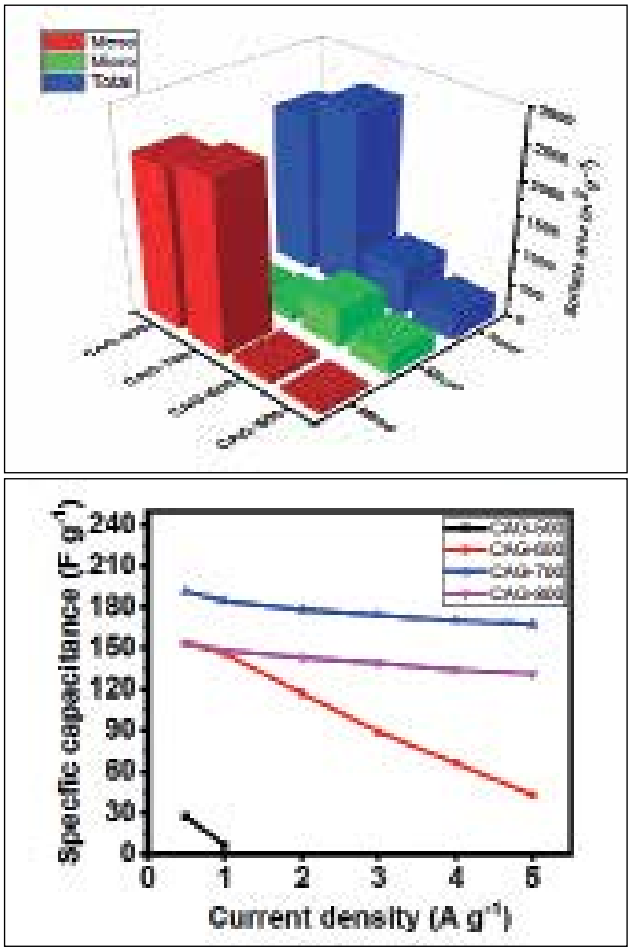

Fig. 13 Specific capacitance of various carbon aerogels with capacity retention

Development of Micro-fuel Cells for Portable Applications

A Micro fuel cell is an electrochemical device that converts a fraction of the chemical energy into useful electrical energy for portable devices. The conventional battery technology has been found lagging in increasing the operating times of these advanced devices, thus leading to frequent and long hours of charging. The devices used in military operations and other emergency

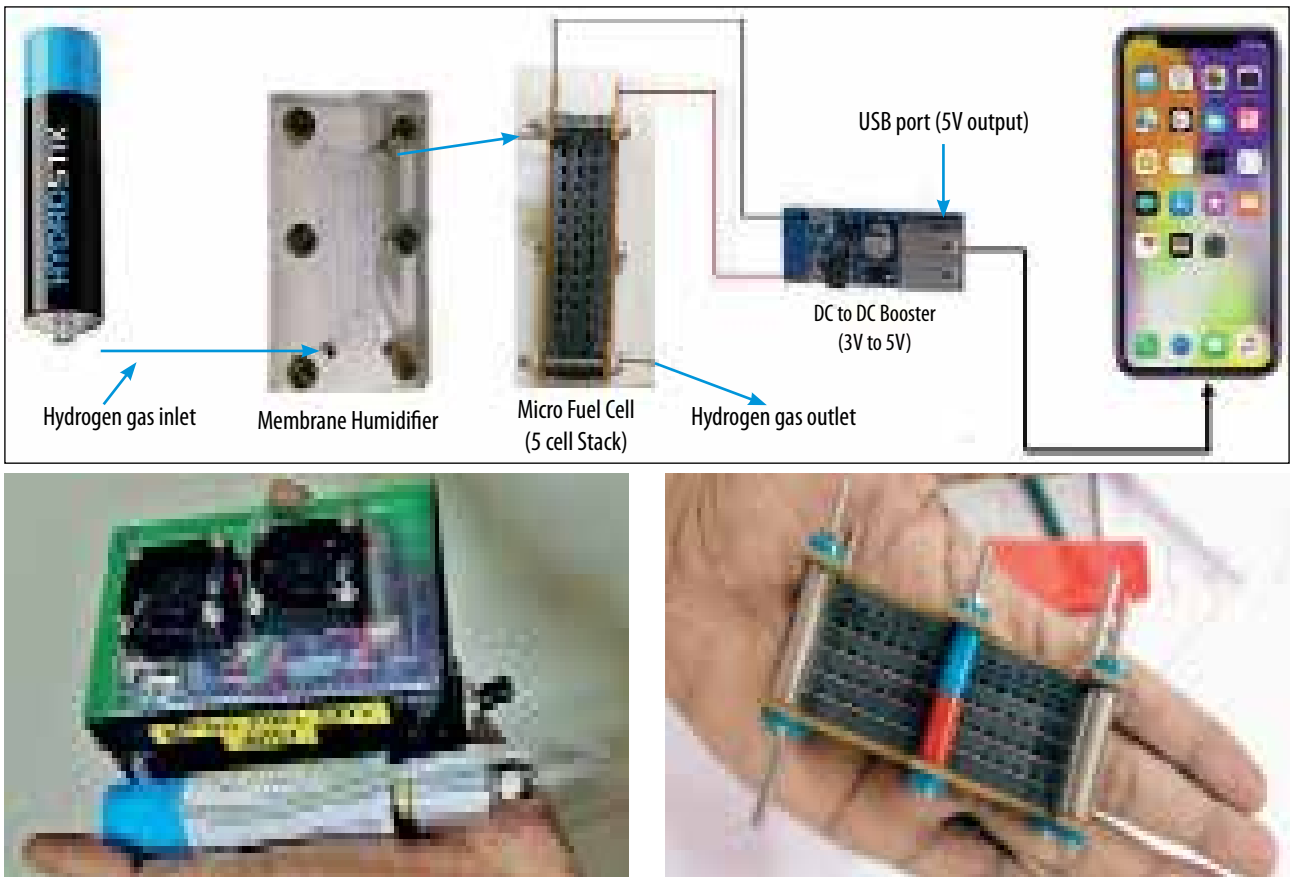

Fig. 14 Schematic of micro-fuel cells and prototype development

services where frequent charging is not feasible, micro fuel cell can be used where instant recharging can be done via replacing or refilling the cartridge.

Fig. 14 shows the micro fuel cell, fabricated which consists of 5 cell stack delivering around 2.5W and this is boosted to 5W output to charge a mobile phone.

Electrochemical Synthesis of α-Aluminium hydride

Among the metal hydrides, Aluminium Hydride, AlH_3, commonly known as Alaneis is the most interesting fuel for propulsion, because of its high hydrogen storage capability of about 10.8wt%. In CFCT attempt has been made to synthesis alane by electrochemical method under ambient pressure and temperature through DRDO funded project. Preliminary experiments were carried out using an aluminum anode and platinum cathode in an electrochemically stable, aprotic, polar solvent such as tetra hydro furan (THF) or ether. Sodium/lithium aluminum hydride ($NaAlH_4$) is dissolved in this solvent, forming the ionic solution (Na^+–AlH_4–THF), which is used as an electrolyte. The obtained product was separated and characterized. The preliminary experimental result shows the formation of Alane. The preparation of desired Alane polymorphs also depends on the other reaction conditions such as time, temperature, concentration and

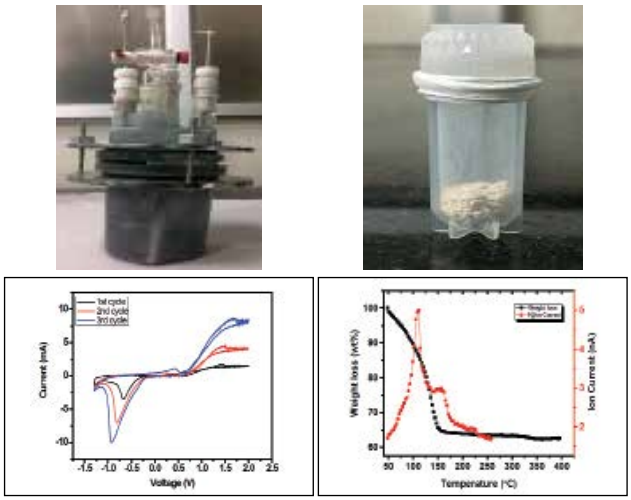

Fig. 15 Electrochemical synthesis of AlH_3 and Mass spectrometry of evolved gas analysis

impurities in the electrolyte, which are currently under progress. The samples start decomposing slowly upto 100°C and a drastic decrease in weight loss is observed (estimated to be around 38 wt%). Hydrogen evolution is observed after 100°C and maximum hydrogen ion current is observed at 111°C in evolved gas analysis using Mass Spectrometer. The product will be having small amount of $LiAlH_4$, whereas dehydrogenation temperature of $LiAlH_4$ is above 150°C.

Centre for Non-Oxide Ceramics

Centre for Non-Oxide Ceramics (CNOC) has been actively pursuing R&D activities in the area of carbides, nitrides, borides and composites for a wide range of applications. CNOC is equipped with the state-of-the-art processing and sintering facilities on a pilot scale and over the years has also developed substantial expertise in product engineering as per user requirements. During the period of this report, the Centre has undertaken several specialized prototype developments as a part of demonstration of technologies. Recently, CNOC has also started working on the development of Silicon Carbide (SiC) based thrust bearing parts for improving the load bearing performance of submersible pumps as well as SiC channels for high temperature kiln furniture.

Ongoing R&D activities of the Centre also includes ready-to-press Si_3N_4 based granules through proper selection of additives and binders, carbon nano-fibre and nano-tube reinforced SiC composites by incorporating them in the matrix as a secondary phase. The Centre is also working on the development of nitride based ceramics with engineered dielectric constant and excellent mechanical properties as well as substrate holder for microwave enhanced plasma CVD reactor.

SiC wear resistant pump parts

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Pressure-less Sintered Silicon Carbide Ceramics for Advanced Applications

Silicon Carbide (SiC) is one of the most attractive non-oxide ceramic materials because of its superior mechanical properties e.g. high strength, moderate fracture toughness, high wear resistance and capability of retaining strength at high temperature, in combination with excellent thermal properties and very high chemical inertness. Therefore, it has been considered for several applications viz. gas turbines, industrial heat exchangers, diesel engines, mechanical seals, structural material in space telescopes, synchrotron optical elements, biomaterials etc. ARCI has developed the technology for producing wide range of pressure-less sintered SiC based products including lightweight structural components, thin walled tubes, disc, combustion liners, thrust and wear resistance pump parts for application in demanding environments. The development of SiC parts involves the formulation of commercially available SiC powder through selection of organic binders, carbon and boron as sintering aids for the pressure-less solid-state sintering of SiC. Green bodies are formed through dry pressing of formulated SiC powder followed by low temperature (~ 500°C) heat treatment for removal of organic volatiles and increase of green strength for handling and machining purposes. Subsequently, SiC parts are sintered at high temperature and machined to final shape and required dimensions. The photographs of some of the SiC components developed by the Centre is shown in Fig. 1.

Spray Granulation of Water Sensitive Nitride Powder into Ready to Press Spherical Granules

The granules used to make SiAlON, are consisting of silicon nitride (Si_3N_4), alumina (Al_2O_3), aluminium nitride (AlN) and yttrium oxide (Y_2O_3). Among them, AlN is highly reactive with water. Hence, aqueous medium is not suitable for making suspension to produce granules; or, an appropriate water resistant (WR) coating is required on AlN particles for which a separate process is needed. Moreover, such WR coating is not stable for long time (>72 h) during processing in aqueous medium. Hence, it is preferable to produce such granules by dispersing the powders in non-aqueous medium (e.g., acetone) where a suitable binder is used to impart strength in granules for transportation. In the present granulation technique, a simple, cost-effective spray granulation process has been developed based on the selection of an organic solvent for slurry preparation. The slurry with optimum solid loading is further atomized through a twin-fluid nozzle by applying gas pressure ≈ 1 bar. The atomized liquid droplets are dried instantaneously under ambient condition through rapid evaporation of organic solvent. This can be attributed to its low intermolecular forces of attraction as well as increase in surface area of spherical granules upon atomization (Fig.2). The uniqueness of the process stands on the rapid drying of granules comprising of water sensitive powder without the requirement of additional drying set-up.

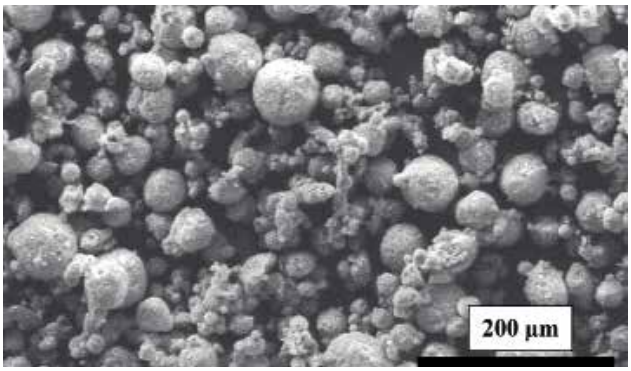

Fig.2 Scanning electron micrograph of spherical granules (Size 40-100 µm)

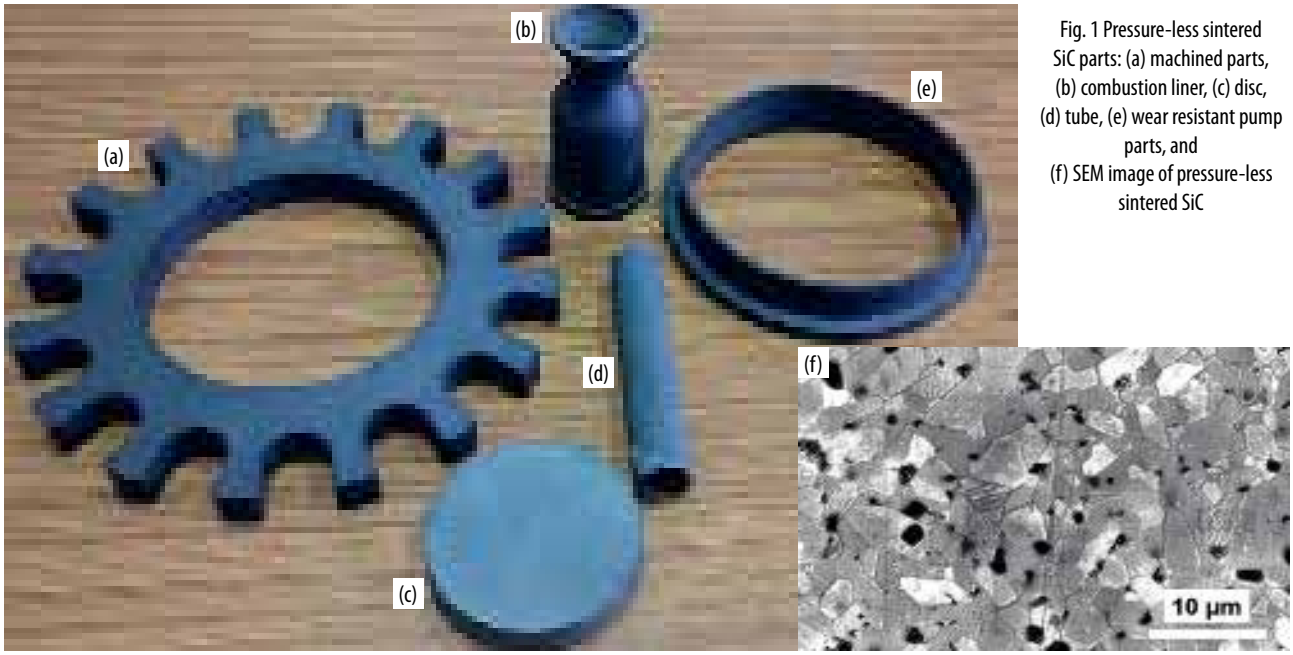

Fig. 1 Pressure-less sintered SiC parts: (a) machined parts, (b) combustion liner, (c) disc, (d) tube, (e) wear resistant pump parts, and (f) SEM image of pressure-less sintered SiC

Centre for Carbon Materials

Nanocarbon technology deals with many forms of carbon (balls, tubes, sheets, diamonds, graphenes, etc.), among which nanotubes and graphene / nanoplates are most widely used. Graphene offers unique set of thermal, mechanical physical and electronics properties which makes it the ideal material for various engineering and technological applications. Energy sector is one such sector where many research groups are attempting to develop a super-capacitor with high energy density and power density. Carbon nanomaterials based composites materials synergetically integrate electric double layer capacitance of MWCNT with fast and highly reversible pseudo capacitance properties. Transition metal oxides or conductive polymers are essential for achieving the best properties.

Porous and high surface area carbon materials are emerging for the electrode materials for super capacitor applications. MWCNT also find applications in Lithium ion batteries applications as it increases the reversible capacity, enhances the rate capability and improves the cyclability. Carbon nanomaterials are highly anisotropic in nature and the properties are dependent on processing route as well as the processing conditions. Optimization of processing parameters and controlling the structure are the key factors for such application, therefore efforts in the centre to get the better carbon nanomaterials are being persuaded. Keeping these emerging applications of carbon nanomaterials, centre for carbon materials have initiated the efforts in the electrode development for supercapacitor applications. To achieve the compatible porosity with good pore size distribution, chemical activation of charcoal has initiated as collaborative research. Studies shows that the inefficient utilization of fuels due to various losses in the system. The most evident loss being due to friction, which led to search for better lubricants both in terms of efficiency and environment aspects has led to testing of various materials as lubricant additives. Graphite due to its self-lubricating property attracted a lot of interest for applications. Separation of graphene from graphite led to new horizons in field of lubrication Carbon Nano materials are being constantly explored for their inherent electrical properties. Graphene as a nano-additive in lubricant oils theoretically improves its lubricating properties and thermal properties as well. Graphene, with its various forms (monolayer, few layer and multi-layer) is a potential replacement of multiple additives being used in present date. The transition from conventional additives to carbon Nano-additives will lead to a big leap towards an efficient lubricant also persuaded in the centre. Centre also initiated the work of flexible carbon nanotubes mat which also find application in the electrode materials.

Chemical Vapour Deposition facility for synthesis of vertically aligned carbon nanotubes

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Porous Carbon Network Derived from Microwave-exfoliated Graphite for Energy Storage

One of the major ambitions of the energy industry in the 21st century is to explore for 'greener," more efficient energy conversion and storage. Ultracapacitors offer a potential alternative to batteries, as they present a prospect to utilize greener materials, have a longer lifetime, high charge and discharge rates, and high power density.

As the maximization of the surface area of the micro- and nanostructure is the key to create a high performance electrode, it is likely that further advancements in porous materials technology will help to realize the full potential of the nanostructures, and optimize the performance of the ultracapacitors as a whole. Exfoliated graphite (EG) was fragmented into ultrathin graphene nanoplatelets (UGNP) via shear force dominated kitchen mixture in a co-solvent. UGNPs were transformed into porous carbon through chemical activation process. This strategy transforms the EG solid into flakes of carbon material with porous structure termed as activated exfoliated graphite (AEG). The morphology of EG, UGNP, and AEG is depicted in Fig.1

The electrochemical characteristics were determined by charge-discharge (Fig.1) in a sandwich type symmetric two electrode configuration in 3M KOH electrolyte. UGNP exhibited gravimetric specific capacitance of 245, 210, 152 and 140 F/g at current density of 0.5, 1, 3, and 5 A/g, respectively. The activation of EG could able to form pores suitable for ion diffusion with less charge transfer resistance and electrochemical double layer capacitance.

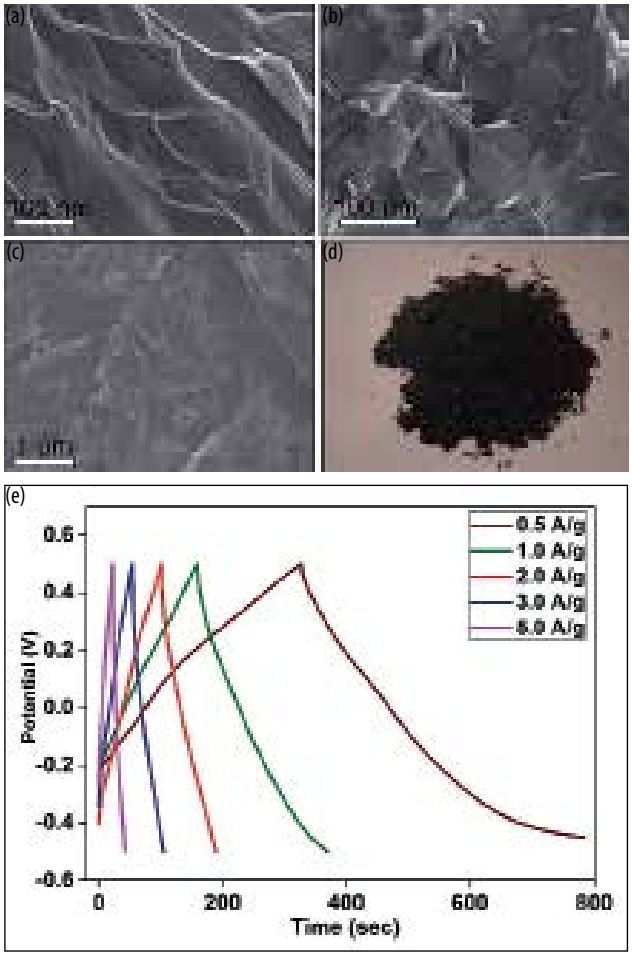

Fig.1 Scanning electron micrographs of (a) EG, (b) UGNP, (c) AEG, and digital image of (d) AEG and (e) charge-discharge curves of AEG at different current density

Carbon Nanotube Hybrid Nanostructures for Supercapacitor Application

Supercapacitor has been in great demand in the past few years, primarily due to its superior features of having fast discharge rates and long cycle life over batteries, and high storage capacity when compared with conventional capacitors. The current work is aimed at utilizing the features of both the types, and building a hybrid supercapacitor in which, the CNT helps in the conducting of electrons (power density) whereas, pseudo material helps in increasing the storage capability (energy density). The hybrid materials under consideration are CNT-MnO_2 and CNT-MnO_2. MnO_2 is preferred over other metal oxides, due to its abundance, high surface area, multiple valence states, and its crystal structure. While for CNT-MoS_2; 2D-layered structure and high surface area of MoS_2 are the prime reasons for exploring this hybrid nanostructure. The hybrid nanostructures have been synthesized using hydrothermal technique. It has been characterized using powder XRD, FESEM, and Electrochemical Analyzer (cyclic voltammetry). XRD results [Fig. 1 (a) and (b)] show that CNT-MnO_2 has Monoclinic (Birnessite) structure and CNT-MoS_2 has Hexagonal structure with well crystallinity. FESEM micrographs show CNT-MnO_2has urchin like structure, while CNT-MoS_2 has layered (flakes-like) structure with MoS_2 flakes wrapped onto CNT surface. A significant improvement in the area of the voltammogram (an indication of capacitance value) is observed in the case of hybrid material than that of individual materials. The electrochemical analysis has resulted in the specific capacitance of 176 F/g at 5 mV/s in the case of CNT-MnO_2, and 296 F/g at 5 mV/s for CNT-MoS_2. From the plots, it is evident that CNT alone has quasi-rectangular structure, typical to an EDLC, while the hybrid material shows redox peaks as shown in Figure 2.

Synthesis of Carbon Nanomaterials using Arc Discharge Method

New classes of carbon materials have entered the scene such as carbon nanotubes, carbon onions and nanoscale diamond. A major turning point was the appearance of graphene as a material available for in-depth investigations – spurred by the development of reliable production methods. The progress in terms of understanding the properties and chemistry of carbon nanomaterials has opened a whole new world of applications for nanomaterials in general. The reliable production of carbon nanomaterial represents a

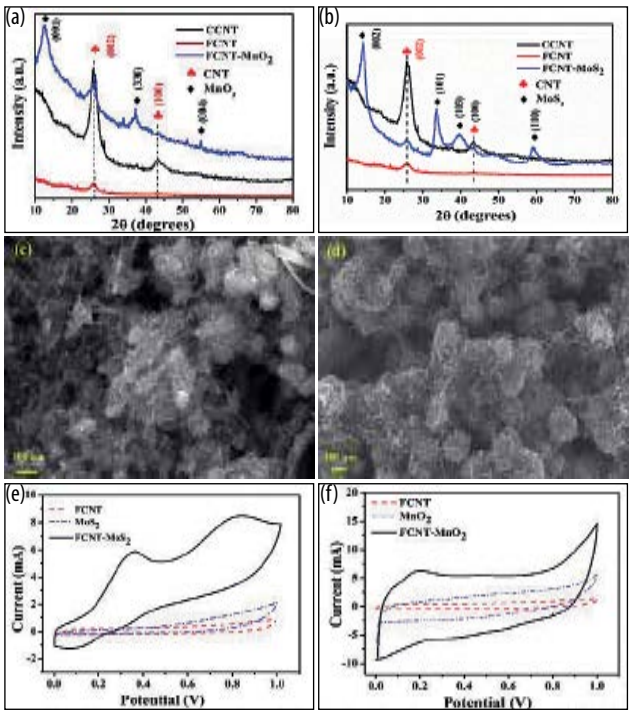

Fig. 2 XRD patterns of (a) CNT-MnO_2 and (b) CNT-MoS_2; FESEM images of (c) CNT-MnO_2 and (d) CNT-MoS_2; Cyclic Voltammetry of (e) CNT-MnO_2 and (f) CNT-MoS_2.

necessary requirement for the development of a research field. There are three main synthesis techniques of carbon nanomaterials, viz., arc discharge, laser ablation and chemical vapor deposition. This article aims to concentrate on synthesizing CNMs using arc discharge by introducing some modifications in the experimental setup. The arc discharge technique generally involves the use of two high purity graphite electrodes. The anode is either pure graphite or contains metals. The distance between the electrode is so set that the current flowing is maintained around 200A. The temperature in the inter-electrode zone is so high that carbon sublimes from positive electrode(anode). A constant gap between the electrodes is maintained by adjusting the position of the anode. A plasma is formed between the electrodes. The plasma can be stabilized for a long time by controlling the distance between the electrodes by means of the voltage control. Various kinds of products are formed in different parts of the reactor: (1) large quantity of rubbery soot on the reactor walls; (2) grey hard deposit at the end of the cathode; and (3) web-like structures between cathode and the chamber walls. When no catalyst is used, only the soot and deposit are formed. The soot contains fullerenes while MWNTs together with graphite carbon nanoparticles are found in the carbon deposit. When metal catalyst is co-evaporated with carbon in the DC are discharge, the core of the deposit contains MWNTs, metal filled MWNTs (FMWNTs), graphitic carbon nanoparticles, while the powder-like soot contains MWNTs, FMWNTs and SWNTs. The quality of CNMs in arc discharge are improved by introducing an artificial wall between the arcing point and the reactor wall using quartz. This wall plays an important role in confining the carbon vapors by acting as a shield and thus influences the trajectory of the carbon vapors. The distance traversed by the vapors is reduced resulting in quick deposition. XRD data justifies this fact. The crystallinity of the CNMs produced using quartz tube (Red Curve) are more compared to the one without (Blue Curve). The SEM micrograph also supports the argument. It is observed that the number of MWNTs are more in the case of experiments where quartz tube was enclosed as compared to the other case where there was no quartz tube.

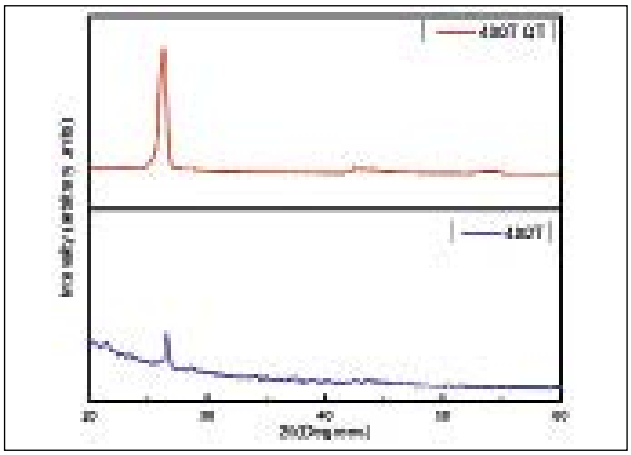

Fig. 3 XRD of MWNTs with and without using quartz

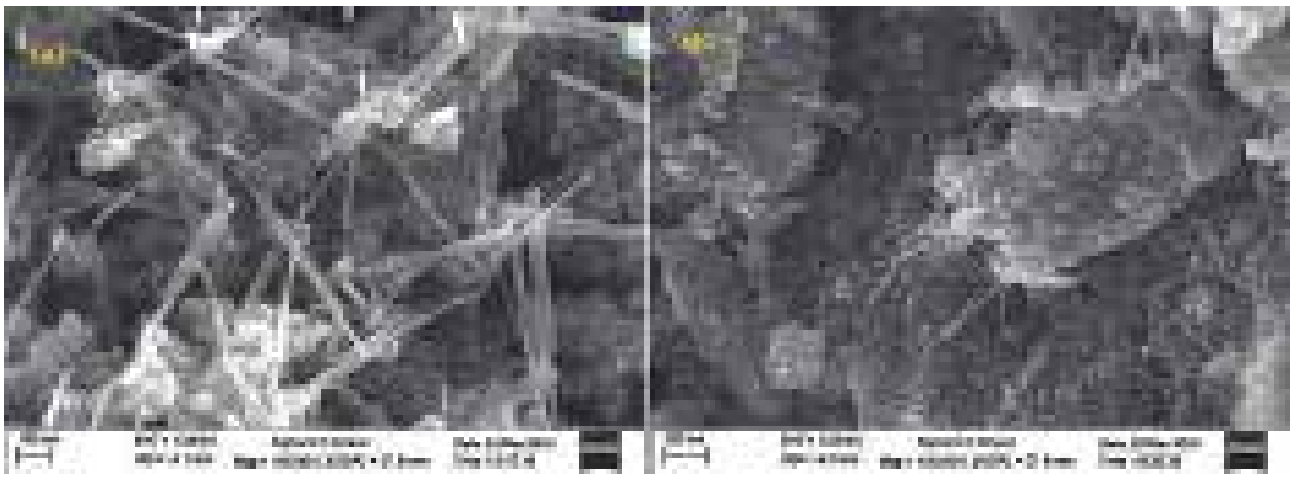

Fig. 4 SEM Micrographs of CNMs (a) with and (b) without quartz

Centre for Sol-gel Coatings

Centre for Sol-Gel Coatings has been consistently working with various industrial partners for commercialization of the sol-based nanocomposite coatings for different applications. The most distinct advantage when sol-gel coatings are used on metals/alloys is that a direct deposition of an adherent coating on the metal/alloy substrate is possible thus obviating the need for use of any adhesion promoters, or any toxic conversion coatings. During the last year, the Centre has been seriously focusing on the following application oriented research

Development of hexavalent chrome-free, self-healing, corrosion protection coatings on Al and Mg alloys for aerospace and automotive applications are in progress. Coatings are designed and formulated based on the layered materials containing organic/inorganic corrosion inhibitors. Developed coatings have been successfully demonstrated for the use on aluminum alloys 2024-T3, 6061-T6 and 70 75-T6 corrosion protection applications.

Durable ultra-hydrophobic surfaces could be generated using a combination of surface texturing and sol-gel coatings useful for antibacterial applications as well as for corrosion protection. Investigations were also carried out to explore the environment friendly and rapid curing technique such as NIR. Based on encouraging results, feasibility parameters for scale-up are being established. Attempts are also in progress at the center to develop the fully dielectric solar control coatings on glass for architectural and automotive applications.

Protective scratch resistant coatings developed by the center have been applied on the retroreflective road marker lenses for enhanced durability during service. Coated lenses are currently undergoing field trials with the user industry.

Chrome-free environmental friendly coating stack applied on AA2024 T3 alloy after 336 hrs of Salt Spray Test showing no corrosion at bent points

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Evaluation of Self-Healing Properties of Inhibitor Loaded Nanoclay-based Anti-corrosive Coatings on Magnesium Alloy AZ91D

Light weight metals such as magnesium and its alloys are used in structural applications where reduction in weight has more dividends such as automobile, communication and aerospace industry. But these materials are prone to corrosion in saline environment. Use of self-healing coatings is the latest concept, where materials have the built-in capability to substantially recover their corrosion protection properties even after their damage. Naturally occurring halloysite nanotubes loaded with cationic corrosion inhibitors Ce^{3+}/Zr^{4+} and dispersed in hybrid organic-inorganic sol-gel matrix sol was used for the present investigation to deposit coatings on AZ91D magnesium alloy substrate and cured at 130°C for 1 h in air. Corrosion resistance of only matrix sol (MAT), matrix sol with only halloysite (CM) and inhibitor loaded halloysite dispersed in matrix sol (SH) coated and uncoated substrates were analyzed using potentiodynamic polarization and weight loss measurements after exposure to 3.5 wt.% NaCl solution for varying time durations between 24 h to 120 h. The anticorrosive and self-healing properties of SH sol coated substrates could be confirmed with EDS analysis after weight loss measurements and micro-Raman spectroscopic analysis. Coatings generated with SH sol were seen to exhibit the highest corrosion resistance when compared to MAT or CM sol, after prolonged exposure to corrosive environment. The reason attributed to the superior corrosion resistance of SH coatings is due to controlled release of corrosion inhibitors, during prolonged exposure to corrosive medium.

Environmental friendly Layered Double Hydroxide (LDH) based Sol-Gel Coatings for Corrosion Protection of AA 2024-T3 Alloy

Aluminum and its alloys are extensively used in aerospace industry due to their high strength/weight ratios. AA2024-T3 alloy is the most important alloy used for structural parts due to its superior mechanical properties. But it is prone to corrosion due to the presence of intermetallic particles such as S-Phase (Al_2CuMg), θ-Phase (Al_2Cu), Al_8Fe_2Si, Fe_2Si and CuFeMn. Organic coatings such as paints are generally used to protect these surfaces to provide a barrier protection. However, when the paint layer gets damaged due to mechanical scratches, the substrate gets exposed to the corrosive medium and corrosion initiates. Hexavalent chromium-based conversion coatings are conventionally being used as first layer adjacent to the substrate due to their self-healing property followed by primer, paint and top coat layers for the most effective and low cost protection system against corrosive atmosphere and has been in

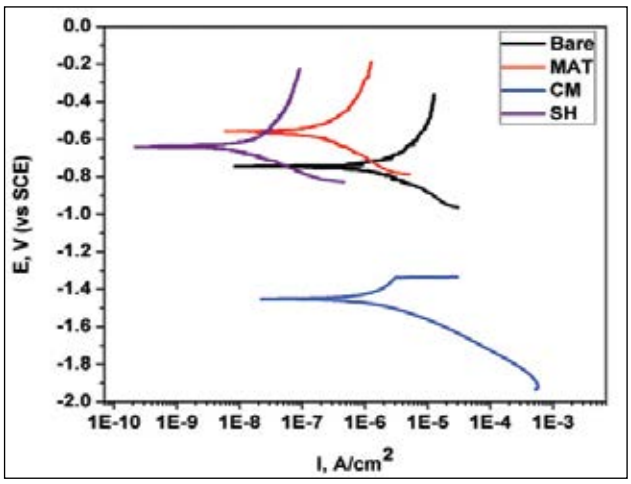

Fig. 1 Potentiodynamic polarization data for bare and coated substrates after 120 h exposure to 3.5 wt % NaCl solution

vogue for the last few decades almost in all segments of industry. But, chromate conversion coatings have recently been globally banned due to their carcinogenic nature. Organic-inorganic hybrid sol-gel coatings are found to be potential replacements for chromate conversion coatings, both from the point of tuning the chemistry to achieve the desired property as well as from the point of ease of deposition on large areas, as they have good adhesion with the substrate, intrinsic durability, flexibility, hardness to with stand mechanical stress and are low temperature curable. Moreover, these coatings are thin and reconcilable with primers. Presence of three-dimensional network silica, as the main component of the coating structure, can provide a dense coating that has an excellent barrier property. Various corrosion inhibitors can also be used as additives to sol-gel coatings to further enhance the corrosion protection property of sol-gel coatings.

Direct addition of corrosion inhibitors is not found to be effective as inhibitor may react with coating or may get consumed quickly due to uncontrolled release of the inhibitor. Layered double hydroxide (LDH) is a biocompatible nano container which has a layered structure and can be successfully used to intercalate either organic or inorganic corrosion inhibitors. For the present investigation, various organic and inorganic corrosion inhibitors were intercalated into LDH and dispersed in a hybrid sol-gel silica matrix sol, which was used to generate coatings on AA 2024-T3 aluminum alloy substrates. A two-layer configuration was employed for generation of coatings, where the top layer had an inorganic corrosion inhibitor intercalated LDH in sol-gel matrix, while the first layer had an organic inhibitor. Coatings generated by dip coating technique were cured at temperatures below 100°C for 30 min - 1 h. Corrosion resistance of coatings deposited from matrix sol with and without inhibitor intercalated LDH was investigated by potentiodynamic polarization for short term 1 hr and long term 120 hr exposure to 3.5% NaCl solution. Adhesion of the coatings to the substrate and to the primer that was applied over

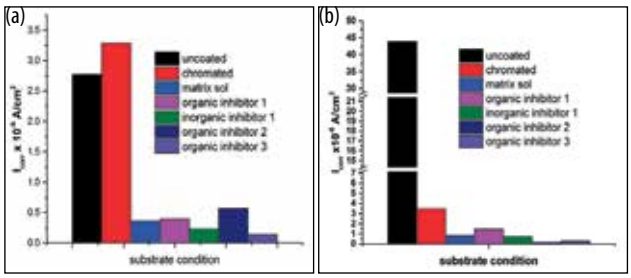

Fig. 2 Corrosion current measurements from (a) 1 hr and (b) 120 hr exposure to 3.5% NaCl solution in potentiodynamic polarization test

sol-gel coatings was evaluated by cross-hatch cut and peel-off tape test.

Potentiodynamic polarization present in the Fig. 2 show that all sol-gel compositions rendered improved corrosion protection to AA 2024-T3 substrates when compared to uncoated and chromate conversion coated samples due to a simple barrier type protection after both 1hr and 120 hr exposure. However, superior enhanced corrosion protection as compared to even chromate conversion coating exhibited during long term exposure, demonstrates the protection behavior due to the controlled release of inhibitors loaded in LDH from the sol-gel matrix. Coatings were also found to be quite adherent to the substrate exhibiting the highest possible adhesion strength of 5B. Results ascertain environmentally benign green sol-gel coatings derived from a hybrid sol containing corrosion inhibitor intercalated LDH was successfully developed on AA2024 substrates.

Development of Durable Super Hydrophobic Coatings on SS 304

Super Hydrophobic (SHP) coatings currently represent an important and interesting field of research in several fields such as aircraft exteriors, automobiles and solar panels. In this study, the SHP property is achieved by the formation of the hierarchical micro-nano structure on the surface. The challenge of SHP coatings is the durability. Hence, in this study SHP coatings were generated using a silica-based nanocomposite sol, which was deposited on a surface modified Stainless Steel (SS) coupon for improving adhesion and durability. The coated samples were cured under different process conditions like thermal & Near infrared (NIR) curing using optimized temperature and time. The samples were characterized for water contact angle, sliding angle, microstructure, surface roughness, weathering resistance, particle size distribution of sol and mechanical durability such as scratch testing, adhesion testing and abrasion testing. As-coated samples exhibit water contact angles of 166±3° and sliding angles ranging from 2-5°. Tape adhesion test conducted on the samples as per ASTM D3359 exhibited 5B adhesion strength. As-coated samples show 2H as Pencil scratch hardness. The average water contact angle of the abraded surface after 125 cycles was found to be 123° with corresponding

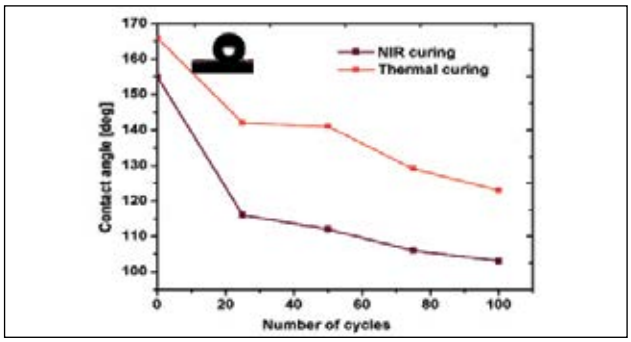

Fig. 3 Contact angle measurements at different cycles

sliding angle of 29°. The water contact angle decreased slightly from 166° to 156° after 100 hrs of exposure to weathering conditions. The present study showed that durable SHP coatings could be successfully generated and is promising for industrial applications.

Development of High Temperature Compliant Seals

Compliant seals or joints extensively used for bonding polymeric/metal/ceramic materials for room temperature or service temperatures up to 250°C. However, typical sealing application such as sensors, solid oxide fuel cells, igniters, heaters and automobile exhaust assembly requires relatively higher temperature in the range 800-1200°C to join metal and ceramic parts. Currently, no indigenous product or technology is available to cater the above applications. As per the requirements from user industry, ARCI has initiated high temperature compliant seals based on indigenously available raw materials as an import substitute. A high temperature ceramic based adhesive paste was successfully developed and tested at 800°C with a major constituent of aluminum oxide and sodium silicate. Fig. 4(a) shows metal (SS) ceramic (silica and SiC) joint bonded using developed high temperature adhesive paste. The joint exhibited the structural integrity even after exposure to 800°C for 1 hr. The shear bond strength of the developing and imported adhesive paste at room temperature is shown in Fig. 4(b). It shows that the shear bond strength of ARCI paste is 1.4 MPa and is comparable with strength 1.8 M.Pa of imported bonds.

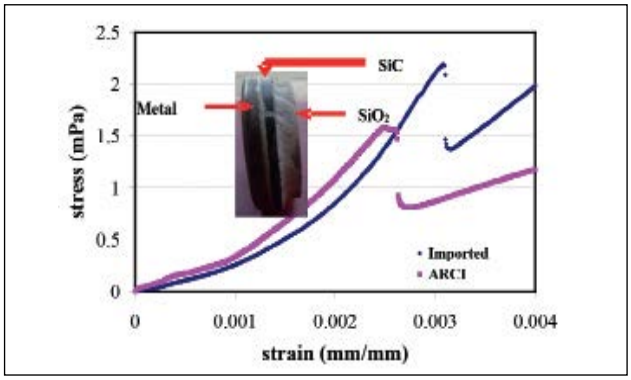

Fig. 4 High temperature compliant seals (a) bond after exposure to 800°C (b) Comparison of shear bond strength at room temperature

Centre for Materials Characterization and Testing

The Centre for Materials Characterization and Testing caters to the characterization needs of all Centres of Excellence on the ARCI Hyderabad campus, and provides services as needed to the Centres in Chennai. In addition, it also takes up work from ARCI's technology receivers and external users, both from industry and academia.

The focus of the work is on microstructure-property correlations. The work undertaken broadly falls under the categories of microstructural, structural, mechanical, chemical and surface probe characterization. The major equipments in the Centre are as follows: Transmission electron microscope, scanning electron microscope with EDS and EBSD attachments, small angle x-ray scattering unit, focused ion beam unit, x-ray diffractometer, non-contact surface profiler and corrosion testing unit.

To keep abreast with ARCI's growing needs for materials characterization, a field emission scanning electron microscope with EDS and EBSD units has been installed during the past year. A photograph of the same is shown in Fig. 1(a), while Fig. 1(b) shows a high resolution image recorded at 500 kx of a carbon nanotube sample, collected using the unit. Procurement of an x-ray diffraction unit with a rotating anode target is in progress.

The members of the Centre also take up independent research projects in areas of interest to ARCI. Recent work has been on the synthesis and study of crystalline SnO_2 nanoparticles by flame oxidation, mapping of the mechanical properties of different types of coatings in the micron length scale, and on the effect of nozzle geometry on corrosion behaviour of cold sprayed Ni coatings. Research highlights of each of these are given below in brief.

Newly installed FESEM

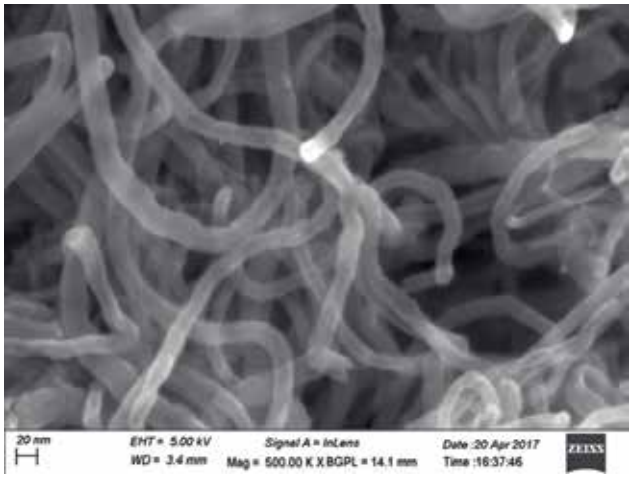

Image at 500 kx of CNT sample

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Synthesis and Characterization of Crystalline SnO_2 Nanoparticles

ARCI, in collaboration with PSG college of Technology (Coimbatore, India), has developed a novel method to synthesise gram-scale quantities of crystalline tin oxide (SnO_2) nanoparticles by flame oxidation using inexpensive tin (Sn) feedstock. SnO_2 metal oxide semiconductor nanostructures possess a wide direct band gap (3.6 eV), high electron mobility (100–200 $cm^2V^{-1}S^{-1}$) and superior chemical tolerance. Hence they are of considerable interest to scientists and engineers due to their potential for technological applications spanning from sensors, displays and catalyst to energy conversion and storage devices. Several studies have shown that the distinctive properties of SnO_2 are largely influenced by its size, morphology, crystallinity, and phase. Therefore, development of synthesis techniques with good control over these parameters has become the subject of intense research.

Fig. 1(a) shows a SEM image with the histogram showing the size distribution as inset. Selection of the optimal feedstock size and resident oxidation time based on computational fluid dynamics ensured complete conversion of Sn into SnO_2 nanoparticles, which were examined using X-ray diffraction (Bruker-D8 XRD, with a step size of 0.02° and dwell time of 2s) and found to be crystalline and phase-pure. The position and broadening of diffracted peaks (Fig. 1(b)) indicate the nanocrystalline nature of SnO_2 powder. Scanning electron microscopy (SEM) image of as-synthesized SnO_2 shows micron-sized agglomerates consisting of loosely connected SnO_2nanoparticles (Fig.1(c)). A representative TEM bright-field image (recorded on an FEI unit, model Tecnai 200) of dispersed product shown in Fig. 1(d) indicates the presence of SnO_2 nanoparticles. The histogram of the particle size distribution (Fig. 1(e)) follows log-normal distribution with a mean size of 15.3 nm and a SD of 15.1 nm. The selected area diffraction pattern (Fig. 1(f)) exhibits a ring pattern, indicative of random orientation of nanoparticles. From the radius of the rings, the interplanar distance was estimated and found to be the same as that of SnO_2 with symmetry of P42/mnm (136). A schematic of the formation mechanism of crystalline SnO_2 nanoparticles from metallic Sn feedstock is shown in Fig. 1(g).

The beneficial application of flame-synthesized SnO_2 nanoparticles is successfully demonstrated as photoanode material in dye-sensitized solar cells (DSSCs) and a maximum power conversion efficiency (η) of 2.72% has been achieved, which is better than that of commercial SnO_2 nanoparticles (η=1.53%). Further details can be found in the article "Rapid and scalable synthesis of crystalline tin oxide nanoparticles with superior photovoltaic properties by flame oxidation", MRS Communications, 7 (2017), 862-866 (10.1557/mrc.2017.97).

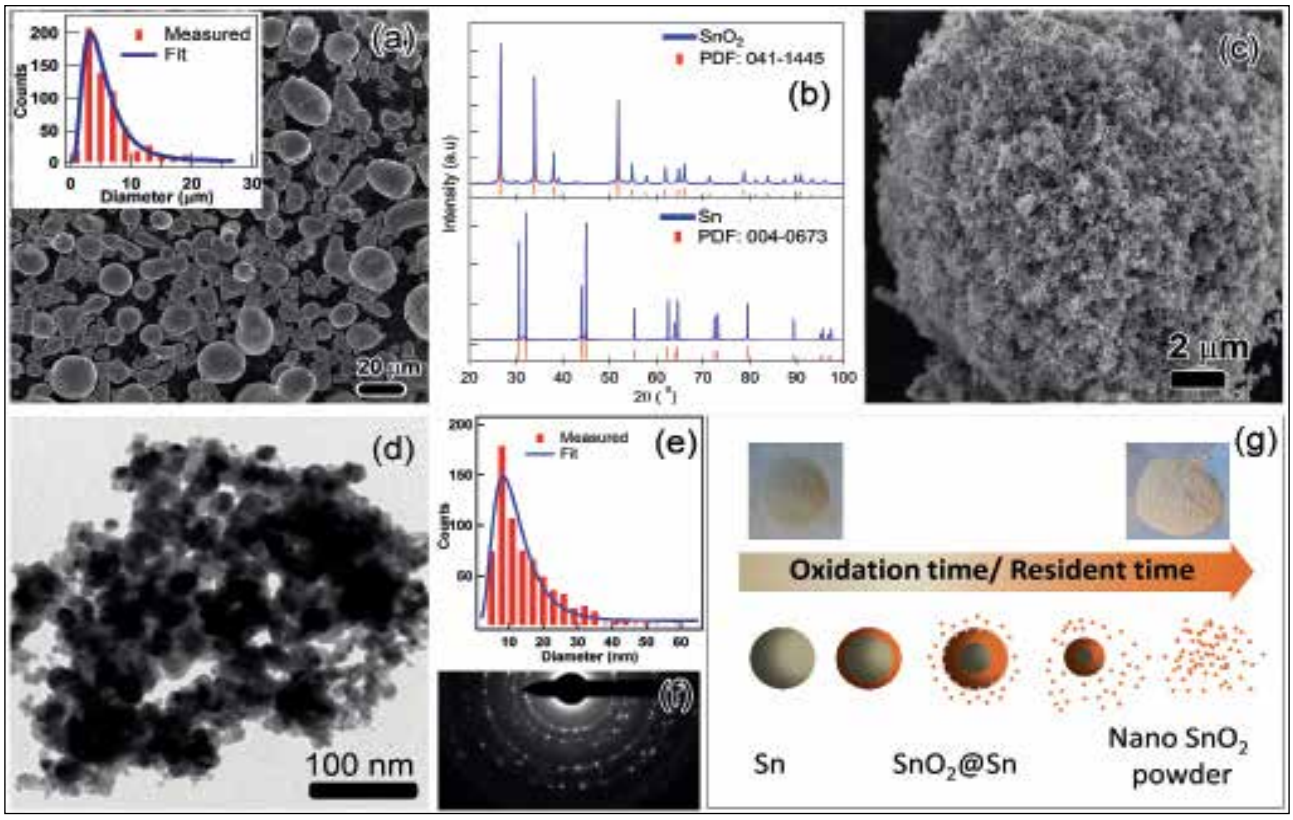

Fig. 1 (a) SEM secondary electron image of metallic Sn feedstock powder. Inset shows the size distribution; (b) XRD patterns of metallic Sn feedstock and flame-synthesized SnO_2 nanoparticles; (c) SEM secondary electron image of agglomerated SnO_2nanoparticles; (d) Representative TEM-BF image of flame-synthesized SnO_2 nanoparticles; (e) Size distribution of SnO_2 nanoparticles obtained from TEM-BF images; (f) Selected area electron diffraction (SAED) pattern from region shown in (d); and (g) Illustration of the formation mechanism of crystalline SnO_2 nanoparticles from metallic Sn feedstock.

Effect of Nozzle Geometry on the Corrosion Performance of Cold Sprayed Nickel Coatings

Cold spray coating technique is one among the thermal spray variants in which high velocity micron-sized particles are impacted onto a substrate or previously deposited layers to form the coating by strain induced adiabatic heating accompanied by shear instability. Due to the low processing temperature and high deposition rate, this process is suitable for rapid production of many metallic coatings. Several conventional metals suitable for corrosion resistance such as Aluminum, Zinc, Titanium, Tantalum, and Niobium have been successfully deposited in ARCI using air as the process gas. A few studies recently reported demonstrate that dense nickel coating could be formed with either helium or nitrogen combined with an external powder pre-heater. However, it is still difficult to form a dense nickel coating using air as the process gas with conventional nozzle geometry. The critical velocity of a metal decreases significantly with increasing particle impact temperature. To increase the heat input to the feedstock powder particle, certain key segments of the nozzle were redesigned and fabricated. Coating trials were carried out using different sets of nozzle geometries at different process temperatures. The quality of the coatings was characterized by microstructural analysis, and electrochemical performance in 3.5% NaCl solution was studied. It is found that the increase in powder particle temperature is directly proportional to the plastic deformation of the impacting particle. It is evident from the scanning electron microscope images that the porosity and inter-splat bonding features of the coatings deposited using modified convergence nozzle have been significantly improved as compared to those deposited by a conventional nozzle as shown in Fig. 2. The impact velocity alone is not sufficient to give rise to intimate bonding in the case of nickel and its alloys. Thermally accelerated enhanced plastic deformation and resultant interface interactions at elevated temperatures are crucial for achieving successful bonding. Though the activation energy of the bonding is much higher (Nickel has higher critical velocity among the conventional metals) than other metals, modifying the thermal history of the feedstock can enhance the adhesion factors which is clearly evident from the results presented here. The corrosion behavior of these coatings has been studied by the potentiodynamic polarization technique using an electrochemical work station (Solartron 1287). The potentiodynamic polarization plots are shown in Figs. 3 (a) and (b).

There is not much improvement in corrosion rates of coatings deposited by nozzle length 20 mm at both 15 and 20 bar. As the nozzle length increased from 20 to 40 and 80 mm, the corrosion rate is decreased and a passive behavior is seen in the graphs. The porosity seen in the coatings allowed the electrolyte to penetrate and corrode the substrate. The porosity has decreased as the nozzle length increased and showed minimum porosity in the coating coated with 80 mm nozzle length Fig. 2(f). The corrosion performance is corroborated very well with the microstructures of the coatings as well as corrosion tests, as shown in Fig. 3.

High Resolution Mechanical Property Mapping using Instrumented Indentation

Composite coatings with Chromium carbide as hard phase and Nickel-rich alloy as binder were generated by

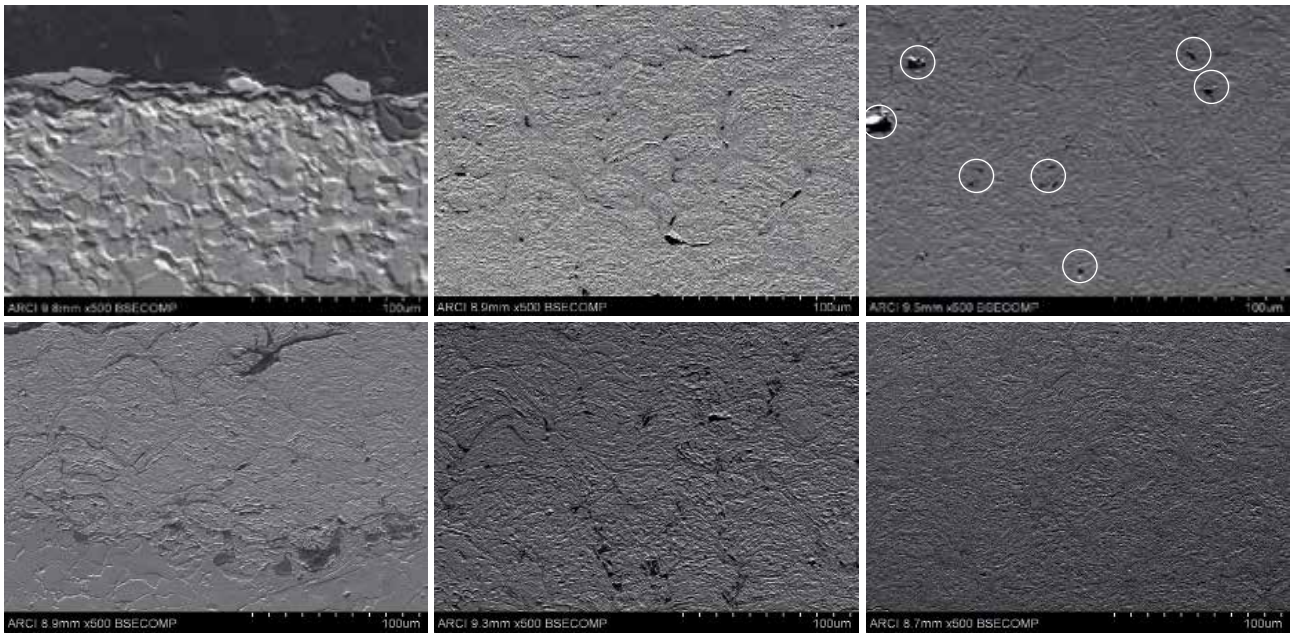

Fig.2 Scanning Electron Microscope images of etched Nickel coatings with nozzle lengths of (a) 20, (b) 40 (c) 80 mm at 15 bar, 600°C and with nozzle lengths of (d) 20, (e) 40 and (f) 80 mm at 20 bar, 600°C

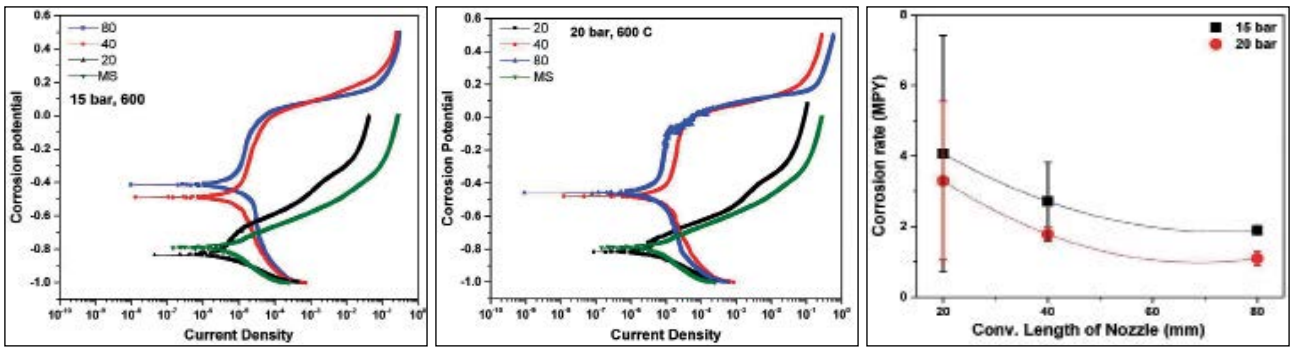

Fig. 3 Potentiodynamic polarization plots of (a) 15 bar, 600°C and (b) 20 bar, 600°C and (c) Corrosion performance vs Nozzle length of the cold sprayed nickel coatings

laser Cladding, detonation spraying and plasma spraying. The microstructure (Fig. 4) of the coatings was found to be a strong function of the processing parameters. Laser clads with cooling rate in the range of 103 to 104 K/s had a dendritic microstructure with interdendritic Nickel-rich alloy phase. In contrast, the microstructure of the thermal sprayed coatings has a splat structure which cools at a much faster rates of 107 to 108 K/s and hence showed lower carbide content. Hardness and modulus evaluation using instrumented indentation testing (IIT) facility in these coatings is a common method to evaluate the mechanical properties. However, there are no reports on mapping of the above-mentioned properties in these coatings. In this study, the microstructure was analyzed using a scanning electron microscope (Gemini 500) and the hardness and modulus mapping were carried out using a high strain rate IIT facility (Nano blitz). The mechanical property measurement is particularly interesting in these coatings owing to the fine features present in the microstructure. The results presented in Figure 4 clearly show a one to one correlation between the microstructure and mechanical property maps in all the coatings. The fine spacing (1 µm) between the indentations used for mapping has produced high resolution maps. There is a clear distinction between the carbide and the metallic phase in the laser clad coating, whereas in the thermal sprayed coating, the final carbides present are the un-melted ones from the feedstock. In the thermal sprayed coatings, the pores and the un-melted Nickel rich phase are also resolved. Such high resolution quantitative mechanical property maps can provide deeper insights into microstructure-property correlations in these coatings.

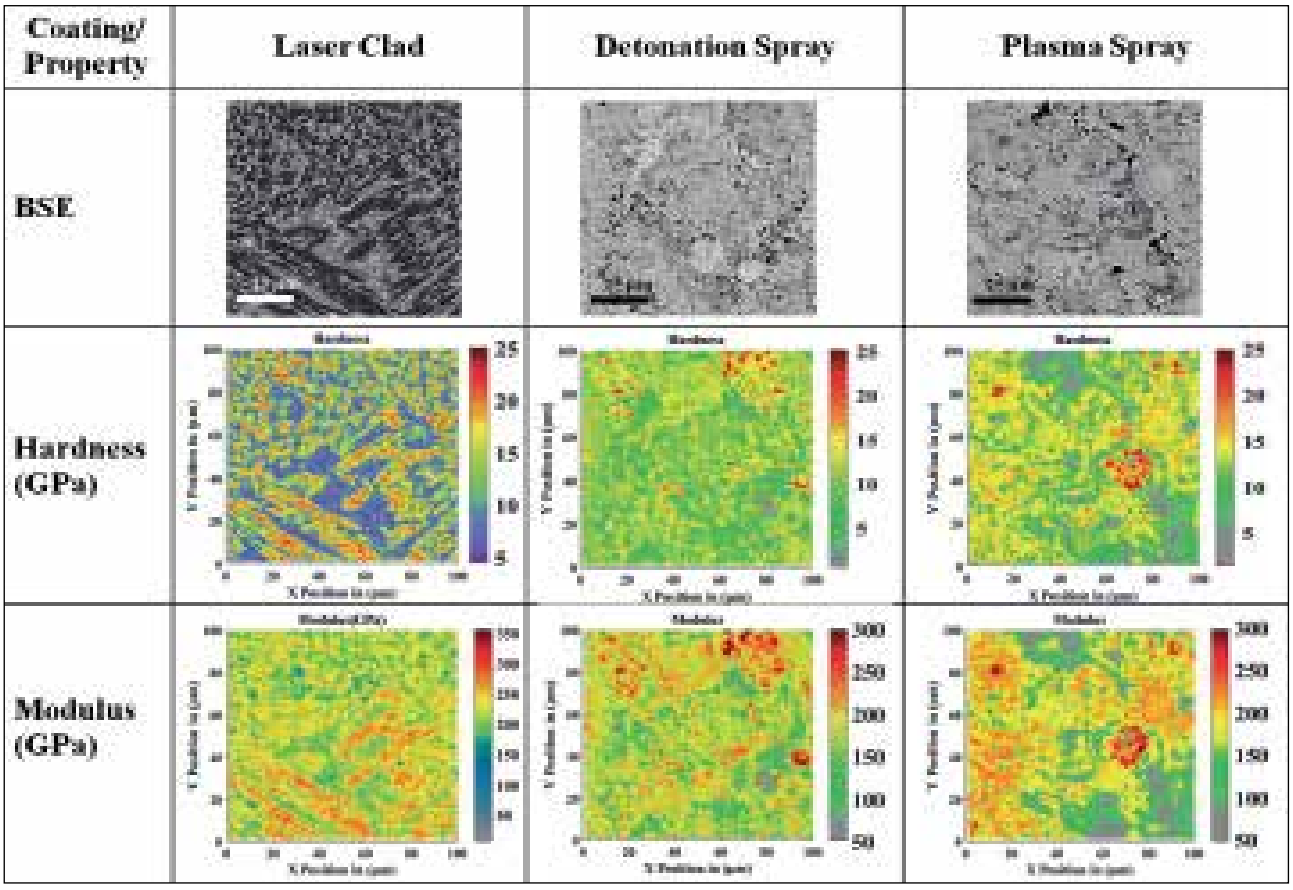

Fig.4 SE image, hardness and madululs map for laser clad, plasma sprayed and detonaion sprayed coatings

Centre for Technology Acquisition and Transfer

Centre for Technology Acquisition and Transfer (CTAT) has been carrying out value addition activities for research and technology development projects at all stages namely exploratory studies, laboratory testing, field demonstration and/or technology transfer. An Intellectual Property Development Indices (IPDIs) methodology is being used to assess the readiness level of R & D, identify collaborative and other value addition requirements so that research can be translated to a technology that is suitable for transfer and commercialization. Methodology, as depicted in Fig. 1, helps in devising a clear roadmap from 'the point of initiating partnership' to 'the point of envisaged objective', milestone-linked deliverables and financial arrangement, and IP sharing and utilization strategy. This approach also provides flexibility in forging mutually beneficial partnerships at any stage in the IP value chain with stakeholders from industry, academia and R & D. At ARCI, we recognize that well-considered collaborations with the private / public–funded organizations for joint technology development/ field demonstration and /or technology transfer are essential to bring-in effectiveness and efficiency in the translational research process. Above methodology and concomitant initiatives are aimed at enhancing the mutual trust between partners who wish to leverage their complementary resources and intellectual capabilities. Major partnership agreements for the following technological areas were signed during 2017-18:

- laser clad coating for a component having application in thermal power plants (April 2017)
- clear coating system for acrylic retroreflective lenses to enhance their abrasion resistance (June 2017)
- inorganic bond material suitable to replace resin as a bonding agent in the production of silica tiles (July 2017)
- electrodeposition of nickel tungsten alloy coatings (August 2017)
- testing the emissions and improve the performance of sanitary pad incinerator in terms of emissions and energy efficiency (September 2017)
- multi-channeled Ceramic Element Holders (MECCH) for sanitary pad incinerator and demonstration of MECCH woven with heating element for sanitary pad incineration (October 2017)
- collaborations in the areas of engineered coatings, nanotechnology and powder metallurgy (October 2017)
- customized cooling channel for the progressive reactive hot press (October 2017)
- glass-to-metal sealing (GMS) process and an automated GMS fabrication unit (December 2017)
- fuel cells for forklifts (February 2018)

Patent analysis has been used to provide inputs for R & D planning, patent filing, publications / technical discussions in nearly 20 cases. To showcase its knowledgebase and capabilities, ARCI participated in 5 exhibitions: Laser World of Photonics at New Delhi, India International Science Festival 2017 at Chennai, Technozion 2017 at Hyderabad, Indian Institute of Welding 2017 conference at Hyderabad, and International Engineering Sourcing Show 2018 at Chennai. Over 25 leads were generated as a result of outreach efforts such as participation in exhibitions, delivering invited lectures, making presentations, and participating in the panel discussions. To intensify the industry interactions, an initiative was taken to constitute the Working Groups for different sectors. Costing of more than 50 projects / technologies was conducted.

Fig. 1 Schematic showing IPDIs , milestones and value addition activities carried out by CTAT

IPDI →	1	2	3	4	5	6	7	8	9	10
Activities →	Basic concepts and understanding of underlying scientific principles	Shortlisting possible applications	Research to prove technical feasibility for targeted application	Coupon level testing in simulated conditions	Check repeatability/ consistency	Prototype testing in real-life conditions	Check repeatability/ consistency	Reassessing feasibility (IP, competition technology, commercial)	Initiate technology transfer	Support in stabilizing production
IP Chain Milestone(s) →	Exploratory studies		Laboratory testing			Field demonstration			Technology transfer	
Role of CTAT →	• Competitive intelligence • Identification of possible collaborators • Selecting appropriate engagement model (decision variables: IPDIs, collaborators, IP ownership & licensing methodology, deliverables, milestones, financials etc.) • Preparing/finalizing contratual agreement • Patent analysis and filing					• Activities mentioned from IPDI 1 to 5 • Preparing status reports on onoging R&D projects and using them for IP/Technology Marketing efforts • Feasibility assessment • Costing of technologies and projects			• Activities mentioned from IPDI 1 to 8 • Receivables management (collection of technology transfer fees/royalties) even beyond IPDI 10	

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Portfolio of ARCI Technologies

Technology Transfers Undertaken

Based on the perceived market size of products/ services based on ARCI technologies, ARCI has adopted exclusive and non-exclusive modes of technology transfer to facilitate healthy competition in the market. So far, ARCI has successfully transferred 15 technologies to 27 receivers and few technologies are under transfer. The following table depicts the technologies transferred:

S.No	Technology	Industry Targeted	Status
1-8	*Electro Spark Coating (ESC) Equipment*	*Hard, wear resistant coatings*	*Transferred to 8 companies on non-exclusive basis*
9	*Magnesia Aluminate Spinel (MAS)*	*Steel, cement and power plants*	*Transferred on exclusive basis*
10	*Ceramic Crucibles*	*Carbon and Sulphur analysis*	*Transferred on exclusive basis*
11	*Energy Efficient Air Heaters from Ceramic Honeycombs*	*Industrial heating*	*Transferred on exclusive basis*
12-15	*Detonation Spray Coating (DSC)*	*Wear and corrosion resistant coatings on various components*	*Transferred to 4 companies on region exclusive basis*
16	*Reinforced Graphite Sheets and Seals*	*Automotive sector*	*Transferred on exclusive basis*
17	*Heat Pipes Heat Sinks*	*Waste heat recovery systems, solar energy applications, power electronics*	*Transferred on exclusive basis*
18	*Evaporation Boats*	*Metallization*	*Transferred on exclusive basis*
19	*Ceramic Honeycomb Molten Metal Filters*	*Molten metal filtration*	*Transferred on exclusive basis*
20	*Calcium Aluminate Cements and Furnace Sealants*	*Refractory castables*	*Transferred on exclusive basis*
21-23	*Micro Arc Oxidation (MAO)*	*Hard (1800 VHN) wear resistant coatings on Aluminum and Titanium alloys*	*Transferred to 3 companies on region exclusive basis*
24	*ESC Equipment Manufacturing*	*Diverse segments*	*Transferred on non-exclusive basis*
25	*Nanosilver Impregnated Ceramic Water Filter Candles to Impart Antibacterial Function*	*Water purification*	*Transferred on non-exclusive basis*
26	*Nanosilver based Textile Finishes for Antibacterial Applications*	*Anti-bacterial applications*	*Transferred on exclusive basis*
27	*Nanotitaniumdioxide based Textile Finishes for Self Cleaning Applications*	*Self-cleaning applications*	*Transferred on exclusive basis*
28	*Aerogel Flexible Sheet Technology*	*Thermal Insulation applications*	*Ongoing*
29	*Laser Cladding Technology for burner tip nozzles*	*Thermal Power Plants Applications*	*Ongoing*
30	*Inorganic bond material to replace resin*	*Ceramic tiles applications*	*Ongoing*
31	*Pulsed Electrodeposition of Nickel Tungsten Alloy Coatings*	*Wear and Corrosion resistance applications*	*Ongoing*

Technologies Available for Adaptation/Transfer

S. No	Technology and Related Issues	Key Features and Applications	
1.	**Advanced Detonation Spray Coating Technology (DSC) MARK-II** **Intellectual Property Development Index (IPDI):** Process parameters were optimized. Coating quality, repeatability and reliability studies were completed.	**Key Features:** - *High productivity due to high pulse frequency* - *Less maintenance: absence of mechanically moving parts* - *Good adhesion strength (>10000 psi)* - *Dense microstructure (< 1%)* - *Negligible thermal degradation and excellent tribological properties* - *Ability to coat wide range of powders, carbide, oxide, metal powders* - *Lower substrate temperature & low oxide content* - *Coatings with 50-2000 microns thickness can be produced*	**Possible Applications:** • *Steel industry application such as Bridle rolls* • *Textile & Paper industry applications such as wire passing pulleys, plungers, steeped cone pulleys, bearing stopper plates, guide rolls* • *Gas compressor applications such as spindle valve, compressor disc, compressor shaft* • *HP & LP turbine blades, compressor discs, LCA nozzles, thrust beating sleeves, propeller shaft seals.* • *Power and Energy applications such as guide vanes, spindle valves, hydro turbine blades.*

S. No	Technology and Related Issues	Key Features and Applications	
2.	**Detonation Spray Coating (DSC) Technology** **Intellectual Property Development Index (IPDI):**Technology transferred to 4 companies and is available for transfer	**Key Features:** - *Attractively priced compared to imported HVOF units* - *Extreme versatility* - *Capable of depositing a vast range of metals, alloys, cermet, ceramic and composite coatings for varied functional applications*	**Possible Applications:** • *Coatings for applications such as wear and corrosion resistance etc. for various industries*
3.	**Micro Arc Oxidation** **Intellectual Property Development Index (IPDI):** Technology transferred to 3 companies and is available for transfer	**Key Features:** - *Ability to coat Al, Ti, Mg and Zr metals and their alloys* - *Ease to coat complex shapes and difficult to access regions* - *Uniform, dense, hard and thick coatings* - *Superior coating properties and performance compared to other conventional acid based processes like anodizing and hard anodizing* - *Excellent tribological properties and corrosion resistance* - *Eco friendly* - *5-40 times service life improvement*	**Possible Applications:** • *For a wide array of applications in industries such as textile, automobile etc.*
4.	**Cold Gas Dynamic Spray Technology** **Intellectual Property Development Index (IPDI):** Reassessing feasibility (IP, Competition, Technology, Commercial)	**Key Features:** - *Indigenously developed state of the art PLC based automated Portable control panel (Max Pressure – 20 bar)* - *Different set of nozzles* *a. For Low melting materials (polymer based)* *b. High deposition rate or coverage area* *c. Low deposition rate or coverage area* *d. For Ni based materials, Steels (Optional)* - *Compressed AIR as process and carrier gas* - *Maximum Pressure- 20 bar; Maximum Temperature-600°C* - *Cu, Al, Ag, Zn, Sn,Ni, SS, Ta, Nb, Ti and alloys and composites*	**Possible Applications:** • *Repair and Refurbishment Applications* • *Coatings for Electrical contacts, lugs, EMI shielding, heat sinks* • *Coatings for High Temp Corrosion resistance, Bio medical, Sputter Target* • *Cathodic Protection coatings* • *Anodic Protection coatings* • *Wear resistant coatings* • *Nanostrcutured / amorpohous coatings* • *High Entropy Alloy Coatings for High Temperature Applications*
5.	**Electro Spark Coating (ESC) Equipment Manufacturing Technology** **Intellectual Property Development Index (IPDI):** Technology transferred to one company and is available for transfer	**Key Features:** - *Simple and cost effective* - *Metallurgical bonded coatings with low heat input to the substrate* - *Any electrically conductive material available in electrode form can be coated on any conductive substrate* - *Equipment is portable and lends itself easily to automation for ensuring reproducibility* - *Capable of providing coating thickness in the range of 10 to 130 µm*	**Possible Applications:** • *Component refurbishment and to combat severe conditions of wear* • *Can be used for enhancing life of cutting tools such as end mills, taps and lathe bits*
6.	**Transparent Ceramics** **Intellectual Property Development Index (IPDI):** Ready for Technology Transfer	**Key Features:** - *Capability to fabricate polycrystalline transparent ceramic specimens of transparent alumina, aluminium oxynitride (AlON), spinel ($MgAl_2O_4$) through slip casting and Hot Isostatic Pressing* - *Capability to fabricate transparent zinc sulphide (ZnS) ceramics through Chemical Vapour Deposition (CVD)* - *Specific parameters depends on ceramic formulation*	**Possible Applications:** • *Dental Ceramics and Artificial Gem Stones* • *Solar Absorber Tubes and Lamp Envelops* • *IR sensor envelops* • *High temperature Furnace windows*

S. No	Technology and Related Issues	Key Features and Applications	
7.	**Electrochemical Methanol Reformation (ECMR) for Hydrogen Generation** **Intellectual Property Development Index (IPDI):** Reassessing Feasibility (IP, competition, technology, commercial)	**Key Features:** - *Energy consumption for Hydrogen production was found to be low, about 1/3rd of water electrolyzer.* - *Hydrogen can be produced at much lower temperature and pressure, unlike methanol reformer.* - *The hydrogen produced is highly pure and Hydrogen separation steps are not required.* - *Carbon based materials can be used for stack fabrication*	**Possible Applications:** • *ECMR can be integrated with renewable energy sources like wind, solar to store the energy in the form of hydrogen and it can be used in fuel cells.* • *In Power station as coolant* • *In Semiconductor industry as a reducing agent*
8.	**PEM Fuel cell Powered Materials Handling Devices** **Intellectual Property Development Index (IPDI):** Check repeatability / consistency at prototype level	**Key Features:** - *Air cooled/ closed loop liquid cooled PEMFC stacks to be developed.* - *PEMFC stacks with reduced weight and volume would be developed* - *Control system development for the battery fuel cell hybrid system.* - *PEMFC stack would operate optimum efficiency at variable operating loads.*	**Possible Applications:** • *Application in material handling devices like Forklifts* • *Application in recreational vehicles like Go Karts, Golf- Carts etc.* • *Power source for all mobile applications.* • *Power source for auxiliary units in mobile applications.*
9.	**PEM Fuel Cell based Power Supply Systems** **Intellectual Property Development Index (IPDI):** Check repeatability / consistency at prototype level	**Key Features:** - *Developed Grid Independent fuel cell systems in the range of 1-20kW power.* - *PEM Fuel cells developed have been continuously operated for 500 hrs and intermittently for several thousand hours with stable performance.* - *Suitable control systems for load following cycle, cell monitoring characteristics, power conditioners and thermal management have been developed.*	**Possible Applications:** • *As decentralised power pack for homes, industries etc.* • *As combined heat and power units for homes* • *As uninterrupted power source even when the power outage is for long duration (>8hrs)* • *As back up power for telecom industries.*
10.	**Sintered Silicon Carbide (SiC) Components** **Intellectual Property Development Index (IPDI):** Check repeatability / consistency at prototype level	**Key Features:** - *Tuneable density and other thermo-mechanical properties.* - *Flexibility in producing SiC parts incorporating solid-state or liquid phase sintering additives.* - *Capable to produce SiC components up to 750 mm diameter.* - *Critical SiC parts can be manufactured.*	**Possible Applications:** • *Mechanical seals particularly for corrosive environment.* • *Impact and abrasion resistance parts.* • *Light-weight structural parts for aerospace applications.* • *Impact and wear resistant parts.*
11.	**Solar Selective Coatings for Stainless Steel and Aluminium Substrates** **Intellectual Property Development Index (IPDI):** Check repeatability / consistency at prototype level	**Key Features:** - *94 ± 1 % absorbance in 300-1500 nm range* - *14 ± 1 % Thermal IR emittance* - *Withstood 20 cycles of thermal cycling at 350°C* - *Withstood 80 h of salt spray test as per ASTM B117* - *Non-toxic and environmental friendly*	**Possible Applications:** • *Solar selective coatings on absorber tubes of Concentrated Solar Power plant (Non-evacuated up to 250 deg C and evacuated up to 400 deg C)* • *Solar selective coatings on metal tubes for water heating applications (up to 100 deg C)*
12.	**Medium & Low Temperature Stable Solar Absorber Tubes for Solar Thermal Applications** **Intellectual Property Development Index (IPDI):** Check repeatability / consistency at coupon level	**Key Features:** - *High selective properties (Solar Abs ~95%; Spectral emittance ~0.12)* - *Low heat loss property: ~0.14 at 300°C* - *Temperature stability: < 300°C* - *Corrosion stability: > 200 hrs withstand in salt spray test* - *High mechanical stability, Long durability and highly enhanced weather protection*	**Possible Applications:** • *Solar water heater /Solar dryer* • *Solar desalination* • *Stream generation for various industrial applications* • *ORC solar collector based power generation*

S. No	Technology and Related Issues	Key Features and Applications	
13.	**High Performance Anti-fogging and Anti-reflective Coatings for Optical, Solar and Display Applications** **Intellectual Property Development Index (IPDI):** Prototype testing in real life conditions	**Key Features:** - *High transmittances in visible and solar regions: >98 % (in visible) >96% (in solar)* - *Low temperature curable (80-100°C)* - *High temperature stability: Max. up to 1000°C* - *Weather stability: > 200hrs withstand in high humidity (>90%) at 50°C* - *High mechanical stability and Long durability* - *Coat effective coating technique*	**Possible Applications:** • *Solar PV & CSP cover glass* • *Optical lenses* • *Video display panels* • *Architectural glasses* • *High power lasers*
14.	**Nanosilver Impregnated Ceramic Candle Filter** **Intellectual Property Development Index (IPDI):** Technology transferred to one company and is available for transfer on non-exclusive basis	**Key Features:** - *Successfully field tested at various villages in Andhra Pradesh with a non-governmental organization* - *Non electrical power and pressurized water required* - *Ease in maintenance* - *Commercially attractive {very low amount of silver used (0.2 wt %), Cost increase: candle (30-50%) and filter assembly (3-5%)}* - *Replacement needed once in six months*	**Possible Applications:** • *Ceramic candles for drinking water purification*
15.	**High Performance Varistors made from Doped ZnO Nanopowders** **Intellectual Property Development Index (IPDI):** Check repeatability / consistency at prototype level	**Key Features:** - *Patented technology* - *Lower sintering temperature and time compared to micron powders* - *Order of magnitude higher breakdown field, 2-3 times coefficient of nonlinearity and comparable leakage current density*	**Possible Applications:** • *Power engineering* • *Automobile industry* • *Household electronics* • *Telecommunications*
16.	**2D-Nanolayered Transition Metal Sulfides (2D-NTMS)** **Intellectual Property Development Index (IPDI):** Reassessing Feasibility (IP, competition, technology, commercial) after completing field trials	**Key Features:** - *Synthesis of pure as well as mixed WS_2/MoS_2 nanosheet powders* - *Synthesis of doped-WS_2/MoS_2 nanosheet powders* - *Reasonably good oxidation resistance* - *Feasibility to synthesize 2D-nanostructures of other transition metal sulphides* - *Scalable process for bulk production*	**Possible Applications:** • *Solid lubricant for aerospace and automotive sector* • *Solid lubricant for forging and other manufacturing processes* • *Additive to automobile Lub-oil* • *Additive to grease for improved performance under high shear stress* • *Petrochem catalyst* • *Electrocatalyst for HER* • *Li-ion battery electrode* • *Self-lubricating composites and coatings (metallic/ceramics/ polymer)* • *Sensors and actuators*
17.	**Fe- based Cerametallic Friction Pads for Clutch Plates of Heavy Vehicles** **Intellectual Property Development Index (IPDI):** Reassessing Feasibility (IP, competition, technology, commercial) after completing field trials	***K*ey Features:** - *Use of non carcinogenic materials* - *Improved wear and coefficient of friction* - *Fe-based sintered pad* - *Flexibility of single or dual sintered friction pads* - *Indigenous equipment for processing* - *Reduced post sintering operations* - *Production level manufacturing process*	**Possible Applications:** • *Clutch and brakes of heavy commercial vehicles* • *Aircraft brakes* • *Passenger vehicles like buses* • *Wind mill applications* • *Railways* • *Military tanks*

S. No	Technology and Related Issues	Key Features and Applications	
18.	**Multifunctional Titania (TiO_2) Microspheres for Self Cleaning Applications** **Intellectual Property Development Index (IPDI):** Checking repeatability/consistency at prototype level.	**Key Features:** - *Titania microspheres suspension in water at neutral pH* - *Efficient photocatalyst* - *Anti-bacterial* - *UV absorber* - *Visible light reflector* - *Simple and scalable chemical synthesis* - *Novel process for which patent is applied*	**Possible Applications:** • *Self cleaning textiles* • *Air purification* • *Water purification* • *Organic effluent treatment* • *Additive to exterior building paint for self cleaning walls*
19.	**Laser Welding and Laser-MIG Hybrid Welding** **Intellectual Property Development Index (IPDI):** Check repeatability / consistency at prototype level	***K*ey Features:** - *High power density* - *Single pass welding of thick* - *sections* - *Controlled heat input welding* - *with precision* - *No vacuum requirement*	**Possible Applications:** • *Tailor welded blanks for automotive applications etc.* • *Can weld a wide variety of materials and thicknesses* • *Can weld magnetic materials unlike electron beam welding* • *Steel plates, thick section welds, ship building etc.*
20.	**Laser Surface Hardening Treatment** **Intellectual Property Development Index (IPDI):** Check repeatability / consistency at prototype level	***K*ey Features:** - *Selective localized area hardening with minimal heat input* - *No quenchant requirement* - *No surface damage* - *Excellent reproducibility with ease of automation* - *Negligible post process machining requirement* - *Controlled case depth* - *Refined homogenous microstructures* - *Minimal distortion* - *Chemical Cleanliness*	**Possible Applications:** • *Suited for wide range of steels, cast irons and profiles* • *The process can be developed for hardening of a variety of components such as crankshafts, camshafts, piston rings, tooling and dies, bearing steels, steam turbine blades, sheet metal etc.*
21.	**Laser Surface Coating (Alloying and Cladding)** **Intellectual Property Development Index (IPDI):** Reassessing Feasibility (IP, competition, technology, commercial) after completing field trials	**Key Features:** - *Material to be coated is fused using a laser beam and deposited on a substrate with good metallurgical bonding but with minimal base metal dilution* - *Low heat input resulting in fine microstructures* - *Provides crack-free clad layers without porosity*	**Possible Applications:** • *Wear plates for different applications* • *Component repair and refurbishment*
22.	**Laser Drilling** **Intellectual Property Development Index (IPDI):** Reassessing Feasibility (IP, competition, technology, commercial) after completing field trials	***K*ey Features:** - *Non-contact drilling method* - *Holes of large aspect ratio and very small diameter (0.3 mm) can be drilled* - *Precise control of heat input* - *Holes can be drilled at shallow angles to the surface*	**Possible Applications:** • *A wide variety of materials such as metals, ceramics and composites etc. can be drilled* • *The process can be used for specific applications such as drilling of fine holes on high pressure nozzle guided vanes and combustion liners for aero-engine applications*
23.	**Exfoliated Graphite and its value added products** **Intellectual Property Development Index (IPDI):** Technology transferred to one company and is available for transfer	**Key Features:** - *Impermeable to fluids* - *Leak proof sealing under low turning torque* - *Easily cut and punched* - *Can withstand temperature range from -200°C to +500°C in oxidizing and up to 3000°C in inert atmosphere* - *Excellent thermal shock resistance. Does not age or creep* - *Cannot be wetted by molten glass, metal etc., self-lubricating, and resistant to all chemicals*	**Possible Applications:** • *Fuel Cells* • *Automotive* • *Oil refineries* • *Petrochemical industries etc.*

Support Groups

Electronics and Instrumentation Group

A Light Sensitive Inverter Circuit for Automatic Switching of Garden Lights

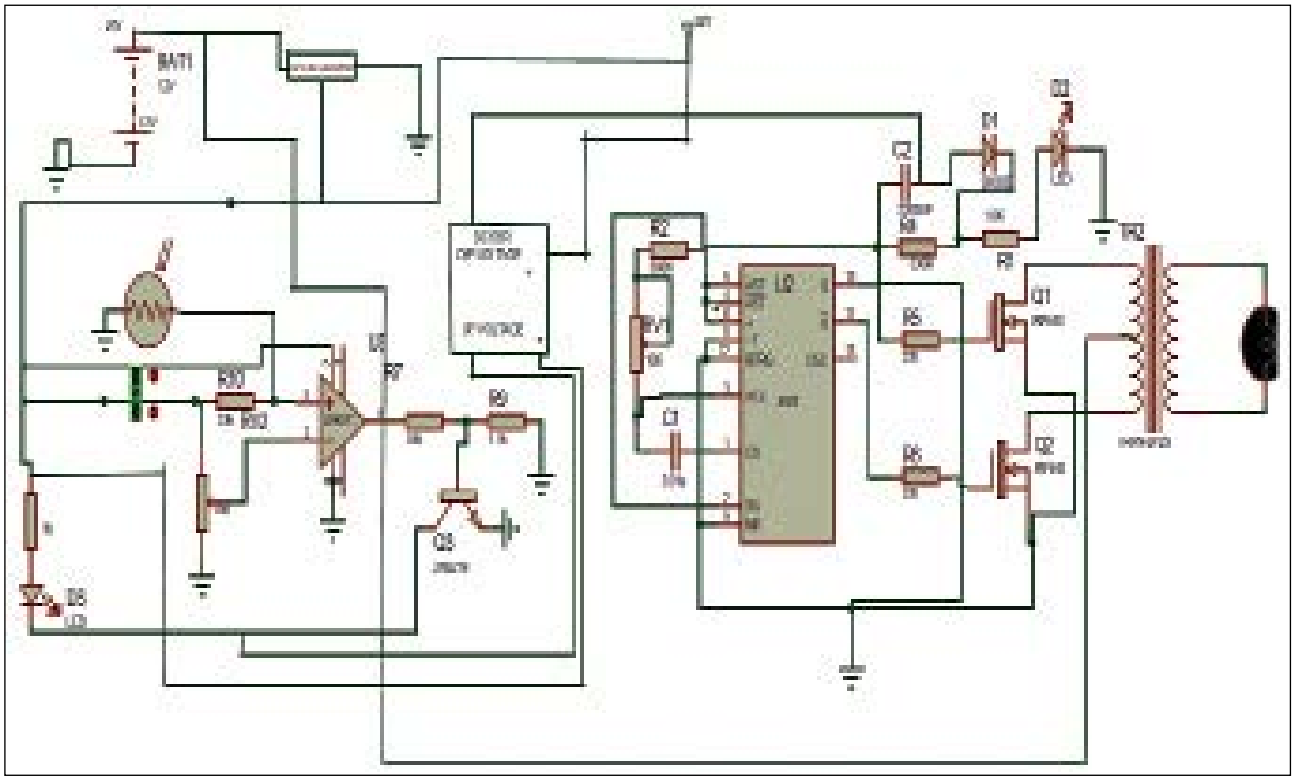
In recent times, a great deal of importance is attached to conserving energy as more and more electrical appliances are available for both domestic and industrial use. To control the wastage of energy used up for lighting, we have developed an automatic circuit for switching on and off lamps, depending on the prevailing light conditions. A 24 Volts battery is used to generate 230 Volts 50 Hz AC that can feed lamp loads. The whole arrangement is wired and connected to garden lights, bordering the EIG premises, on a round the clock basis to demonstrate the ruggedness and reliability of the devices and circuitry.

The main component in the circuitry is a Photo resistor or Light Dependent Resistor which is abbreviated commonly as LDR. Since the development of a LDR has also been taken up by Scientists at ARCI, this facility can also serve as a very useful tool for testing such developed products. A LDR is a semiconductor that has a very high resistance when kept in the dark but which reduces dramatically on the incidence of light. It consists of a semiconducting material that has many valence electrons that are bound to atoms in normal dark conditions. When such a material is exposed to light, the valence electrons gain extra energy from the incident light to overcome the bond from the atoms. On obtaining release, they jump into the conduction band so that they can easily act as charge carriers for current flow.

An astable multivibrator is built using a 4047 IC to operate at 50 Hz. Its output is stepped up to 230 Volts AC using a specially made transformer and two MOSFETs Q1 and Q2. However, the 12 V power supply for the 4047 IC is disconnected from it, if the light conditions are favorable e.g. during the daytime. This increases the life of the 24 Volts battery as well as the load on some of the switching components. On the other hand, when the LDR senses insufficient light conditions, which are adjustable by the potentiometer R6, the IC 4047 starts functioning and allows the 230 Volts output at the secondary of the transformer to feed the lights.

The main features of the circuitry are high reliability, light sensitivity adjustment to suit local requirements, small space requirement, absence of noise due to usage of all solid state devices, non dependence on mains electric supply and very low built up, operating and maintenance cost. The circuit is flexible and can be modified to include additional features, if required. The battery can be connected to a Solar panel so that it gets charged during day light and helps to provide backup during nights.

Applications of LDRs: Light Dependent Resistors are simple and low cost devices. These devices are used where there is a need to sense the presence and absence of light is necessary. These resistors are used as light sensors and the applications of LDR mainly include alarm locks, street lights, light intensity meters, burglar alarm circuits.



Schematic of the electronic circuitry

Electrical and Civil Maintenance

The Electrical and Civil Maintenance group is responsible for the operation and maintenance of basic infrastructural systems at ARCI. The group also builds new systems, with various augmentations and alterations in order to keep pace with the latest needs of various Centers of Excellence (CoEs) at ARCI. The areas under which the group does development and maintenance work are electrical, civil, water supply and air conditioning.

Under electrical maintenance, the main activity comprises of maintaining the HT 33 KV system to LT 0.415 KV system, that is used for power distribution to the various equipment at the shop floor and also for various electrical systems such as lights, fans and air conditioners at various CoEs. During the year, the group carried out major maintenance jobs such as overhauling of the 11 KV vacuum circuit breakers (VCB- Siemens make), air circuit breakers (L&T make) and replacement of 33 KV incoming VCB. The group also takes up various power quality studies of different electrical loads as a part of its activities. The group also maintains a 2500KVA Diesel Generator (DG) Captive Power Plant (CPP) which provides emergency power supply, during power shutdown, for the smooth operation of critical equipment at various CoEs. The group also developed electrical distribution systems for shop floor and office space at newly constructed buildings such as Centre for Engineered Coatings (CEC), Centre for Laser Processing of Materials (CLPM), Center for Ceramic Processing (CCP) and Center for materials Characterization and Testing.

Under maintenance of water supply system, which is spread across 30 acres within ARCI campus, the group makes sure that there is continuous water supply from the receiving point from Hyderabad metro water, to various users including industrial equipment and portable supply to all COEs. Through continuous monitoring and maintenance, the group makes sure that the daily demand of water was reduced from 330 KL to 250 KL, this helped ARCI save considerable amount on water bill. The group also carried out a major repair job at Centre for Nanomaterials, by replacing a new 250 mm Ø pipe line within a short span of time, which did not hinder the operation of major equipment at the Centre requiring industrial water.

Under civil maintenance, the group constructs new buildings expanding the existing infrastructure of various CoEs. During the year, the group initiated new activities such as development of office space and specialized spaces for equipment (measuring 4854 sq. mtrs.) at various CoEs such as CEC, CLPM, CCP and ML. During the year, the group also has undertaken the renovation work of the canteen building and is also building clean rooms at CLPM and CCP. These activities are still in progress.

Under air-conditioning system maintenance, the group carried out maintenance and repair work of air conditioners at different CoEs (a total of 330 units and with total capacity of 650 tons). The group installed, maintained and repaired water dispensers/coolers present at 32 buildings across the campus. The group also installed new air-conditioners at newly constructed buildings at Center for Engineered Coatings, Centre for Laser Processing of Materials, Centre for Ceramic Processing and Center for materials Characterization and Testing.

ARCI joined the National Solar Mission under National Action Plan on Climate Change (NAPCC). The NAPCC gives the direction which India needs to take, to mitigate and adapt to climate change. Under this mission, the ECI group was assigned the task of working on a project to set up 500 KWp grid connected Roof Top Solar (RTS) plant. This plant will be spread over three roof tops at Centre for Nanomaterials, Center for Engineered Coatings and Centre for Sol-gel Processing.

ARCI has already placed the work order to BHEL and currently the work is in progress. ECI group along with BHEL has already installed a 90 KWp over the Centre for Sol-gel Processing building and electricity was generated from this installed unit. During the year, the group also developed and established electro luminescence (EL) testing of solar modules (to be used in 500 KWp solar plant) as a part of quality assurance plan. The solar modules that passed the EL test were installed at different sites and only 3% failure was found. The group is also working on an infrastructural system renovation project, for upgrading and renovating all electrical, and water supply systems in ARCI, for which processing is complete. ARCI is planning to execute this with the help of a consultancy firm.

Electro luminescence (EL) unit

Technical Information Centre

Technical Information Centre (TIC) plays an active role in effective dissemination of scientific and technical information to its users by providing vital scientific information through published scientific and technical information sources. To keep pace with the growing requirements of the scientific community, it provides electronic subscription to journals of almost all the major publishers such as Elsevier, Wiley, Springer, Taylor & Francis, American Chemical Society (ACS), Institute of Physics (IoP), Nature Publishing Group (NPG). These information sources are well used by the users. In addition to this, TIC provides services like Inter Library Loan (ILL) and Plagiarism Detection. TIC also carries out citation analyses for all of ARCI's journal publications, which include h-index, i10 index, average citations etc.

ARCI is a member of National Knowledge Resources Consortium (NKRC), an e-journal consortium of libraries of CSIR and DST Institutions. NKRC is formed primarily to support the scientific community by providing electronic access to the required published scientific literature. NKRC has become the backbone of knowledge resources for all the CSIR and DST laboratories and currently ARCI has online access to about 2000 journals from various publishers by way of NKRC. This year NKRC has provided license to Grammarly, an English language writing enhancement platform. This software is helpful to researchers and students while writing journal articles, conference papers, theses, project reports etc.

Communication is the process of expressing ideas and feelings, and sharing ideas and information between people. Indeed, it is an integral part of our everyday lives and an individual would find it very difficult to live in isolation without interacting with others. In the arena of research and development, communication of ideas, procedures and methods accurately and effectively is of paramount importance. New researches often need to learn the primary skills of scientific writing. English is the third most spoken native language in the world today after Chinese and Spanish but has come to be the lingua franca of communication in the sciences, and in engineering and technology. By mastering a single language, scientists and technologists around the world gain access to the vast body of technical literature and would be able to communicate their discoveries to other researchers anywhere in the world. However, the use of English as the de-facto universal language often creates some challenges to non-native speakers. As opposed to writing for communication in newspapers and other media, scientific writing has a certain approach and it is not uncommon for editors of journals to return manuscripts to the authors for review because the writing style does not conform to certain defined standards.

Considering the importance of effective communication through scientific writing for our Scientists and students, ARCI has licensed a software platform called Grammarly (www.grammarly.com/edu), which is a cloud based English language writing enhancement platform developed by M/s Grammarly Inc., USA. It is licensed through the National Knowledge Resource Consortium (NKRC), a Consortium of CSIR and DST libraries. The software helps detect errors in grammar, spellings, punctuation, word choice and style in the uploaded manuscripts. The following types of documents can be uploaded to the Grammarly Editor (with a size limit):

- MS Word (.doc, .docx)
- Open Office (.odt),
- .txt
- .rtf

One can use the 'Upload' button on the dashboard to load manuscripts on to 'My Grammarly', which are then checked by the Grammarly editor. Alternatively, one can drag and drop a document to the 'My Grammarly' directory. All the uploaded documents are automatically saved within the Grammarly Editor, and will be available for download the next time the user logs in. On successful upload, Grammarly suggests corrections for spelling, grammar and alternate vocabulary choices. Users can review the suggestions and apply them to the document by manually selecting the highlighted sections, and download the corrected document from the 'Download Detailed Report' section.

About 40 users of ARCI had registered with Grammarly and 2740 manuscripts were uploaded during the year.

Grammarly Dashboard

Grammarly editor showing corrections

Events, Data and Statistics

Major Events

Jayanti Celebrations

Dr. B.R. Ambedkar, Dr. Babu Jagjivan Ram and Mahatma Jyothirao Phule Jayanti celebrations were conducted at ARCI on April 14, 2017. Dr. K. Murugan, President ARCI SC/ST Employees Welfare Association welcomed the gathering. Dr. T. Narasinga Rao, Dr. Roy Johnson, Associate Directors Mr. R. Vijay Kumar, Chief Finance & Accounts Officer including ARCI SC/ST Employees Welfare Association paid rich floral tributes and spoke about the contributions made by Dr. Ambedkar and Dr. Babu Jagjivan Ram towards the upliftment of downtrodden and women.

Dr. T Narasinga Rao paying tributes on the occasion of Dr. BR Ambedkar, Dr. Babu Jagjivan Ram and Mahatma Jyotirao Phula's Jayanthi celebrations at ARCI

International Yoga Day

As part of "International Yoga Day Celebrations" a lecture on "Physical Fitness with Yoga" was organized at ARCI on June 21, 2017. Mr. Awadhnath Roy, Senior Finance Officer (Retd.), Accountant General Office, Hyderabad delivered the lecture and demonstrated some important Yoga Asanas, which was attended by the staff members and research students.

Independence Day

ARCI celebrated Independence Day on August 15, 2017. Mr. S. Kalyanaraman, Security, Fire & Safety Officer welcomed the gathering, Dr. G. Padmanabham, Director ARCI hoisted the National Flag and addressed the gathering. Dr. T. Narasinga Rao and Dr. Roy Johnson, Associate Directors have also addressed the gathering.

Study-visit of the Department-related Parliamentary Standing Committee on Science & Technology, Environment & Forests

The meeting with Parliamentary Standing Committee (PSC) on Science & Technology, Environment & Forests, Rajya Sabha was held at National Remote Sensing Centre (NRSC), Shadnagar on August 30, 2017. The purpose of PSC's visit was to gather first-hand information about the capabilities of the Centre and to disseminate the information and developments to the rest of the nation. Dr. G Padmanabham, Director-ARCI made a crisp presentation before the Committee about ARCI and its capabilities. A short-film on the activities of ARCI was also presented before the Committee. The PSC commended on the achievements of ARCI.

Annual Medical Check-up

Annual Medical Check-up (AMC) programme for ARCI employees for the year 2017 was carried out during September 7-8, 2017. Medical tests were carried-out for the employees categorized under two age groups i.e. below 45 years and 45 years &above. Apart from prescribed medical tests under AMC, special tests such as TMT/2D Echo, Liver function tests etc., were carried out for the employees who were 45 years and above. Additional tests like Vitamin B12, Vitamin D were carried out for all the women employees.

Official Language (Hindi) Implementation at ARCI

The Official Language Implementation Committee (OLIC) under the Chairmanship of Dr. G. Padmanabham, Director, ARCI has been successful in the implementation and progressive use of Hindi at ARCI.ARCI conducted internal OLIC meetings on a quarterly basis to review the progressive use of Hindi at ARCI. The minutes of the meeting were sent to DST and Quarterly reports on Hindi works were sent to DST, Department of Official Language (D.O.L), Regional Implementation Office (South), Bengaluru with a copy to Town Official Language Implementation Committee (TOLIC-3) and by online to D.O.L. Ministry of Home Affairs, Govt. of India for review. During the year 2017-18, ARCI issued 4700 letters in bilingual form and surpassed the target set by the D.O.L, Ministry of Home Affairs, Govt. of India. To propagate, the use of Hindi in a better way, ARCI conducted Hindi workshops on a quarterly basis for its employees as well as to the nominated research students. ARCI has also been imparting Training in Hindi to its Employees under the Hindi Teaching Scheme and many employees have obtained training in Prabodh, Praveen and Pragya.Meritorious employees were given cash awards and incentives as per norms. To encourage the employees to carry out their day-to-day official works in Hindi, a cash incentive scheme was introduced during the year, and accordingly, four employees received cash awards for carrying out official works in Hindi.

ARCI celebrated "Hindi Saptah" during September 11-15, 2017. As part of Hindi Saptah celebrations,

Employees and students with Dr. T Narasinga Rao, Associate Director-ARCI during Hindi Saptah Celebrations at ARCI

employees and students participated in various Hindi competitions like quiz, elocution, noting & drafting, essay writing, hand writing, translation, typing, scrabble, Just-A-Minute, debate and poem. Dr. M. Venkateshwar, former Professor and Head, University of English and Foreign Languages, Hyderabad was the chief guest for Hindi Saptah Celebrations. He delivered a lecture on "Problems and Solutions while using Hindi in Scientific field" and a lecture on “How to make sentences in Hindi for official use” was delivered by Shri. Jaishankar Prasad Tiwari, Assistant Director, Central Hindi Teaching Scheme, Hyderabad. Shri Naveen Naithali, Hindi Lecturer, Central Hindi Teaching Scheme, Hyderabad, conducted the quiz programme. All the nominated employees and research students actively participated in the Hindi Saptah celebrations which concluded on September 15, 2017. All the winners were given prizes.

Dr. Malobika Karanajai and Dr. Rambha Singh were elected as members for the "Award Committee" and “Magazine Committee" in TOLIC respectively.

Swatch Bharat Abhiyan at ARCI

As part of 'Swatch Bharat Mission', ARCI regularly observed cleanliness. All the staff members of ARCI Hyderabad, Chennai Centres and Gurugram Offices actively participated in the “Swatchhta Hi Seva” campaign held from 15th September - 02nd October 2017. During the campaign, a mass pledge was administered to the employees and cleaning activity of each of the Centres were carried out by the respective staff members. Mass cleaning activities were coordinated by the committee members throughout ARCI campus. As a part of the outreach programme on Swatchhta, the committee members have visited Government Zilla Parishad High School at Balapur Village and carried out mass plantation of saplings by students and teachers. Senior scientists delivered motivational speeches on cleanliness and also donated lighting systems and dust bins. Drawing competitions were also conducted for school children based on Swatchhta theme and awards were presented to the selected drawings. The Committee members cleaned and renovated bus shelter opposite to ARCI for the convenience and use by the general public.

Vigilance Awareness Week

Vigilance Awareness Week was observed at ARCI from 30/10/2017 to 04/11/2017. The theme of Vigilance Awareness Week for the year 2017-18 was “My Vision – Corruption Free India". The messages from the honourable President, honourable Vice President and CVC were read by Dr. R. Vijay, Scientist “F” & Vigilance Officer, ARCI. Dr. G Padmanabham, Director-ARCI administered the pledge to all the employees, project staff and students and they were also encouraged to take the e-pledge. As part of the Vigilance Awareness Week, Mr. K. Sampath Kumar, Joint Director (Retd.), Anti-Corruption Bureau, and OSD, Head of Taskforce, Department of Civil Supplies, Government of Telangana, Hyderabad and Mr. Mujib Pasha, ITS, Chief Vigilance Officer, Bharat Dynamics Limited, Hyderabad

Renovated bus shelter opposite ARCI premises

Mr. K Sampath Kumar and Mr. Mujib Pasha delivering talks on the occasion of Vigilance Awareness Week at ARCI

Dr. G. Padmanabham, Director-ARCI administering the pledge on occasion of Vigilance Awareness Week

delivered lectures on October 31, 2017 and November 01, 2017 respectively, which were attended by all the employees and students. On this occasion, posters on vigilance awareness were displayed in the Administrative Building.

Constitution Day

As part of Constitution Day celebrations, the "Preamble" to the Constitution was read out in all the centres of excellence/centres by all the team leaders along with staff members and students on November 24, 2017.

Annual Day

At ARCI, Hyderabad 21st Annual Day was celebrated on December 22, 2017. On this occasion, Dr. Y. Srinivasa Rao, Scientist "F" and Chairman, Annual Day Committee welcomed the gathering. Dr. G. Padmanabham, Director, ARCI in his address briefed about the major achievements of ARCI during the year. Dr. T. Narasinga Rao and Dr. Roy Johnson, Associate Directors also addressed the gathering. Various cultural events were organized as part of the Annual Day Celebrations and many employees and students actively participated in these events along with their children and family members. Prizes were distributed to winners of all activities. The celebrations concluded with vote of thanks by Dr. Y. Srinivasa Rao.

Annual day celebrations at ARCI-Chennai were held on January 18, 2018 at the IIT Madras sports ground. Dr. N. Rajalakshmi, Senior Scientist welcomed the gathering and Dr. R. Gopalan, Associate Director addressed the gathering and briefed about the achievements of Chennai Centres. All the staff members along with some of their family members participated in outdoor games such as Cricket, Indoor games like Badminton, Table Tennis and other fun events.

Dr. G Padmanabham, Director-ARCI addressing the gathering on the occasion of ARCI Annual Day celebrations

Republic Day

ARCI celebrated Republic Day on January 26, 2018. Mr. A. Srinivas, Administrative Officer and Additional Charge, (Security, Fire & Safety) welcomed the gathering and Dr. G.Padmanabham, Director ARCI hoisted the National Flag and addressed the gathering. Dr. T. Narasinga Rao and Dr. Roy Johnson, Associate Directors have also addressed the gathering.

Dr. G Padmanabham, Director-ARCI hoisted the National Flag on the occasion of Republic Day celebrations at ARCI

National Science Day

National Science Day was celebrated at ARCI on February 28, 2018. Dr. Sanjay Bhardwaj, Scientist "F" gave his welcome remarks and Dr. G. Padmanabham, Director-ARCI briefed about the importance of National Science Day celebrations in the country and the importance of contribution of Scientists in the development of the Nation. In line with this year's science day theme on "Science and Technology for Sustainable Future", Dr. Y.V.N. Krishna Murthy, Director, National Remote Sensing Centre, Hyderabad delivered a lecture on "Space Technology and its Applications for National Development". A slide show

Dr. Y.V.N. Krishna Murthy, Director-NRSC with Dr. G Padmanabham, Director-ARCI, Employees and Students at ARCI

Comprehensive safety audit by expert panel auditors from National Safety Council at ARCI-Hyderabad

on Dr. CV Raman's life and his achievements were displayed on the occasion.

Safety

Fire and Safety

As part of fire and safety awareness programme at ARCI, a training on fire fighting was arranged in collaboration with Telangana State Fire Brigade on May 19, 2017. Employees, Project staff and students attended the programme.

Safety Audit

A Comprehensive Safety Audit of ARCI-Hyderabad and Chennai centres was conducted by National Safety Council (NSC), Navi Mumbai during February 6 - 9, 2018. NSC experts panel of auditors Mr.Srinivasan, Mr. M.R. Rama Rao and Mr.Swapan Bhattacharjee, visited all the Centres of ARCI and verified the safety procedures adopted by ARCI in each of its Centres. The audit team has also inspected the safety records and held discussions with Safety Committee members and other key persons. Various suggestions recommended by NSC experts in the audit report are being implemented by the Safety committee in view of improving the safety.

Mr.P.V.Vidyadhara Rao, CEO, ESD Control Systems, Hyderabad delivering a talk on the occasion of Safety Day Celebrations at ARCI

Hands-on training on fire fighting equipment in progress

Safety Day Celebrations

ARCI observed National Safety Week during March 4-10, 2018. As part of 47th National Safety Day celebrations which was held on March 5, 2018, Dr. Roy Johnson, Associate Director and Chairman, Safety Committee, welcomed the gathering and in his address emphasized on various steps adopted for proper implementation of safety aspects at ARCI. Mr. A. Srinivas, Admin. Officer and Additional Charge (Security, Fire & Safety) administered safety pledge to the employees and students. Dr. G. Padmanabham, Director, appreciated the various steps taken by the Safety Committee in implementing proper safety at ARCI. Dr. Sanjay Dhage, Scientist "E", ARCI delivered a talk on the safety practices adopted in Centre for Solar Energy Materials. Mr. P.V. Vidyadhara Rao, CEO, ESD Control Systems, Hyderabad delivered safety lectures. On the occasion, the employees and students actively participated in the interactive session and safety demonstrations. Dr.Dulal Chandra Jana, Scientist "E", ARCI delivered safety lecture which was well attended by research fellows and students. The event concluded with vote of thanks by Mr. G. Gopal Rao, Officer "A" and Incharge Security.

Sports

ARCI constituted a 15 member sports committee to conduct sports and games for the year 2017-18. Sports and games was inaugurated on February 13, 2018 by Dr. G. Padmanabham, Director during the inaugural session he stressed on the importance of sports in our life. In all 11 events were conducted and 200 participants, which includes employees, project staff, research fellows and students actively participated in the games such as Volleyball, Football, Cricket, Badminton, Tennikoit, Carom, Chess, Table Tennis, Athletics, quiz etc.

Inauguration of sports and games for the year 2017-18 at ARCI

ARCI Internal Complaints Committee (AICC)

Internal Complaints Committees (AICCs) are functioning both at ARCI, Hyderabad and at ARCI Chennai, Centres. Both these Committees are actively involved in promoting awareness regarding Sexual Harassment of Women at Workplace. Bilingual awareness posters were placed at prominent locations in ARCI Hyderabad and Chennai campuses and timely awareness is created among the newly joined research fellows/project students and trainees.

International Women's Day (IWD) was celebrated at ARCI, Hyderabad on 8th March 2018. Dr. Malobika Karanjai, Scientist "F" and Chairperson, AICC welcomed the gathering. Padmasri Dr. Ananda Shankar Jayant, Director, Shakarananda Kalakshetra (A premier institute for classical music) Hyderabad and India's eminent and renowned classical dancer, choreographer and dance scholar was the Chief Guest on this occasion. She

Prof. Ligy Philip along with ARCI employees on the occasion of International Women's Day celebrations at ARCI-Chennai

delivered a motivational speech based on her own life experiences, which was well attended by employees, project staff and students.

At ARCI Chennai, IWD was also celebrated on 8th March, 2018. Dr. Rajalakshmi, Senior Scientist and Chairperson, AICC welcomed the gathering. Prof. Ligy Philip, Dean Planning, IIT Madras was keynote speaker. Her contributions towards domestic and industrial waste treatment with emphasis on waste water reuse and recyclingwere highlights of the lecture. Her research and field work on water treatment and rural water supply proved motivational and inspired entire Chennai team to work towards value added research. The lecture was followed by luncheon at IITM research park for all the staff members of ARCI Chennai.

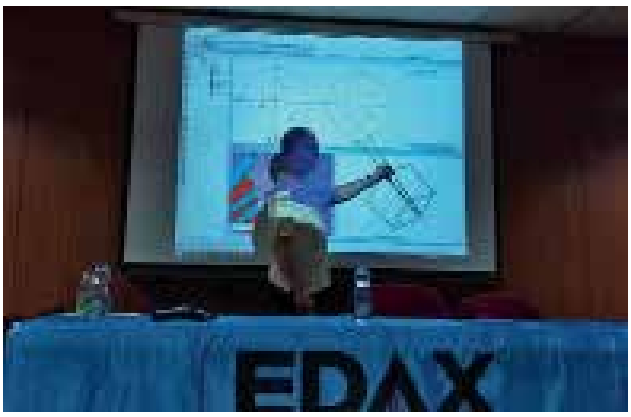
Dr. Ananda Shankar Jayant delivering a talk on the occasion of International Women's Day celebrations at ARCI-Hyderabad

Dr. Ananda Shankar Jayant along with ARCI employees on the occasion of Internatinal Women's Day celebrations at ARCI-Hyderabad

Conference/Workshops/Symposia Organized by ARCI

- **Workshop on Electron Backscatter Diffraction:**

  ARCI in association with EDAX, USA organised a workshop on "Recent Advances in Electron Back scattered Diffraction Techniques" during October 12-13, 2017. About 30 delegates from ARCI and other academic institutes/research laboratories participated in it. The workshop included lectures and practical demonstration of the technique by Dr. Rene De Kloe, who is one of the foremost experts in this field.



Dr. Rene De Kloe delivering a talk at the Workshop on Electron Backscatter Diffraction

- **One-day Orientation Program on 'Latest Advances in Nanomechanical Testing':**

  One-day orientation program on 'Latest Advances in Nanomechanical Testing' was organized on January 24, 2018 to increase the awareness about the products on the Joint Centre for Advanced Nano Mechanical Characterization (ANCC), was organized at Centre for Engineered Coatings. The workshop was attended by representatives of Nanomechanics Inc., from all over the country. Key technological aspects of nanomechanical testing and latest advances in high speed, high strain rate and high temperature nanomechanical testing were discussed in the workshop.

Participants at the One-day Orientation Programme held at ARCI

- **One-day Workshop on "Advanced Ceramics: Powder to Product":**

  A Joint workshop on the topic "Advanced Ceramics: Powder to Product" was organized by ARCI and Indian Ceramic Society, Hyderabad chapter on February 16, 2018 at ARCI, Hyderabad. The workshop was inaugurated by Dr. G. Padmanabhan, Director ARCI. In his inaugural address, he had highlighted the contributions of ARCI in the area of advanced ceramics and also emphasized the immediate need for development of indigenous and high purity powders for the fabrication of advanced ceramics in the country. Technical presentations and discussions were made by eminent scientists, academicians and industrialists during the technical sessions focusing on the theme of the workshop. Panel discussions followed by the tour and demonstration of ceramic processing in the facilities of ARCI also held during the workshop for the benefit of the participants. There were about 90 delegates from various part of the country participated in the workshop.

Dr. Roy Johnson giving his Welcome remarks at the One-day Workshop on "Advanced Ceramics: Powder to Product"

Participants at the One-day Workshop

Human Resource Development

ARCI-IIT Fellowship Programme

ARCI continues to sponsor fellowship programmes at Indian Institute of Technology (IIT) – Bombay, IIT-Hyderabad and IIT-Madras. As a part of these ARCI–IIT Fellowships, ARCI supports the doctoral study of talented students selected as ARCI Fellows to work in areas of immediate interest to ARCI under the expert guidance of an identified Faculty member. The ARCI support includes stipend, procurement of consumables and essential equipment. After successful completion of the programme, the ARCI Fellow is awarded a Ph.D. degree by the respective academic institution

The status of project completed is as follows:

Project	*Collaborating Institute*	*Name of the Fellow*	*Date of admission*	*Status*
Studies on Reactive Magnetron Sputtered Cu_2ZnSnS_4 (CZTS) Absorber Layers prepared in H_2S Plasma	*IIT - Madras*	*Deepak Kumar*	*01/08/2012*	*Completed*

Recognition of ARCI as an External Centre for Carrying Out Ph.D. Research

(a) Foreign University: Deakin University, Australia

(b) Apart from the above, the following Indian academic institutes recognized ARCI as an External Centre for carrying out Ph.D. Research. Accordingly, interested ARCI employees, Project Scientists and Research Fellows are encouraged to register for Ph.D. (as per university norms) at the Institute/University.

01. Indian Institute of Technology – Bombay
02. Indian Institute of Technology – Kharagpur
03. Indian Institute of Technology – Kanpur
04. Indian Institute of Technology – Hyderabad
05. Indian Institute of Technology – Madras
06. National Institute of Technology – Warangal
07. National Institute of Technology – Tiruchirappalli
08. Visvesvaraya National Institute of Technology –Nagpur
09. University of Hyderabad (Central University) –Hyderabad
10. Andhra University – Visakhapatnam

List of Research Fellows who Completed Ph.D. during the year 2017-18

Name of the Student	*Topic*	*Ph.D. Registered at*	*Status*
M. Nagini	*Effect of Milling on Microstructural Evolution in Nanostructured ODS-18Cr Ferritic Steel and the Resultant Mechanical, Corrosion and Oxidation Properties*	*University of Hyderabad*	*Completed*

Post Doctoral Fellows, Research Scholars, Senior / Junior Research Fellows, Post Graduate/ Graduate Trainees and M.Tech. / B.Tech. / M.Sc. Project Students joined during the Year at ARCI

DST - Inspire Faculty	02
SERB – National Post Doctoral Fellowship	02
INSA Visiting Scientist Fellowship	01
Post Doctoral Fellows/Research Scholars	03
DST Women Scientist – A (WOS – A)	02
Senior Research Fellow	14

Junior Research Fellow	19
Post Graduate Trainees	18
Graduate and Diploma Trainees	24
M.Tech Project Students	25
B.Tech. / M.Sc. Projects Students	21
Summer Research Interns	45

Project Scientists/Research Fellows Whose Ph.D. is Ongoing

List of Project Scientists (as per date of Ph.D. registration

Sl. No.	Name of the Student Mr./Ms.	Ph.D Topic	Ph.D Registered at
01.	VVN Phani Kumar	Low Cost Aqueous Binders for the Application of Lithium Ion Batteries	National Institute of Technology, Warangal
02.	JA Prithi	Cathode Materials for Improved PEMFC Performance and Impurity Tolerance	Indian Institute of Technology, Madras
03.	K. Nanaji	Development of Porous Carbon Electrode Materials for Super Capacitors	Indian Institute of Technology, Madras
04.	Sumit Ranjan Sahu	Carbon Nano Horns based Anode Material for Lithium-Ion Battery	Indian Institute of Technology, Madras
05.	Ravi Gautam	Microstructure- Magnetic Properties Correlation of Fe-P based Soft Magnetic Alloy	Indian Institute of Technology, Madras
06.	Amol C. Badgujar	Development of CIGS Thin Film Solar Cells	Indian Institute of Technology, Bombay
07.	Vallabharao Rikka	Study on Ageing Mechanism of Lithium Ion Battery	Indian Institute of Technology, Bombay
08.	Kumari Konda	Eectrochemical Performance of various Cathode Materials using Half and Full Cell	Indian Institute of Technology, Bombay
09.	S. Vasu	Structure – Electrochemical Property Correlation of layered Oxide & Lithium rich layered Oxide as a Cathode Materials for LIB Electric Vehicle Applications	Indian Institute of Technology, Madras
10.	Srinivasa Rao Atchuta	Development of Stable Selective Solar Absorber Coating for Concentrated Solar Thermal Application	CSIR – National Aerospace Laboratories, Bangalore
11.	P. Mahender	Development of Composite Cathode Materials for High Energy Density Li-ion Battery	Indian Institute of Technology, Madras
12.	Muni Bhaskar Siva Kumar	Microstructure – Magnetic Properties Correction in Grain Boundary Diffused NdFeB Magnetic Material	Indian Institute of Technology, Madras
13.	Pothula Vijaya Durga	Processing and Evaluation of Micro Structural and Mechanical Properties of Oxide Dispersion Strengthened Iron Aluminides for High Temperature Applications	Indian Institute of Technology, Madras
14.	Puppala Laxman Manikanta	Development of High Energy Density Electrode Materials for Sodium Ion Battery	Indian Institute of Technology, Madras
15.	S. Ramakrishnan	Hot Corrosion Studies on Thermal Barrier Coatings	Indian Institute of Technology, Kanpur

Research Fellows whose Ph.D. is Ongoing (as per date of Ph.D. registration)

Sl. No.	Name of the Student Mr./Ms.	Ph.D Topic	Ph.D Registered at
1.	Bolla Reddy	Uniaxial Compression and Spherical Indentation Behaviour of Porous Cu	Indian Institute of Technology, Hyderabad
2.	L. Subhashini	Laser- MIG Hybrid Welding of High Alloy Steels	University of Hyderabad, Hyderabad
3.	NS Anas	Microstructure, Mechanical and Tribological Properties of Al Alloy-CNT Composites	University of Hyderabad, Hyderabad
4.	Puneet Chandran	Design and Development of Hard Protective Coatings for Cutting Tools for DryMachining Applications	National Institute of Technology, Warangal
5.	E. Hari Mohan	Synthesis and Characterization of Nano Structured Electrodes for Li-s Batteries	National Institute of Technology, Warangal
6.	P. Tejassvi	Electro Spun Nano Fibrous Materials Li-ion and Li-s Batteries	National Institute of Technology, Warangal
7.	Anusree Unnikrishnan	Polymer Electrolyte Membrane Fuel Cells: Impurity Studies Experimental and Modelling Investigations	Indian Institute of Technology, Hyderabad
8.	S. Bhuvaneshwari	Structure, Morphology and Electrochemical performance Correlation in Metal Doped Spinel (Li Mx Mn2-x O4) (M = Transition metals) as Li ion Battery Cathode Materials	Indian Institute of Technology, Madras
9.	T. Ramesh	Activated Carbon for Energy Storage	National Institute of Technology, Warangal

Sl. No.	Name of the Student Mr./Ms.	Ph.D Topic	Ph.D Registered at
10.	N. Manjula	Studies on Depolariser Assisted Water Electrolysis for Hydrogen Generation	National Institute of Technology, Warangal
11.	PM Pratheeksha	Development of Nano Structured Electrodes for High Energy Density Lithium Ion Battery Applications	National Institute of Technology, Warangal
12.	VV Ramakrishna	Micro Structure andMagnetic Property Correlation in Permanent Magnets	National Institute of Technology, Thiruchirappalli
13.	N. Sasikala	Structure and Electrochemical Property Correlation of Ni rich layered Oxides for Lithium Ion Battery Applications	Indian Institute of Technology, Madras
14.	S. Harish	Design, Development, Performance evaluation ofOptimization of Engineering Parameters of Thermoelectric Generator System for Automotive Exhaust Waste Heat Recovery	Indian Institute of Technology, Madras
15.	Imran Karajagi	Studies on Metal-Air Battery	Indian Institute of Technology, Bombay
16.	S. Manasa	Nano Clay-based Self-Healing, Corrosion Protection Coatings on Aluminium Alloys AA2024-T4 and A356.0	National Institute of Technology, Warangal
17.	B. Divya	Fabrication of Solar Cell Photovoltaic Energy System using Pulsed-Electrodeposited CIGS Absorber layer under n-type CdS Semiconductor Film Window	National Institute of Technology, Warangal
18.	T. Mitravinda	Design and Development of Electrode Active Materials for Supercapacitor Application	Indian Institute of Technology, Hyderabad
19.	Brijesh Singh Yadav	Development and detailed Investigation of Chalcopyrite CIGS Absorber layer	Indian Institute of Technology, Hyderabad
20.	B. Jayachandran	Interface Engineering of High Temperature Thermoelectric Materials and its effect on the Thermoelectric Device Performance.	Indian Institute of Technology, Bombay
21.	M. Shiva Prasad	Development of Solar Selective Absorber Coatings for Concentrating Solar Power Applications	National Institute of Technology, Warangal
22.	B. Priyadarshini	Investigation of Thermoelectric Properties in Magnesium Silicides	National Institute of Technology, Thiruchirappalli
23.	Keerthi Sangamitra Kollipara	Study of Thermo- physical Properties of Aerogel Products for Thermal Insulation Application	National Institute of Technology, Warangal
24.	Shaik Mubina	Development of CNFs Dispered Sic Composites with Optimized Properties	National Institute of Technology, Warangal
25.	Y. Madhavi	Influence of Process Parameters on Properties and Performance of Micro Arc Oxidation Coatings	National Institute of Technology, Warangal
26.	Swapnil Hanmant Adsul	Nano Clay- based Self – Healing Corrosion Protection Coatings on Magnesium Alloys	National Institute of Technology, Warangal
27.	Adigilli Harish Kumar	2D-Nanolayered WS2 based Self Lubricating Composites	National Institute of Technology, Warangal
28.	Mohd. Aqeel	Suitability of Laser Hybrid Welding of Inconel 617 Alloy for Steam Boilers	University of Hyderabad, Hyderabad
29.	E. Anusha	Optimization and Control of Heat Input in Laser Based Manufacturing Processes	National Institute of Technology, Warangal
30.	VP Madhurima	Syntheisis of Carbon Nano Materials and their Composites	National Institute of Technology, Warangal
31.	Santwana H. Dhongade	Processing and Characterization of Solid Electrolytes for Energy Applications	National Institute of Technology, Warangal
32.	P Samhita	Electro Deposited Nano Metal Oxides for Super Capacitor Applications	Indian Institute of Technology, Hyderabad
33.	KK Phani Kumar	Nano Composite Based Solar Selective Absorber Coatings	Indian Institute of Technology, Bombay
34.	P Sreeraj	Studies on Precious Component recovery form PEM Fuel Cell/ Electrolyser stack	Indian Institute of Technology, Bombay
35.	Narendra Chundi	Development of Anti Soiling Coatings and their Evaluation for Applications in Photovoltaic Modulus	Indian Institute of Technology, Bombay
36.	Battula Ramya Krishna	Detailed Investigation on the Degradation of Organo Metal Halide Perovskite Solar Cells	Indian Institute of Technology, Madras
37.	Surabattula Yasodhar	Studies on Electrolytic Hydrogen Generation Compression	Indian Institute of Technology, Madras
38.	V Sai Harsha Swarna Kumar	Metallic flow field plates for PEM Based Electrolyser for Hydrogen Production	Indianl Institute of Technology, Madras

Sl. No.	Name of the Student Mr./Ms.	Ph.D Topic	Ph.D Registered at
39.	Gudimella Tirumala Harini	Synthesis of Ti Foams as Gas Diffusion Electrodes-cum-Flow Field Plates	Indian Institute of Technology, Madras
40.	AB Aravind	Electrochemical studies on Non- Aqueous electrolytes	National Institute of Technology, Thiruchirapally

Promotions

ARCI has been following its existing assessment and promotion policy since the year 2000-01. As per the policy, assessments were carried out for all eligible employees and the following were promoted during the year 2017-18:

Name of the Promotees	Effective Date	Post	
		From	To
D. Srinivasa Rao	October 1, 2017	Scientist "F"	Scientist "G"
Dr. I. Ganesh	October 1, 2017	Scientist "E"	Scientist "F"
Dr. Joydip Joardar	October 1, 2017	Scientist "E"	Scientist "F"
Dr. Malobika Karanjai	October 1, 2017	Scientist "E"	Scientist "F"
Dr. Kaliyan Hembram	October 1, 2017	Scientist "D"	Scientist "E"
Dr. K. Murugan	October 1, 2017	Scientist "D"	Scientist "E"
Dr. Dulal Chandra Jana	October 1, 2017	Scientist "D"	Scientist "E"
Debajyoti Sen	October 1, 2017	Technical Officer "D"	Technical Officer "E"
G. Venkata Ramana Reddy	October 1, 2017	Technical Officer "C"	Technical Officer "D"
P. Nagendra Rao	October 1, 2017	Officer "C"	Officer "D"
N. Aparna Rao	October 1, 2017	Officer "B"	Officer "C"
M. Srinivas	October 1, 2017	Technical Officer "B"	Technical Officer "C"
K. Naresh Kumar	October 1, 2017	Technical Officer "A"	Technical Officer "B"
M. Ilaiyaraja	October 1, 2017	Technical Officer "A"	Technical Officer "B"
T. Venu	October 1, 2017	Assistant "B"	Officer "A"
A. Ramesh	October 1, 2017	Technician "C"	Technician "D"
D. Kutumba Rao	October 1, 2017	Technician "C"	Technician "D"
B. Subramanyeswara Rao	October 1, 2017	Technician "C"	Technician "D"
K. Vigneswara Rao	October 1, 2017	Technician "C"	Technician "D"
A. JayaKumaran Thampi	October 1, 2017	Technician "C"	Technician "D"
G. Anjan Babu	October 1, 2017	Technician "B"	Technician "C"
Mothe Lingaiah	October 1, 2017	Technician "A"	Technician "B"
Gaje Singh	October 1, 2017	Lab. Assistant "C"	Lab. Assistant "D"

Appointments

ARCI has added the following employees to its fold to take up varied responsibilities:

Employee Name	Designation	Date of Joining
Sudheendra	Assistant "A"	28/12/2017
K.V. Sri Vidya	Assistant "A"	24/01/2018
P. Shiva Prasad Reddy	Assistant "A"	01/03/2018

Superannuation

Employee Name	Designation Held	Date of Superannuation
T. Venu	Officer "A" (Security)	31/01/2018
K. Shankunthala	Assistant "B" (MACP)	31/03/2018
D. Manikya Prabhu	Technician "B"	31/03/2018

Resignations

Employee Name	Designation Held	Date of Relieving
Sreekanth Vallabhaneni	Assistant "A"	23/06/2017

Repatriation

Employee Name	Designation Held	Date of Repatriation
S. Kalyanaraman	Security, Fire & Safety Officer	30/09/2017

Reservations and Concessions

The Reservations and Concessions for SCs/STs/OBCs and persons with disabilities are followed as per Government of India orders from time to time. At ARCI, the overall

Mr. T. Venu was presented with a Memento for his valuable services at ARCI during a function organized on the occasion of his superannuation

Mr. D. Manikya Prabhu was presented with a Memento for his valuable services at ARCI during a function organized on the occasion of his superannuation

Mrs. K. Shakunthala was presented with a Memento for her valuable services at ARCI during a function organized on the occasion of her superannuation

representation of employees under SC is 16.56%, S.T is 4.29%, OBC is 23.92% and that of persons with disabilities is 1.84% as on March 31, 2018.

Faculty Internship Programme

During the year, a new Faculty Internship Programme was initiated. Teaching faculty from Engineering colleges, interested to be associated with research work, to carry out part of their research work, to become familiar with latest R&D activities and facilities are permitted to work for a period of 2 to 8 weeks during their vacation. About six faculty have attended this programme during the year.

Outreach Programme under Scientific Social Responsibility

Some of the Scientists on voluntary basis have visited nearby government schools and delivered motivational/ science talks for the benefit of the school students. On invitation by reputed government/private engineering colleges, scientists delivered lectures in the area of their specializations and shared their research experiences with the faculty and students.

Visit by Students and Faculty to ARCI

1. 33 B.Tech. (Chemical Engineering) students and faculty from BITS Pilani Hyderabad Campus visited ARCI on April 6, 2017.
2. 33 B.Tech. (Chemical Engineering) students and faculty from Chaitanya Bharathi Institute of Technology (CBIT), Hyderabad visited ARCI on April 7, 2017.
3. 30 B.Tech. (Mechanical Engineering) students and faculty from Basavakalyan Engineering College, Basavakalyan visited ARCI on May 16, 2017.
4. 21 Officers from National Academy of Defence Production (NADP), Nagpur visited ARCI on June 21, 2017.
5. 60 faculty members from SAEINDIA, Hyderabad Division visited ARCI on June 23, 2017.
6. 40 faculty members of various Engineering and Degree Colleges from all over India, as part of training programme of Jawaharlal Nehru Technological University (JNTU), Hyderabad visited ARCI on July 25, 2017.
7. 15 B.Tech. (Material Science and Engineering) students and faculty from Indian Institute of Technology (IIT), Kanpur visited ARCI on July 27, 2017.
8. 20 M.Tech. Students and faculty from Anna University, Chennai visited ARCI on August 24, 2017.
9. 12 participants and faculty from Penden Cement Authority Ltd. & Druk Green Corporation, Bhutan as part of training programme of ESCI, Hyderabad visited ARCI on September 20, 2017.
10. 38 B.Tech. (Aeronautical Engineering) students and faculty from MLR Institute of Technology, Dundigal visited ARCI on September 22, 2017.
11. 22 B.E. (Nano Technology) students and faculty from Srinivas Institute of Technology, Mangalore visited ARCI on October 6, 2017.
12. 60 B.Tech./M.Tech. (Metallurgical & Materials Engineering) students and faculty from National Institute of Technology (NIT), Warangal visited ARCI on October 25, 2017.
13. 25 Scientists/Engineers from ISRO who participated in ASCI's "Management Development Programme" visited ARCI on November 10, 2017.

14. 45 M.Sc. (Nano Science & Technology) students and faculty from Bharathiar University, Coimbatore visited ARCI on December 14, 2017.
15. 45 M.Tech. (Nano Science & Technology) students and faculty from JNTU, Hyderabad visited ARCI on January 25, 2018.
16. 30 B.E. (Metallurgical Engineering) students and faculty from PSG College of Technology, Coimbatore visited ARCI on February 1, 2018.
17. 30 participants from various Defence Laboratories who attended CEP course on 'Additive Manufacturing: A Disruptive Technology' visited ARCI on February 6, 2018.
18. 45 M.Tech. (Mechanical Engineering) students and faculty from Gokaraju Rangaraju Institute of Engineering & Technology, Hyderabad visited ARCI on February 9, 2018.
19. 20 Scientists/Engineers from various Government Organisations who participated in ASCI's training programme on 'Managing Technology Value Chains for Directors & Division Heads' visited ARCI on February 14, 2018.
20. 30 B.Tech. (Mechanical Engineering) students and faculty from Vignan Institute of Technology & Science, Hyderabad visited ARCI on February 16, 2018.
21. 45 M.Sc. (Chemical Engineering) students and faculty from St. Francis College for Women, Hyderabad visited ARCI on February 23, 2018.
22. 12 B.Tech. (Mechanical Engineering) students and faculty from Narsimha Reddy Engineering College, Hyderabad visited ARCI on March 3, 2018.
23. 17 Senior Scientists/Technologists from various R&D Centres/Institutions of Government of India and State Government who participated in ASCI's training programme on "Science Governance and Management" visited ARCI on March 7, 2018.
24. 42 B.Tech. (Mechanical Engineering) students and faculty from C.M.R College of Engineering & Technology, Hyderabad visited ARCI on March 9, 2018.
25. 19 Scientists/Professors and Managers from various R&D Centres, Universities, and Colleges who are participated in ESCI's training programmeon "Creativity and Innovation Management in Research" visited ARCI on March 13, 2018.
26. 45 M.Tech. (Mechanical Engineering) students and faculty from National Institute of Technology, Warangal visited ARCI on March 14, 2018.
27. 45 B.Tech. (Mechanical Engineering) students and faculty from Geethanjali College of Engineering & Technology, Keesara visited ARCI on March 16, 2018.
28. 17 M.Tech. (Material Engineering) students and faculty from University of Hyderabad, Hyderabad visited ARCI on March 21, 2018.
29. 40 B.Tech. (Mechanical Engineering) students and faculty from Vivekananda Institute of Technology & Science, Karimnagar visited ARCI on March 23, 2018.

Summer Research Internship Programme

Students from IIT's, NIT's, IIIT's, Central Universities and various other state and private universities from all over the country were short-listed for availing Summer Research Internship Programme (SRIP) at ARCI, Hyderabad and Chennai Centres for the year 2017. 45 students, who were selected have attended the programme from May 17, 2017 for a period of minimum 45 days to a maximum period of 60 days. The selected students initially underwent a week long orientation course at various Centres of Excellence so as to get familiar with the activities being carried out at ARCI. Each student was guided by a scientist to carry out a mini project. The students were issued certificates on successful completion of the programme.

Dr. G. Padmanabham, Director-ARCI with the studnets of Summer Research Programme conducted at ARCI, Hyderabad

Seminars by Indian and Foreign Visitors

1. Dr. Robert L. Aalund, Director, SPS/DCS Business Development Thermal Technology LLC, U.S.A, delivered a lecture on "Latest Techniques in Spark Plasma Sintering" on May 08, 2017.
2. Dr. Mark Cleary, Director of Chemical Technology, Materials and Manufacturing, Boeing Research & Technology, USA delivered a lecture on "Inventing the Future of Aerospace Materials and Manufacturing" on May 11, 2017.
3. Dr. Rajas Mazumdar, Technology Specialist, Dassault Systems, India delivered a lecture on "Mechanics and Manufacturing"on July 19, 2017.
4. Ms. Kavita Emanuel, Head, Woman of Worth, delivered a lecture on "Woman Welfare and Leadership" on July 21, 2017.
5. Dr. Michael Toney, Senior Scientist, Stanford Linear Accelerator Center, USA delivered a lecture on "Solar Energy Research at SLAC and SSRL" on August 24, 2017.
6. Dr. M. Manoharan, Assistant Professor, Japan Advanced Institute of Science and Technology (JAIST), Japan delivered a lecture on "Multifunctional Graphene Nano- Electro-Mechanical (GNEM) Devices for Extreme Sensing" on September 07, 2017.
7. Prof. Nikolai Gaponenko, Head of Laboratory of Nanophotonics, Belarusian State University for Informatics and Radio Electronics (BSUIR), Belarus delivered a lecture on "Sol-gel derived Coating for Nano Photonics and Microelectronics" on October 06, 2017.
8. Dr. K. Subramanian, President, STIMS Institute Inc., USA delivered a lecture on "System Thinking and Transformational Skills for Professional Success in the 21st Century" on November 24, 2017.
9. Dr. Oksana Golovnia, Senior Researcher, M.N. Miheev Institute of Metal Physics of Ural Branch of Russian Academy of Sciences, Russia delivered a lecture on "Effect of Elastic Stresses on the Formation of Nanocrystalline Structure and Magnetic Hardness of the Sm-Co- Fe-Cu- Zr Magnets" on December 04, 2017.
10. Dr. T. V. Venkateshwaran, Scientist-F & Head-Science Communication, Chief Editor-India Science Wire, VigyanPrasar, Department of Science and Technology, New Delhi delivered a lecture on "Heart of Science Communication" on January 22, 2018.
11. Dr. Detlef Bahnemann, Professor, Institute for Technical Chemistry, Leibniz University, Germany delivered a lecture on "Mechanism(s) of Photocatalytic Processes: Revisited" on January 29, 2018.
12. Dr. R. Sivakumar, Senior Research Scientist, AS&M Inc, USA delivered a lecture on "Technology Development and Scientific Understanding of Siloxane based AeroKret Coating" on March 06, 2018.
13. Prof. Liggy Philips, Professor, Indian Institute of Technology (IIT) Madras, Chennai delivered a lecture on "Appropriate Interventions and Technology for Providing Safe Drinking Water for Rural and Underprivileged Communities" on March 08, 2018.
14. Dr. Karsten Wegner, Senior Lecturer, ETH Zurich, Switzerland, delivered a lecture on "Recent Advances and Scale-up in Flame Spray Synthesis of Nanomaterials" on March 16, 2018.

Indian and Foreign Visitors for Technical Discussion

1. Dr. Rathindra Nath Das, General Manager, Bharat Heavy Electricals Limited (BHEL), Hyderabad visited on April 7, 2017.
2. Mr. Subrata Biswas, Director, Engineering, R & D, BHEL and Mr.Neeraj Sharma, Scientist G, Adviser, Office of the Principal Scientific Adviser to Government of India, visited on April 12 and 20, 2017.
3. Mr.Pratik Mishra, Chief Executive Officer (CEO), Rile India, Mumbai, visited on May 18, 2017.
4. Dr. S.Venkatesh, Associate Professor and Dr. E. Elangovan, Associate Professor Vellore Institute of Technology (VIT) visited on May 19, 2017.
5. Dr. Ravi Damodaran, President, Technology and Strategy Division, Varroc Group Pvt. Ltd., Aurangabad visited on May 25, 2017.
6. Dr. Hubert Mancher, President & CEO, Magnum Pyrex AG GmbH, Germany visited on July 17, 2017.
7. Mr. Matthias Hein, International Manager, Newport Corporation, USA visited on August 14, 2017.
8. Mr. Vijai Arumugam, Head- Quality and Fuel Management, N.Ramesh, CEO, IL and FS Tamilnadu Power Company Ltd, Chennai, visited on August 16, 2017
9. Mr. Ajay.D.Joshi, Leader, Design for Six Sigma (DFSS), Mr.Vikrant H. Bhalerao, Project Manager, Cummins Pune, visited on August 21, 2017.
10. Mr. Ujjwala S karle, General Manager, Dr.N.H.Walke, General Manager, Power Train Enginering ,Vijay A. Pankhawala, Deputy Director, Automotive Research Association of India (ARAI),Pune visited on August 24, 2017.
11. Dr. M. Manoharan, Professor, Japan Advanced Institute of Science and Technology (JAIST), Japan visited on September 07, 2017.
12. Prof. Krishna Vasudevan, Professor, Indian Institute of Technology(IIT)-Madras, Chennai, visited on September 14, 2017.
13. Mr. S.R.Mishra, General Manager, Sales, MVS Engineering, New Delhi, visited on September 15, 2017.

14. Mr. Scott D. Pratt, Application specialist, Thermo Fischer Scientific,USA, visted on September 19, 2017.
15. Prof. Nikolai Gaponenko, Head of Laboratory of Nanophotonics, Belarusian State University for Informatics and Radio Electronics (BSUIR), Minsk, Belarus visited during October 04 – 11, 2017.
16. Dr.Detlef Bahnemann, Professor, Institute for Technical Chemistry, Leibniz University, Hannover, Germany visited during October 04 –11, 2017.
17. Dr. René de Kloe, Applications Specialist from Ametek Netherlands visited on October 12-13, 2017.
18. A three member team from Tata Steel Limited, Jamshedpur headed by Dr. D. Srinivas, Head, Agglomeration Research Group, along with Dr. Dmiytri Fedorov, Ladotherm, Ukraine visited on October 17, 2017.
19. Mr. Besira Mihiretie, Research Physicst, Hot Disk Instruments, Sweden visited on November 01 , 2017.
20. Dr. Arti Kashyap, Associate Professor, IIT- Mandi, visited on January 05, 2018.
21. Mr. Rajamani, Director and Mr. Raghu Venkatanarayan, Vice President, Corporate Planning and Programme Implementation., Simpsons Co. Ltd, Chennai, visited on January 10 and January 24, 2018.
22. Dr. Sreejith Karthikeyan, Research Assistant Professor, SRM University, Chennai visited during January 16-19, 2018.
23. Dr. David Ventola, Director Business and Development, Babcock and Wilcox Corporation, USA visited on January 17, 2018.
24. Dr. Pallab Sinha Mahapatra, , IIT- Madras, Chennai visited on January 19, 2018.
25. Mr. N. Kalyanasundaram, Assistant Vice President (Operations) Heavy Chemicals Division, Tamilnadu Petro Products Limited (TPL), Chennai visited on January 24, 2018.
26. Dr. Detlef Bahnemann, Professor, Institute for Technical Chemistry, Leibniz University, Hannover, Germany visited on January 29, 2018.
27. Dr. Robert D. Shull, Fellow, National Institute of Standards and Technology(NIST), USA visited on February 08, 2018.
28. A 5-member team from Tata Advanced System Limited (TASL), Hyderabad headed by Mr. K.K. Gupta, Head-Technical and Skill Development and Mr. Ajay P. Chowdary, Program Manager- TASL, Hyderabad visited on February 16, 2018.
29. Dr. Kazuhiro Kondo, General Manager (R&D, Japan), Mr. Katsuya Tsuchimoto, General Manager (R&D, India), Ms. Megumi Toda (Planning Dept, Japan) and Mr. Noriyuki Asano (Team Leader, Planning Dept) from Aisin Cosmos R&D Co. Ltd, Japan visited on February 22, 2018.
30. Mr.Ramalingam Vijaykumar, General Manager & Director Robert Bosch Engineering and Business Solutions Limited, Bengaluru, visited on February 26, 2018.
31. Dr. Karsten Wegner, Senior Lecturer, ETH Zurich, Switzerland visited on March 16, 2018.
32. Mr. L. Jayepragash, Director, Mr. R. Sivakumar, Managing Director, ACT Plast Paints (P) Ltd., visited during 2017-18.

Visits Abroad

1. Dr. K. Suresh and Dr.R. Easwaramoorthi visited Japan during May 05-13, 2017 to carry out synchrotron x-ray experiments pertaining to the project on 'Structural Stability Studies of Organometalic Halide Perovskite Photovoltaic Films under Harsh Environment Conditions are using In-Situ X-Ray Diffraction' at Photon Factory, KEK, Japan.
2. Ms. Prithi. J. A (Dr. N.Rajalakshmi) visited United Kingdom (UK) during May 31 –June 01 2017 to participate in the 'Fuel Cell and Hydrogen Technical Conference - (FCH2 2017)' held at Birmingham University and presented a paper on "Durable Zirconium Carbide Supports for Oxygen Reduction Reaction in PEMFC".
3. Dr. R. Gopalan visited Singapore during June 15 – 24, 2017 to participate in the International Conference on Materials for Advanced Technologies (ICMAT-2017)' held at Suntech, Singapore and presented a paper on "Doping and Nanostructure Control to Enhance Thermoelectrical Properties in the Bulk CoSb3 Skutterrudites".
4. Dr. R. Subasri visited Belarus and The Netherlands during June 17 – July 02, 2017 for a) technical discussion on Indo-Belarus joint project at Belarusian State University for Informatics and Radio electronics(BSUIR), Belarus and delivered an invited lecture on 'Hybrid Nano Composite Coatings Derived through Wet Chemical Route for Diverse Applications' at Minsk and b) presented a paper on "Layered Nano clay based Corrosion Protection Coatings on AA 2024-T4" at the ' Coatings Science International (CoSI) 2017' held at Noordwijk, The Netherlands.
5. Dr. D. Sivaprahasam visited USA during July 29 – August 06, 2017 to participate in the '36th Annual International Conference on Thermoelectrics (ICT)' held at the California and presented a paper on "Effect of Ni based Diffusion Barrier between Doped PbTe and Cu Electrode on the Interfacial Stability and High Temperature Thermoelectric Properties".
6. Dr. Nitin P. Wasekar was deputed to Australia during August 30, 2017 - May 30, 2018 for conducting advanced research on "Performance Evaluation of Ni-W based Nanocomposite Coatings for Hard

replacement in Automotive Applications" under the Indo-Australian Early and Mid-Career Fellowship at the Queensland University of Technology (QUT), Australia.

7. Dr. G. Padmanabham visited UK during September 17-23, 2017 to attend the '7th IIW Welding Research and Collaboration Colloquium' held at TWI Ltd., Abington, UK and also to review Indo-UK project on coatings at University of Cambridge.
8. Ms. Anusree Unnikrishnan, SAF, ARCI visited Maryland, USA during September 29-October 06, 2017 for participating in the '232nd Electrochemical Society (ECS) Meeting' and presented a paper on "Electrochemical Modeling of HTPEM Fuel cells using elementary step kinetics".
9. Dr. Kavita Srikanti visited USA during October 06-15, 2017 for pre-dispatch inspection and training of 'Physical Property Measurement System (PPMS)'.
10. Dr. Tata Narasinga Rao visited China during October 26-31, 2017 to participate and deliver an invited lecture on "Recent Trends in Indigenous Nanomaterials based Technologies (Relevant to Energy Environment and Health)" at the '8th MRS Trilateral Conference on Advances in Nanomaterials: Energy, Water & Healthcare' held at University of Chinese Academy of Sciences.
11. Dr. R. Gopalan visited USA during October 31 - November 12, 2017 to participate in the "International Conference on Magnetism and Magnetic Materials, (MMM 2017)" and also visited University of Stony Brook.
12. Dr. Rajalakshmi Natarajan visited Australia during November 04–08, 2017 to participate in the "The Australian-Indian workshop for Women in Energy Research" held at Deakin University, Australia.
13. Dr. Tata Narasinga Rao visited Germany during November 05-09, 2017 to participate in the '6th Workshop: Lithium-Sulfur-Batteries held at Dresden, Germany and made a poster presentation on "Latest Research Results and Developments in the field of Battery Technology".
14. Dr. R. Gopalan visited Pittsburg, USA during November 06-10, 2017 and made a poster presentation on "Strategy of TbCu7 Structure in Sm2Co17 Type Magnets and its Influence on High Coercivity" at the '62nd Annual Conference on Magnetism and Magnetic Materials, (MMM2017)'.
15. Dr. G. Padmanabham and Dr. Roy Johnson visited Belarus during November 06-12, 2017 as members of Indian contingent to Minsk for technical discussions - on the prospects of creation of an Indo–Belarus Joint Technology Centre at ARCI, Hyderabad.
16. Dr. S.M. Shariff visited Germany during December 06-13, 2017 for pre-dispatch inspection and technical discussion on the laser system procured from Laserline GmBH, Germany and also visited Fraunhofer Institute for Machine Tools & Forming Technology (IWU), Chemnitz, Germany for holding technical discussions regarding collaborative technical work.
17. Mr. Manish Tak visited Germany during January 10–24, 2018 for i) technical discussions at BIAS, Bremen and Fraunhofer IWU; for ii) Advanced Operator Training on 'SLM system' at SLM Solution facility in Lubeck.
18. Dr. Gururaj Telasang, Dr. K. Divya, Mr. N. Venkata Rao visited Germany during January 13–21, 2018 for Advanced Operator Training on 'SLM system' at SLM Solution facility in Lubeck.
19. Dr. G. Sundararajan delivered an invited talk on "Evaluation of high Strain Rate Plastic Flow Behavior of Nanocrystalline Nickel by using Ultra Fast Nanoindentation Test System" at the 'TMS 2018 Annual Meeting & Exhibition' held at Arizona, USA during March 11-15, 2018.

Lectures by ARCI Personnel in India

1. Dr. Sanjay Bhardwaj delivered a lecture on "ARCI and its Collaborative Approach" for Indian Institute of Chemical Engineers (IIChE) members and students of Chaitanya Bharathi Institute of Technology (CBIT), Hyderabad on April 07, 2017.
2. Dr. G. Padmanabham delivered an invited lecture on "Recent Trends in Laser Based Manufacturing" at Mahatma Gandhi Institute of Technology (MGIT), Hyderabad on April 07, 2017.
3. Dr. R. Subasri delivered a special invited lecture on "Surface Engineering through Sol-Gel Nanocomposite Coatings (Basics of Processing and Applications)" for the students of M.Tech/MS/PhD, Department of Metallurgical and Material Engineering Indian Institute of Technology (IIT)-Madras, Chennai on April 08, 2017.
4. Dr. G. Ravi Chandra delivered an invited lecture on "Characterization of Materials with Focus on Composites" at RVR & JC College, Guntur on April 20, 2017.
5. Dr. Sanjay Bhardwaj was a panelist in the panel discussion session on "Open Innovation & IP: Strategies for Implementing the Right IP Structure for Harnessing the Advantages of Open Innovation" during 'World Intellectual Property Forum (WIPF)' held at Bangalore during April 26-28, 2017.
6. Dr. R. Subasri delivered a guest lecture on "Nanoscience and Nanotechnology for Society" at the 'Dr. A.S. Rao Awards Council's Science Workshop' held at Hyderabad on April 29,2017.

7. Dr. S. Anandan delivered an invited lecture on "Development of Nanomaterials for Energy Storage (Li-Ion Batteries and Super Capacitors) and Environmental Application" at GMR Institute of Technology, Rajam on May 12, 2017.
8. Dr. Ravi Bathe delivered an expert lecture on "Science and Technology of Laser Micro Machining" at the training program on 'Micro Machining Technologies' held at Kalyani Centre for Technology & Innovation, Pune on May 13, 2017.
9. Dr. L. Rama Krishna delivered invited lecture on "Surface Engineering Technologies for Combating Wear and Corrosion: Conceptualization and Applications" as a part of the two-week faculty development program on 'Current trends in materials and manufacturing' held at CMR College of Engineering and Technology, Hyderabad during May 15-27, 2017.
10. Dr. Roy Johnson delivered an invited lecture on "Current Trends in Ceramic Materials Manufacturing" as a part of the 'Faculty develop-ment programme' held at CMR College of Engi-neering and Technology, Hyderabad on May 16, 2017.
11. Dr. R. Gopalan delivered an invited lecture on "New Soft Magnetic Alloys for Motor Applications" at a 'Seminar on Electrical Machines' held at Indian Institute of Science (IISc) Bengaluru on May16, 2017.
12. Dr. N. Rajalakshmi delivered an invited lecture on "Materials for Energy Conversion and Devices" at the 'National Conference on Recent Advances in Materials Science & Nanotechnology (RAMN-2017)' held at AMET University, Chennai on May 26, 2017.
13. Dr. G. Padmanabham delivered a keynote lecture at a one-day workshop on 'Challenges in Joining of Advanced Materials (CJAM)' organized by the Indian Institute of Welding, Hyderabad Chapter at Nuclear Fuel Complex (NFC), Hyderabad on May 26, 2017.
14. Mr. K. V. Phani Prabhakar delivered an invited talk on "Challenges in Dissimilar Materials Joining by Cold Metal Transfer (CMT) Weld Brazing Technique" at the one-day workshop on 'CJAM' held at NFC, Hyderabad on May 26,2017.
15. Dr. R. Gopalan delivered an invited lecture on "The Role of Magnets, Li-Ion Battery and Thermoelectric Materials for Automotive Applications" at the 'International Conference on Materials Engineering (ICME)' held at IIT, Kanpur on June 01, 2017.
16. Dr. G. Padmanabham delivered an invited lecture on "Some Microstructural Effects of Laser Processing of Materials" at the 'International Conference on Materials Engineering(ICME)' held at IIT, Kanpur during June 02-04, 2017.
17. Dr. D. Prabhu delivered an invited lecture on "Introduction to Magnetism" at the 'Summer Training Programme in Physics (STPIP 2017)' held at University of Madras, Chennai on June 05, 2017.
18. Dr. T.N. Rao delivered an invited lecture on "Application of Nanomaterials: from laboratory to market" at workshop on 'Faculty Improvement Programme' at National Institute of Technology (NIT), Warangal on June 23, 2017.
19. Dr. Pramod H. Borse, delivered an invited lecture on "Nanostructuring Photo-Electro Catalyst for Solar Hydrogen Energy Generation" at GMRIT, Rajam on June 30, 2017.
20. Dr. N. Rajalakshmi delivered a invited lecture on "Fuel Cells for Airways" while at the 'Stakeholder's Consultation Workshop on Technology Needs Assessment for Climate Change for Transport Sector' held at IITMRP, Chennai on July 07, 2017.
21. Dr.Ravi Chandra delivered an invited lecture on "Utility of Electron Microscopy in the Design of PVD Multi-Layer Nitride Coatings with Industrial Applications" at the 'International Conference on Electron Microscopy and Allied Techniques' held at Mahabalipuram on July 17, 2017.
22. Mr. K. V. Phani Prabhakar delivered a lecture on "Laser based Joining" at the 'Workshop on Advanced Metal Processing' organized by Society of Defence Technologists (SODET), Bengaluru on July 20,2017.
23. Dr. L. Rama Krishna delivered an invited lecture on "Surface Engineering of Automotive Applications" at PVP Siddhartha Institute of Technology, Vijayawada on July 28, 2017.
24. Dr. G. Ravi Chandra delivered a lecture on "Advances in Materials Characterization" at a 'Refresher course for lecturers from various Universities' held at University of Hyderabad, Hyderabad on August 07, 2017.
25. Dr. T.N. Rao delivered an Invited Lecture on "Application of Nanomaterials; Energy, Health and Environment" at an International conference held at SRM University, Chennai on August 10, 2017.
26. Dr. R. Gopalan delivered an invited lecture on "Probing Nano Functional Materials for Energy Applications" at the 'International Conference on Emerging Technologies on Nano Electronics and Nano medicines' held at AMET University, Chennai on August 11, 2017.
27. Dr. Ravi Chandra delivered a lecture on "Study of Mechanical Properties at the Micron Lengthscale" at National Institute of Technology (NIT), Warangal on August 17, 2017.

28. Dr. N. Rajalakshmi gave a key note address and delivered a lecture on "Hydrogen Fuelled Vehicles" at a 'Seminar on Hydrogen Fuelled Vehicles' sponsored by Tamilnadu State Council for Science and Technology, Chennai at Velalar College of Engineering and Technology, Erode on August 18, 2017.
29. Dr. N. Rajalakshmi delivered a guest lecture on "Energy Conversion Devices- Activated Carbons" at Velalar Arts College for Women, Erode on August 18, 2017.
30. Dr. Roy Johnson delivered an invited lecture on "Advanced Oxide Ceramic Processing" as a part of 'UGC-HRDC Refresher Course on Material Science' held at University of Hyderabad, Hyderabad on August 21, 2017.
31. Dr. N. Rajalakshmi delivered an invited lecture on " PEMFC – Recent Developments" during the 'International Workshop on Renewable Energy Materials-2017 (REM17)' held at Manonmaniam Sundaranar University, Tirunelveli during August 28-29, 2017.
32. Dr. Raman Vedarajan delivered an invited lecture on "High Performance Electrocatalaysts Developed Using Facile Procedures" at 'REM 2017' held at Manonmaniam Sundaranar University, Tirunelveli during August 28-30, 2017.
33. Dr. Easwaramoorthi Ramasamy delivered an invited lecture on "Perovskite Solar Cells: Basics to Advanced Device Concepts" at 'REM 2017' held at Manonmaniam Sundaranar University, Tirunelveli during August 28-30, 2017.
34. Dr. Neha Hebalkar delivered an invited lecture on "Nanotechnologies developed at ARCI: Lab to Market" at the 'Nanotechnology Conclave' Organized by Confederation of Indian Industry (CII) at New Delhi during August 30-31, 2017.
35. Dr.Ravi Chandra delivered an invited lecture on "Study of Mechanical Properties at the Micron Length Scale" at Rajiv Gandhi University of Knowledge Technologies (RGUKT), Basara on September 01, 2017.
36. Dr. T.N. Rao delivered an invited talk on "Battery Technology and Recent Advances" organized by Hindustan Petroleum Corporation Limited (HPCL) at Bengaluru on September 08, 2018.
37. Dr. T.N. Rao delivered an invited lecture on "Indigenous Nanomaterials-based Technologies; A Chemist's Approach" at the 'Diamond Jubilee Celebration of Chemistry Group' Atomic Minerals Division (AMD) held at Hyderabad on September 13, 2017.
38. Dr. Sanjay Bhardwaj made presentations on "Intellectual Property Development Indices (IPDIs) and Value Addition Opportunities from IP/Technology Transfer Groups" and "ARCI Technologies for Collaboration and Transfer: Opportunities for Industry" at the 'Society for Technology Management (STEM) Annual Summit 2017' held at Hyderabad during September 14 -15, 2017.
39. Dr. Sanjay Bhardwaj was an invited panel member for the plenary session on "Accelerating Tech Transfer & its Commercialization as a Drive for Make-in-India" in the Society for Technology Management (STEM) Annual Summit 2017 held in Hyderabad during September 14 -15, 2017
40. Dr. Ravi Chandra delivered a invited lecture on "Ti-Al-N based multilayer coatings for tribological applications" at 'National Conference on Recent Advances in Materials Science and Technology' held at Telangana University South Campus, Nizamabad on September 15, 2017.
41. Dr.G. Padmanabham delivered an invited lecture on "Laser based joining for aerospace applications" at a National Seminar on 'Failure Analysis and Advances in Welding Technology for Aero engine' organized by the Society for Failure Analysis, Koraput Chapter at Hindustan Aeronautics Limited (HAL) Koraput on September 15, 2017.
42. Dr. R. Subasri delivered an invited lecture on "Micro–Raman spectroscopic studies for evaluation of self-healing property of corrosion protection coatings on Al and Mg alloys" at 'CORCON-2017' held at Mumbai during September 17-20, 2017.
43. Dr.N.Rajalakshmi delivered an inaugural lecture on "National Theme Meet on University-Industry Interface – 2017" at Alagapa University, on September 19, 2017.
44. Dr. Sanjay Bhardwaj delivered an invited lecture on "Surface Modification Technologies from ARCI" for participants of a continuing Professional Development Programme on 'Welding Technologies and NDT Techniques' organized by ESCI, Hyderabad at ARCI, Hyderabad on September 20, 2017.
45. Dr. Joydip Joardar delivered an invited lecture on '2D materials' at GMR Institute of Technology, Rajam, on September 25, 2017.
46. Dr. Raman Vedarajan delivered an invited lecture on "High Performance Electrocatalyst for Oxygen Reduction Reaction" at a symposium on 'analytical techniques and instruments', held at Anna University, Chennai on September 27, 2017.
47. Dr. P. Sudharshan Phani delivered an invited lecture on "Advances in Nanomechanical Testing"

at Tata Steel Limited, Jamshedpur on October 06,2017.

48. Dr. N. Rajalakshmi delivered a lecture on "Practical Science" during the 'Annual Science Fair - Akriti 2017' held at NPS International School, Chennai on October 14, 2017.

49. Dr. Sanjay Bhardwaj delivered invited lectures on "R & D Project Monitoring : A Value Addition Perspective", "Innovation Partnering" and "Importance of Leveraging R & D Results for Application Development and Technology Transfer : Case Study" at the SN Bose National Centre for Basic Sciences, Kolkata during October 24- 25, 2017.

50. Dr. Roy Johnson delivered a guest lecture on "Advanced Materials for Future" on the occasion of convocation ceremony of M.Tech and MBA at Carmel Engineering College, Kerala and also delivered an invited lecture on "Advanced Ceramics: Development of Novel Applications at ARCI" as a part of lecture series in the college on October 27, 2017.

51. Dr. Sanjay Bhardwaj made presentations on "Approaches Adopted by ARCI for R & D Assessment", "Collaborative and Technology Transfer Strategy" and "Case Study on R&D Commercialization" for students / faculty of ICAR – National Academy of Agricultural Research Management (NAARM), Hyderabad on October 30, 2017.

52. Mr. Vallabha Rao Rikka delivered an invited lecture on "Lithium Ion battery: Sustainable Energy Storage System for EV and Grid Applications" held at VIT, Vellore on November 02, 2017.

53. Dr. T. N. Rao delivered an invited talk on "Nanomaterials: Fundamental & Applications" at an International conference held at St. Francis College for Women, Hyderabad during November 06-11, 2017.

54. Dr. R. Balaji delivered an invited lecture on "Hydrogen Energy- The Perfect Energy Source for Sustainable Living" at the 'Workshop on Sustainable Energy Technologies' held at Vellore Institute of Technology (VIT), Vellore, on November 09, 2017.

55. Dr. Sanjay Bhardwaj delivered invited lectures on "Intellectual Property (IP) Assessment: Strengthening the Research to Technology Transfer Chain", "Optimizing the IP Utilization", "Role of an R & D Lab for Start-up Businesses: A Case Study" at the 'Management Development Programme for ISRO Scientists/Engineers' organized by Administrative Staff College of India (ASCI) at ARCI, Hyderabad on November 10, 2017.

56. Dr. Ravi Chandra delivered an invited lecture on "Microstructural Studies of Oxide Dispersed Strengthened Iron by Electron Backscatter Diffraction" at the 'Annual Technical Meeting of the Indian Institute of Metals' held at Goa on November 13, 2017.

57. Dr. N. Rajalakshmi delivered an invited lecture on "Role of Hydrogen Fuel Cells for Stationary Power Generation" at the '2nd National Workshop on Hydrogen Energy and Fuel Cells of NISE' at New Delhi on November 22, 2017.

58. Dr. N. Rajalakshmi delivered an invited lecture on "Hydrogen Production at CFCT-ARCI-Development of Solar based Electrochemical Reformation' at Hindustan University, Chennai on November 27, 2017.

59. Dr. G. Padmanabham delivered an invited lecture on "Sustainability in Chemical Industry through Innovation : Material Perspective" at a Conference on 'Chemistry Everywhere' organized by CII at New Delhi on November 28, 2017.

60. Dr. T.N. Rao delivered keynote lecture on "Indigenous Nanomaterials-Based Technologies; A Make in India Initiative" at the '3-Day National Seminar on Navigating New Frontiers in Manufacturing Processess-2017 (NNFMP-2017)' held at Sreenidhi Institute of Science & Technology, Hyderabad during December 04-06, 2017.

61. Dr. R. Gopalan delivered an invited lecture on "Renewable Energy: National Scenario, Technology & Challenges" at 'India Turkmenistan Meeting' held at New Delhi on December 04, 2017.

62. Dr. Ravi Bathe delivered an invited lecture on "Application of Lasers in Precision Manufacturing" at the '10th International Conference on Precision, Micro, Meso and Nano Engineering (COPEN 10) -Open Workshop Series-Workshop 1: 'Precision Manufacturing and its Applications' held at IIT Madras, Chennai on December 06, 2017.

63. Dr. G. Padmanabham delivered an invited lecture on "Al-Steel Joining by CMT Weld-Brazing; Effect of Filler Wire Composition on the Interface and Mechanical Properties" at the 'IIW International Congress (IC 2017)' held at Chennai Trade Centre, Chennai during December 07-09, 2017.

64. Dr. R. Vijay delivered an invited lecture on "Nanomaterials for High Performance Applications" at the 'National Workshop on Smart and Emerging Materials' held at MVGR

Engineering College, Vizianagaram during December 08-09, 2017.

65. Dr. Pramod H. Borse delivered an invited lecture on "Nano-Engineering of Photoanode Surface for Photoelectrochemical (PEC)- H2 Generation" at the '6th International Hydrogen and Fuel Cell Conference (IHFC-2017)' held at Pune, during December 10-12, 2017.

66. Dr. T.N. Rao delivered an invited talk on "Nanomaterials-based Technologies: A Make in India Initiative" at the 'INST In-House Symposium' held at Mohali during December 11-12, 2017.

67. Dr. N. Rajalakshmi delivered an invited lecture on "Role of Electrochemistry in the Paradigm Shift to Sustainable Energy" at the 'International Conference -ICAER 2017' held at Mumbai on December 12, 2017.

68. Dr. G. Padmanabham delivered a lecture on "High Performance Coatings and Process for Aerospace Applications" at the 'ADMAT Conference' organized by VSCC, Trivandrum during December 14-16, 2017.

69. Dr. Y.S. Rao delivered a Key Note Lecture on "Pressure Slip Casting-An Adoptable Manufacturing Technique for Advanced Ceramics" in the 'International Conference on Expanding Horizons of Technological Applications of Ceramic and Glasses (EH-TACAG-2017)' held at Pune on December 12-16, 2017.

70. Dr. R. Balaji delivered an invited lecture on "Hydrogen fuel cell Technology-an Introduction" at a 'Seminar on Renewable Energy' held at Rural Energy Centre, Gandhigramam Rural Institute, Gandhigramam, Tamilnadu on December 15, 2017.

71. Dr. R. Balaji delivered an invited lecture on "The Role of Material Sciences in the Development of Hydrogen Energy Technology" at the 'Workshop on Frontiers in Materials Research for Energy Applications' held at Thiagarajar College of Engineering (TCE), Madurai on December 16, 2017.

72. Dr. Srinivasan Anandan delivered an invited lecture on "Development of Visible-light-active Photocatalysts for Environmental Issues" at the '3rd National Seminar on Advanced Oxidation Processes (AOP-2017)' at Anna University BIT campus, Tiruchirappalli during December 17-19, 2017.

73. Dr S. Sakthivel delivered an invited lecture on "Nanostructure Materials and Nanocoatings for Concentrated Solar Thermal Power (CSP) & PV Applications" at the '3rd National Seminar on Advanced Oxidation Processes, (AOP-2017)' held at Anna University BIT campus, Tiruchirappalli during December 17-19, 2017.

74. Dr. D. Prabhu delivered an invited lecture on "Unveiling Some Truths in Magnetic Materials through 3DAP" at the 'Advanced Characterization Workshop on 3D Atom Probe Tomography' held at Indian Institute of Technology (IIT), New Delhi on December 19, 2017.

75. Dr. Malobika Karanjai delivered a lecture on "Official Language Policy" at the 'Hindi Workshop' held at ARCI, Hyderabad on December 19, 2017.

76. Dr. Rambha Singh delivered a lecture on "Usage of Technical Terminology in Laboratory" at the 'Hindi Workshop' held at ARCI, Hyderabad on December 19, 2017.

77. Dr. R. Gopalan delivered an invited lecture on "Materials Technology Challenges for Electric Vehicles" at the 'E Vehicles Exhibition (EVREX 2018)' held at Hyderabad on January 06, 2018.

78. Dr. R. Gopalan delivered an invited lecture on "Thermoelectric (TE) Materials with high ZT and TE Generator System Development" at the 'Indo-UK Workshop on Thermoelectric Materials for Waste –Heat Harvesting' held at Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Bengaluru during January 08-10, 2018.

79. Dr. Manjusha Battabyal delivered an invited lecture on "Enhanced Thermoelectric Properties in Ni doped CoSb3 Skutterudites Processed by Spark Plasma Sintering" at the 'Indo-UK Workshop on Thermoelectric Materials' held at JNCASR, Bengaluru, during January 08-10, 2018.

80. Dr. P. Sudharshan Phani delivered an invited lecture on "Wide Dynamic Range 2-D Nanoindentation: Friction and Partial Slip at Contacts" at the 'International Workshop on Nanoscale Effects in Macrotribology' held at Goa during January 08-12, 2018.

81. Dr. Srinivasan Anandan delivered a lecture on "Development of Visible-Light-Active Photocatalysts for Environmental Issues" at the 'International Conference on Frontiers in Advanced Materials and their Applications (FAMA 18)' held at Bishop Herber College, Tiruchirappalli on January 09, 2017.

82. Dr. Easwaramoorthi Ramasamy delivered an invited lecture on "Scaleup and Stability Issues of Perovskite Solar Cells" at the 'Indo-US Bilateral Workshop on Nanotechnology for Clean Energy Generation and Storage' held at PSG Institute of Advanced Studies, Coimbatore during January 10-12, 2018.

83. Dr. T.N. Rao delivered an invited talk on "Transformation of Materials Research into

Technology" at the 'Seminar on Chemical Engineers and Technologists' held at Nuclear Fuel Complex (NFC), Hyderabad on January 24, 2018.

84. Dr S. Sakthivel delivered a keynote lecture on "Nanostructure Materials Synthesis and Development Nanocoatings for Concentrated Solar Thermal Power (CSP) & PV Applications" at the '3rd National Workshop on Solar Energy Utilization (SUN) for Sustainable Development' held at CSIR-NEERI, Nagpur during February 01-02 , 2018.

85. Dr. R. Gopalan delivered an invited lecture on "Magnetic Materials to Application Engineering through Structure-Process-Property Map Correlation" at the 'IUSSTF Symposium (an Indo-US joint Conference)' held at IIT Bombay, Mumbai on February 05, 2018.

86. Dr. R. Vijay delivered an invited lecture on "Development of Powders for Additive Manufacturing of Metallic Parts" at the 'Workshop on Additive Manufacturing – A Disruptive Technology' held at DMRL, Hyderabad on February 05-07, 2018.

87. Dr. R. Gopalan delivered an invited lecture on "Multi-Scale Characterization Tools in the Field of Clean Energy Materials Technology" at the 'Indian Analytical Science Congress (IASC 2018)' held at Kumarakom, Kottayam on February 08, 2018.

88. Dr. G. Padmanabham delivered an invited lecture on "Laser-MIG Hybrid Welding of Cr-Mo Steels" at the 'Asia Steel International Conference' held at Bhubaneshwar on February 08, 2018.

89. Dr. K. Murugan delivered an invited lecture on "Design and Fabrication of Thin Film Coatings for Energy and Environmental Application" at Vel Tech Multi Tech Engineering College, Chennai on February 08, 2018.

90. Dr. Manjusha Battabyal delivered an invited lecture on "High Efficient Thermoelectric Materials and Thermoelectric Modules for Waste Heat Recovery" at an International conference '5th ICNN 2018: Challenges in Nanomaterials and Nanocomposites: Special Emphasis on Health, Energy and Environment' at VIT Chennai during February 08-10, 2018.

91. Dr. G. Padmanabham delivered an invited lecture on "Materials for Sustainable Energy" at a 'National Conference on Emerging Materials for Sustainable Future' held at Coimbatore on February 09, 2018.

92. Dr. N. Rajalakshmi delivered an invited lecture on "Fuel cells- Power Conditioner- Automotive Applications " at the VIT, Vellore on February 10, 2018.

93. Dr. T.N. Rao delivered an invited talk on "Indigenous Material Technologies: A National Necessity" at the 'APAM-MRSI Meeting' held at Tiruchirappalli on February 13-14 , 2018.

94. Dr. R. Gopalan delivered an invited lecture on "Materials for Energy Emergency" at 'the DST-Curire Workshop on Nano materials fabrication and Devices' held at Avinashilingam University, Coimbatore, on February 15, 2018.

95. Dr. Y.S. Rao delivered a lecture on "Oxide Ceramics Processing" at the 'One-Day Workshop on Advanced Ceramics: Powder to Product' held at ARCI, Hyderabad on February 16, 2018.

96. Dr. D.C. Jana delivered a lecture on "Techniques for Processing of Non-Oxide ceramics" at the 'One-Day Workshop on Advanced Ceramics: Powder to Product' held at ARCI, Hyderabad on February 16, 2018.

97. Dr. Krishna Valleti delivered an invited lecture on "Reclamation & Life Extension Facilities at ARCI" at the 'National Seminar on Emerging Trends in Repair, Reclamation and Life Extension of Helicopters, Aero Engines and their Aggregates' held at 3BRD, Chandigarh on February 19, 2018.

98. Dr. Malobika Karanjai delivered an invited lecture on 'Core-shell Powders of Fe-MnxZnyFe2O4 Powders for their Application as Magnetic Composites/Cores: Design & Evaluation' at the 'International Conference on Powder Metallurgy and Particulate Materials (PM18)' held at Navi Mumbai during February 21-22, 2018.

99. Dr. S. Sakthivel delivered an invited lecture on "Nanomaterials and Coatings for Concentrated Solar Thermal Power (CSP) and Photovoltaic (PV) Application" at the 'National Conference on Advanced Materials Chemistry at the Interfaces of Energy' held at Manonmaniam Sundaranar University,Tirunelveli during February 21-23, 2018.

100. Dr. R. Balaji delivered an invited lecture on "Hydrogen Energy Storage- A New Solution to the Renewable Energy intermittency issue" at the 'Workshop on Recent Advances in Materials for Photovoltaic Cells and Energy Storage Devices' held at Thiagarajar College of Engineering (TCE), Madurai on February 22, 2018.

101. Dr. G. Padmanabham delivered an invited lecture on "Coatings for High Temperature Applications" at the 'National Seminar on Development Processing and Applications of High Temperature Materials- Current Trends and Challenges Ahead' organized by IIM Hyderabad Chapter at Midhani on February 22, 2018.

102. Dr. R. Vijay delivered an invited lecture on "Development of Oxide Dispersion Strengthened Iron Based Alloys for High Temperature Applications" at the 'National Seminar on Development, Processing and Applications of High Temperature Materials- Current Trends and Challenges Ahead' held at Hyderabad during February 22-23, 2018.

103. Dr. G. Padmanabham delivered an invited lecture on "Emerging Thermal Fusion Joining Techniques in Dissimilar Materials Aluminum to Steel Aimed at Light Weighting in Automotive Industry" at the 'International Conference on Aluminum and Magnesium as Sustainable Lightweight Solution for Transport Section' organized by Lightweight Technology Group, Pune on February 23, 2018.

104. Dr. B. V. Sarada delivered an invited lecture on "Materials for Energy Conversion and Storage Applications" at the 'National Workshop on Opportunities and Challenges in Science and Technology' held at Mahatma Gandhi University, Nalgonda on February 27, 2018.

105. Dr. T.N. Rao delivered a Guest Lecture on "Application of Nanomaterials in Energy, Health and Environment" on the occasion of 'Science Day' held at Vignan University, Guntur on February 28, 2018.

106. Dr. V. Ganapathy delivered an invited lecture on "Perovskite, Next-Generation Photovoltaics for Sustainable Green Energy" at the 'National Seminar on Emerging Trends in Harnessing Green Energy' held at Government Degree College, Ananthpur during February 28-March 01, 2018.

107. Dr. L. Rama Krishna delivered invited lecture on "Functional Composite Coatings for Industrial Applications" as a part of 'the one-day National Level Tech Fest – Tech Resonance' held at Avanthi Institute of Engineering & Technology, Hyderabad on March, 03, 2018.

108. Dr. Sanjay Bhardwaj delivered an invited lecture on "Technology Assessment and Partnership Strategy: Case Studies" during a training programme on 'Science Governance and Management' organized by ASCI at ARCI, Hyderabad on March 07, 2018.

109. Dr. R. Gopalan delivered an invited lecture on "Li-Ion Battery and Manufacturing Emergency for Electric Mobility" at the 'Workshop on Battery Technology and Electric Mobility" held at Bengaluru on March 08, 2018.

110. Dr. R. Prakash delivered an invited lecture on "Green Technology Development at ARCI" at the 'National Conference on Global Warming, Green Energy and Environmental Pollution' held at Velammal Institute of Technology, Chennai on March 09, 2018.

111. Dr. N. Rajalakshmi delivered an invited lecture on "Fuel Cells- Science, Engineering and Technology" at the Society of Plastics and Rubber Technologies (SPART), MIT, Chennai on March09, 2018.

112. Dr. R. Prakash delivered an invited lecture on "Lithium-Ion Battery on Electric Mobility" at the 'Electric Vehicles Initiatives and Technology (eVIT) Conclave' held at Vellore Institute of Technology (VIT), Chennai, on March 10, 2018.

113. Dr. D. Prabhu delivered an invited lecture on "Magnetic Materials an Indispensable Component of Energy" at the 'National Seminar on Renewable Energy' held at Valliammai Engineering College, Chennai on March 10, 2018.

114. Dr. Sanjay Bhardwaj delivered an invited lecture on "Intellectual Property (IP) Assessment for Technology Development and Transfer" for the participants of a DST sponsored programme on 'Creativity & Innovation Management in Research' organized by ESCI, Hyderabad at ARCI, Hyderabad on March 13, 2018.

115. Dr. V. Ganapathy delivered an invited lecture on "Next-Generation Photovoltaics" at MVSR Engineering College, Hyderabad on March 14, 2018.

116. Dr. P. Sudharshan Phani delivered an invited lecture on "A Holistic Approach to Surface Engineering" at the 'National Seminar on Surface Coating Technologies' organized at Osmania University at Hyderabad on March 16, 2018.

117. Dr. Manjusha Battabyal delivered an invited lecture on "Thermal Conductivity and Thermoelectricity" at a 'Faculty Development Program' held at Vellore Institute of Technology, Vellore on March 17, 2018.

118. Dr. Malobika Karanjai delivered an invited lecture on "World of Composites-Conventional and Niche Applications' at GMR Institute of Technology, Rajam on March 20, 2018.

119. Dr. G. Padmanabham delivered an invited lecture on "Additive Manufacturing for Functional and Repair" at the 'Indo-Australian Workshop' held at IIT Madras, Chennai on March 21, 2018.

120. Dr. T.N. Rao delivered a keynote lecture on "Nanomaterials-based Technologies: A Make in India Initiative" at the 'Annual National Level Techno-Cultural Fest -Techno Mania 2k18' held at Osmania University, Hyderabad on March 22, 2018.

121. Dr. Sanjay R. Dhage delivered an invited lecture on 'Thin film Solar Cells' at the 'One-Week Interdisciplinary AICTE QIP FDP on Solar Energy

Harvesting' held at Sri Guru Gobind Singh Institute of Engineering and Technology, Nanded on March 31, 2018.

Papers Presented at Indian Conference/ Symposia

1. Mr. T. Ramesh (Dr. N. Rajalakshmi) presented a paper on "Facile synthesis of carbon microspheres/ MnO2 composite as high performance electrodes for super capacitors" at the 'National Conference on Recent Developments in Chemical Sciences and Allied Technologies' held at the National Institute of Technology (NIT) Warangal during June 29-30, 2017.
2. Ms. B. Divya (Dr. B. V. Sarada) presented a paper on "Room temperature pulse electrodeposition of CdS thin films for application in solar cells" at the 'National Conference on Recent Developments in Chemical Sciences and Allied Technologies (RDCST-2017)' held at NIT, Warangal during June 29-30, 2017.
3. Dr. L. Venkatesh presented a paper on "Preferred orientation and orientation dependence of hardness in laser clad chromium carbide coatings" at the 'International Conference on Electron Microscopy and Allied Techniques' held at Mahabalipuram on July 17, 2017.
4. Mr. Sumit Ranjan Sahu presented a paper on "Synthesis of graphene sheets from single-walled carbon nanohorns" at the 'In-house Symposium' held at Indian Institute of Technology-Madras, Chennai during July 29-30, 2017.
5. Mr. Swapnil H.Adsul (Dr. R. Subasri) made a poster presentation on "Investigations on anticorrosion properties of montmorillonite clay based sol-gel coatings on Mg alloy AZ91D" at the '2nd International Conference on Electrochemical Science and Technology (ICONEST-2017)' at Indian Institute of Science (IISc), Bengaluru during August 10-12, 2017.
6. Ms.S.Manasa (Dr.R.Subasri) made a poster presentation on "Smart nanocontainer-based self-healing corrosion protection coatings on AA2024-T4" at 'ICONEST-2017' at IISc, Bengaluru during August 10-12, 2017.
7. Dr. R. Balaji presented a paper on "Study and evaluation of stainless steel as bipolar plates for PEM fuel cell" at 'ICONEST 2017' held at IISc Bengaluru during August 10-12, 2017.
8. Ms. Prithi.J (Dr. N. Rajalakshmi) presented a paper on "Durable Zirconium Carbide support for Oxygen Reduction Reaction on Polymer Electrolyte Membrane Fuel Cells " at 'ICONEST 2017' held at IISc, Bengaluru during August 10-12, 2017.
9. Mr. M. Rajkumar (Dr. N. Rajalakshmi) presented a paper on "Design and formability of metallic bipolar plates for proton exchange membrane fuel cell with flow analysis using ANSYS fluent" at the 'International Conference on Advances in Materials and Manufacturing Applications (ICON AMMA 2017)' held at Bengaluru during August 17-19, 2017.
10. Mr. S. Ramakrishnan (Dr. N. Rajalakshmi) presented a paper on "Plasma nitrided SS bipolar plates for PEM fuel cell- preliminary analysis" at 'ICON AMMA 2017' held at Bengaluru during August 17-19, 2017.
11. Mr. A. Harish Kumar (Dr.Joydip Joardar) presented a paper on "Synthesis and oxidation resistance of nanostructured 2D-WS2" at the '24th Congress and General Assembly of the International Union of Crystallography (IUCr)' held at Hyderabad during August 21-28, 2017.
12. Dr. K. Suresh presented a paper on "Structure and micro structure of primary particles in mesoporous SnO2 beads" at the '24th Congress and General Assembly of the International Union for Crystallography (IUCr)' held at Hyderabad during August 21-28, 2017.
13. Dr. Kumari Konda presented a paper on "Optimization of Li-ion battery electrode by various modes of slurry preparation" at the '55th National Metallurgist Day & 71st Annual Technical Meeting of the Indian Institute of Metals (NMD ATM-2017)' held at BITS Pilani, Goa during November 11-14, 2017.
14. Mr. Ravi Gautam presented a paper on "Effect of phosphorous on the magnetic properties of Si-steels" at the 'NMD ATM-2017' held at BITS Pilani, Goa during November 11-14, 2017.
15. Dr. K. Suresh presented a paper on "Microstructure of cold sprayed Al-6061 alloys" at the 'NMD ATM-2017' held at Birla Institute of Technology and Science, Pilani, Goa during November 11-14, 2017.
16. Dr. P. Suresh Babu presented a paper on "Study of microstrucutre-property-performance of detonation sprayed WC-(W,Cr)2C-Ni coatings" at the 'NMD ATM-2017' held at BITS Pilani, Goa during November 11-14, 2017.
17. Mr. Naveen M. Chavan presented a paper on "Structure-property correlation in Cold sprayed aluminuim bronze coatings with varying stacking fault energies (SFE) and post treatments", at the 'NMD ATM-2017' held at BITS Pilani, Goa during November 11-14, 2017.
18. Dr. Gururaj Telasang presented a paper on "Design for additive manufacturing –self supporting conformal cooling channels" at the at the 'NMD ATM-2017' held at BITS Pilani, Goa during November 11-14, 2017.
19. Mr. Amol C. Badgujar made an oral presentation on "Cu (In, Ga) Se2 thin film absorber layer by flash light post-treatment" at the '17th International Conference on Thin Films (ICTF17)' held at National Physical

Laboratory (NPL), New Delhi during November 13-17, 2017.

20. Mr. T. Ramesh (Dr. N. Rajalakshmi) presented a paper on "Aluminium Hydride synthesis by electrochemical route" at the '11th International High Energy Materials Conference and Exhibits (HEMRL)' held at Pune during November 23-25, 2017.
21. Mr. D Nazeer Basha (Dr. Ravi Bathe) presented paper on "Laser surface micro-texturing of gray cast iron using ultrafast laser" at the '10th International Conference on Precision, Micro, Meso and Nano Engineering (COPEN 10)' held at Indian Institute of Technology (IIT) Madras, Chennai during December 07-09, 2017.
22. Mr. K. Nanaji (Dr. S. Anandan) made a poster presentation on "Bio-waste inspired graphene sheet like nanoporous carbon as a versatile electrode material for Energy Storage Applications" at the '9th Bengaluru India Nano 2017' held at Bengaluru during December 07 - 09, 2017.
23. Ms. P.M. Prathiksha (Dr. S. Anandan) made a poster presentation on "Large scale synthesis of high performance zero strain lithium titanate for high energy density Li-ion battery application" at the '9th Bengaluru India Nano 2017' held at Bengaluru during December 07 - 09, 2017.
24. Ms. T. Mitravinda (Dr. T.N. Rao) made a poster presentation on "Development of super capacitive carbon from agro-waste precursor for supercapacitor application" at the '9th Bengaluru India Nano 2017' held at Bengaluru during December 07 - 09, 2017.
25. Ms. P. Tejassvi (Dr. T.N. Rao) made a poster presentation on "Cobalt doped carbon nanofibers as an effective interlayer for high performance lithium-sulfur batteries" at the '9th Bengaluru India Nano 2017' held at Bengaluru during December 07 - 09, 2017.
26. Dr. D. Prabhu presented a paper on "Nanocrystalline Fe-P based soft magnetic materials for automotive applications" at the '9th Bengaluru India Nano 2017' held at Bengaluru during December 07 - 09, 2017.
27. Mr. K. Hari Gopi (Dr. N. Rajalakshmi) made a poster presentation on "Development of air cooled PEFC stack design of land & pillar flow field and its flow analysis validation by computational fluid dynamics (CFD)" at the '6th International Hydrogen and Fuel Cell Conference' held at Pune during December 10-12, 2017.
28. Mr. S.R. Atchuta (Dr. S. Sakthivel) presented a paper on "Optically enhanced solar selective and thermally stable absorber coating for concentrated solar thermal application" at the '6th International Conference on Advances in Energy Research 2017' held at IIT Bombay, Mumbai held on December 12-14, 2017.
29. Dr. M. Buchi Suresh presented a paper on "Correlation of pore former and morphology with the mechanical properties of zirconia based ceramics with engineered porosity" at the '81st Annual Session of Indian Ceramic Society and International Conference on Expanding Horizons of Technological Applications of Ceramics and Glasses(EH-TACAG'17)' held at Pune during December 14-16, 2017.
30. Dr. Papiya Biswas presented a paper on "Fabrication of transparent spinel through flash sintering and hot isostatic pressing" at 'EH-TACAG-2017' held at Pune during December 14-16, 2017.
31. Mr. P. Ramavath presented a paper on "Microstructure and mechanical properties of powder-HIPed alumina and zirconia toughened alumina ceramics" at 'EH-TACAG-2017' held at Pune during December 14-16, 2017.
32. Mr. V.P. Shippin (Y.S. Rao) presented a paper on "Ceramic foams for eco-friendly LPG combustion" at 'EH-TACAG-2017' held at Pune during December 14-16, 2017.
33. Ms.S. Mamatha (Dr. Y.S. Rao) presented a paper on "Investigations on 3D printing of complex shaped alumina parts" at 'EH-TACAG-2017' held at Pune during December 14-16, 2017.
34. Mr. P. Barick made a poster presentation on "Effect of processing parameters on the characteristics of spray-freeze-dried silicon carbide granules and its importance on the improvement of mechanical properties" at 'EH-TACAG-2017' held at Pune during December 14-16, 2017.
35. Mr. B. Jayachandran (Dr. D. Sivaprahasam) made a poster presentation on "Synthesis and interface studies on the LASTT thermoelectric materials for automotive waste heat recovery applications" at the 'India-UK Workshop on Thermoelectric Materials for Waste-Heat Harvesting' held at Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Bengaluru during January 08-10, 2018.
36. Mr. S. Harish (Dr. D. Sivaprahasam) made a poster presentation on "Evaluation of transport properties and thermal stability studies in tetrahedrite" at 'India-UK Workshop on Thermoelectric Materials for Waste-Heat Harvesting' held at JNCASR, Bengaluru during January 08-10, 2018.
37. Ms. B. Priyadarshini (Dr. Manjusha Battabyal) presented a paper on "Investigation of microstructure and thermoelectric properties of n-type Mg2Si " at the 'Indo-UK Workshop on Thermoelectric Materials for Waste-Heat Harvesting' held at JNCASR, Bangalore during January 08-10, 2018
38. Mr. Vikrant Trivedi (Dr. Manjusha Battabyal) presented a paper on "Effect of thermo mechanical treatment on the microstructure and the thermoelectric

properties in doped CoSb3 skutteruidities" at 'Indo US Bilateral Conference on Clean Energy' held at PSG College of Engineering, Coimbatore during January 10-12, 2018.

39. Mr. M. Shiva Prasad (Dr. S. Sakthivel) presented a paper on "High performance and thermally stable tandam solar selective absorber coating for concentrated solar thermal power (CSP) application" at the 'International Conference on Nano Materials for Energy Conversion and Storage (NECSA-2018)' held at Gandhi Nagar during January 29-31, 2018.
40. Dr. Bijoy Kumar Das presented a paper on "Electrochemical impedance spectroscopy (EIS) analysis for lithium ion battery" at the 'Indian Analytical Science Congress (IASC) – 2018' held at Kottayam during February 08-10, 2018.
41. Ms. Reshma Dileep (Dr. V. Ganapathy) made a poster presentation on "Hole conductor and metal cathode-free stable perovskite solar cells" at the 'National Conference on Emerging Materials for Sustainable Future' held at PSG Tech, Coimbatore during February 09 -10, 2018.
42. Ms. Shaik Mubina (Dr. B.P. Saha) presented a paper on "Effect of processing parameters on the properties of silicon carbide and its composites used for harsh environments" at the 'International Conference on Engineering Materials, Metallurgy & Manufacturing' held at Chennai during February 15-16, 2018.
43. Mr. Anas N.S (Dr. R. Vijay) made a poster presentation on "Development of higher strength Al alloy (Al-4.4Cu-0.5Mg) by mechanical alloying" at the 'National Conference on Development of Aluminium alloys and Downstream Products for Defence, Aerospace and other Strategic applications" held at JNARDDC Nagpur during February 23-24, 2018.
44. Dr. Sanjay Bhardwaj was a Panelist in a session on 'Technology Commercialization – Issues and Solutions' during ISBA 2018 Conference organized by Indian STEPs and Business Incubators Association with the support of NSTEDB, DST during February 26-28, 2018.
45. Mr. K. Nanaji (Dr. S. Anandan) made a poster presentation on "Graphene sheets like nanoporous carbon derived from agricultural bio-waste (jute stick) as electrode material for high performing supercapacitors" at the 'Workshop on Battery Technologies & Electric Mobility" held at Bengaluru during March 08-09, 2018
46. Ms. B. Divya (Dr. B. V. Sarada) made a poster presentation on "Application of electrodeposited CdS as n-type semiconductor layer for the CIGS-based thin film solar cells" at the 'International Conference on Advanced Semiconductor Materials and Devices (ICASMD-2018)' held at Hyderabad during March 08-10, 2018.
47. Ms. N. Manjula (Dr. N. Rajalakshmi) made a poster presentation on "A preliminary study on synthesis of sulfonated PVDF-CO-HFP membrane and its application in electrochemical methanol reformation" at the 'International Conference on Nanoscience & Technology (ICONSAT2018)' at CeNS, JNCASR, Bengaluru during March 21-23, 2018.
48. Ms. Sasikala Natarajan (Dr. M.B. Sahana) presented a paper on "Electrochemical property of nano/micro hierarchical structured LiNi1-x-yCoxAlyO2 synthesized by co-precipitation assisted solid state synthesis" at the 'International Conference on Nanoscience & Technology (ICONSAT2018)' held at CeNS, JNCASR, Bengaluru during March 21-23, 2018.
49. Ms. R. Yogapriya (Dr. R. Subasri) presented a paper on "Investigations on the durability of spray deposited superhydrophobic coatings on stainless steel AISI 304" at the 'National Conference on VLSI Design, Communication and Nano Technologies (VDCNT18)' held at PSG College of Technology, Coimbatore during March 23-24, 2018.
50. Mr. K. Sriram (Dr.N.Rajalakshmi) presented a paper on "Enhanced corrosion resistance of Pt modified polyaniline coated on 316L SS as metallic bipolar plates for PEM fuel cell application" at the '5th International Corrosion Prevention Symposium for Research Scholars (CORSYM 2018)' held at IIT Madras, Chennai during March 23-24, 2018.

Participation in Indian Conferences/ Symposia/ Seminars/ Workshops/Exhibitions

1. Mr. V. Balaji Rao, Ms. V.Uma and Mr. V.C. Sajeev attended the 'Workshop on Assessing Performance of PV Modules in the Field' at the National Centre for Photovoltaic Research and Education (NCPRE), IIT Bombay, Mumbai during April 06- 07, 2017.
2. Ms. S. Nirmala, Mr. Ch. Sambasiva Rao and Ms. N. Aruna attended the 'Key Sight 2017 Aerospace & Defence Symposium' held at Hyderabad on April 13 2017.
3. Dr. Easwaramoorthi Ramasamy attended 'Workshop on R&D Activities on Solar Photovoltaics in India' organized by SERIIUS at IIT Bombay, Mumbai on April 24, 2017.
4. Mr. G. M. Rajkumar and Mr. Anirban Bhattacharjee attended the 'National Conference on GST Programme' held at Hyderabad on May 12, 2017.
5. Dr. S. M. Shariff attended the 'Workshop on Challenges in Joining of Advanced Materials (CJAM)' held at Hyderabad on May 26, 2017.
6. Dr. S. Sakthivel and Dr. Easwaramoorthi Ramasamy attended the 'Conference on Green Power:

Challenges and Innovation' held at NTPC, Noida during June 08-09, 2017.

7. Mr. Manish Tak, Ms. K. Divya and Mr. E. Anbu Rasu attended the 'Workshop on Research Methodology and Faculty Advisers Forum' held at Hyderabad during June 19-24, 2017.
8. Dr. R. Subasri, Dr. L. Ramakrishna, Mr. Manish Tak and Mr. K.R.C. Soma Raju attended the 'Seminar on Creating Capabilities with MSME's' held at Hyderabad on July 14, 2017.
9. Mr. Sai Kishore attended the 'Seminar on TDS' held at Hyderabad on August 08, 2017.
10. Dr. Papiya Biswas attended 'CEP Workshop on 3D Printing' held at IIT-Bombay, Mumbai during August 21-22, 2017.
11. Dr. T. N. Rao attended the '2nd Edition of Energizing South - Conference on Economic Growth: Smart, Reliable & Sustainable Power' held at Visakhapatnam during September 01-02 , 2017.
12. Dr. K. Suresh, Ms. K. Divya, Dr. S B Chandrasekhar, Mr. Sai Karthik and Dr. Uday Bhaskar, attended a 'Seminar on Heat Treatment of Steels and other Alloys-Latest Trends and Opportunities' held at Hyderabad on September 04, 2017.
13. Mr. Anbu Rasu attended the course on 'Advanced Welding Technology' held at IIT Bombay, Mumbai during September 12- 16, 2017.
14. Dr. N. Rajalaskshmi and Dr. M.B. Sahana attended a 'Workshop on Sexual Harassment of Women at Workplace (Prevention, Prohibition and Redressal) Act, 2013' held at Chennai on September 13, 2017.
15. Mr. K. V. Phani Prabhakar and Mr. Manish Tak attended the 'National Seminar on Failure Analysis and Advances in Welding Technologies for Aero Engine' held at HAL, Koraput, Odisha on September 15, 2017.
16. Dr. Pramod H. Borse attended the 'Workshop on Scale up of Hydrogen Production through Photo-Electro-Chemical (PEC) Water Splitting' held at Indian Oil Corporation-R&D Centre, Faridabad during November 06, 2017.
17. Dr. Sanjay R. Dhage and Ms. Priya Anish Mathews attended 'One Day Conclave on Connecting the Dots in Telangana's Defence & Aerospace Sector' held at Hyderabad on November 16, 2017.
18. Ms. S. Nirmala, Mr. Sambasiva Rao and Ms. Aruna attended the 'One Day Workshop on Emerging Trends in Intelligent Machines' held at Hyderabad on December 02, 2017.
19. Mr. A. Srinivas and Dr. Rambha Singh attended the 'Regional Official Language Conference of South and South-East' held at Vishakhapatnam on December 8, 2017.
20. Mr. Sai Kishore attended 'One-Day Workshop on Tax Related Issues' held at Chennai on January 11, 2018.
21. Mr. K. Srinivasa Rao attended a 'Two Day Workshop on Metal Finishing Technologies on Electroplating-2018' held at IISc, Bengaluru during February 01-02, 2017.
22. Mr. Sudheendra attended "One Day Hindi Workshop' organized by Town Official Language Implementation Committee' at Hyderabad on February 02, 2018.
23. Dr. S.Kavita attended the 'Indo-US Symposium on Magnetism' held at IIT Mumbai, Bombay during February 05-06, 2018.
24. Dr. R. Gopalan attended the 'Indian Analytical Science Congress (IASC-2018)' held at Kottayam during February 08-10, 2018.
25. Dr. G. Ravi Chandra attended the 'Annual General Body Meeting of the Materials Research Society of India and the National Symposium on Advanced in Functional and Exotic Materials' held at Tiruchirapally during February 14-16, 2018.
26. Dr. Kaliyan Hembram attended the '3rd International Exhibition and Conference on Medical Device Sector (Indian Medical Device 2018)' held at Bangalore International Exhibition Center, Bengaluru during February 15-17, 2018,
27. Mr. Manish Tak attended a 'National Seminar on Emerging Trends in Repair, Reclamation and Life Extension of Helicopters Aero Engines and their Aggregates' at the 3-Base Repair Depot, Chandigarh on February 19, 2018.
28. Dr. Malobika Karanjai chaired the Plenary session talk at the 'International Conference on Powder Metallurgy and Particulate Materials (PM 18)' held at Navi Mumbai during February 21-22, 2018.
29. Dr. Rambha Singh attended one day Workshop on 'How to Draft Replies for Questionnaire on Parliament Official Language Committee' held at Hyderabad on February 22, 2018.
30. Dr. M. Buchi Suresh and Mr. M. Ramakrishna attended the 'National Seminar on Development Processing and Application of High Temperature Materials-Current Trends and Challenges Ahead' held at Hyderabad during February 22-23, 2018.
31. Mr. K.V. Phani Prabhakar and Dr. S. M. Shariff attended the 'International Conference on Aluminium & Magnesium the Sustainable Light Weight Solutions for Transport Sector' held at Pune during February 23-24, 2018.
32. Dr. Raman Vedarajan participated in 'National Seminar on Development of Aluminum Alloys and Downstream Products of Defence, Aerospace and Other Strategic Applications' at the Jawaharlal Nehru Aluminum Research Design and Development Centre, Nagpur during February 23-24,2018.

33. Mr. B. Balaji Rao, Ms. V. Uma, Mr. V C Sajeev and Mr. A. R. Srinivas attended the 'International Conference on Engineer Infinite and 'Product Exhibition at ELECRAMA 2018' held at New Delhi during March 10-14, 2018.
34. Mr. Manish Tak attended 'Indo-Australian Workshop on Advances in Materials and Additive Manufacturing (AM2)' held at IIT Madras, Chennai during March 21-22, 2018.

Participation in Training Programmes in India

1. Ms. B. Priyadarshini attended the training programme on 'Application Training Program for Master Sizer Particle Size Analysis' held at AIMIL Limited, Chennai on April 12, 2018.
2. Mr. S. Kalyanaraman attended the training course on 'Swachh Bharat Abhiyan' held at New Delhi on May 08, 2017.
3. Dr. Gururaj Telasang attended the 'Faculty Development Programme (FDP) on 3D Printing Technology in Engineering Education' held at National Institute of Technology (NIT), Warangal during June 05-10, 2017.
4. Mr. Narendra K. Bhakta and Mr. P. Sai Kishore attended a training programme on 'Latest Trends in Material Management and Supply Chain Management' held at Hyderabad on June 24, 2017.
5. Dr. K. Suresh attended the 'LEAP' training programme held at IIT Madras, Chennai during July 24- August 01, 2017.
6. Dr. R. Vijay, Dr. Dibyendu Chakrabarty and Dr. R. Balaji attended the training programme on 'Research Excellence in Organizations' held at Hyderabad on August 07, 2017.
7. Dr. K. Suresh and Dr. Gururaj Telasang attended the 'Aerospace & Defence Manufacturing Show (ADMS)-2017' held at Bengaluru during August 17-18, 2017.
8. Dr. D.C. Jana attended a three day training on 'Introduction to SIMULIA ABACUS Course' held at ARCI, Hyderabad during September 06-08, 2017.
9. Mr. E. Anbu Rasu attended a certificate course on 'Advanced Welding Technology' conducted by IIT-Bombay at Mumbai during September 12-16, 2017.
10. Mr. K. Naresh Kumar and Mr. Narendra K. Bhakta attended a training programme on 'GeM & GRFs 2017 Training' conducted by NIFM at Faridabad during September 18 -19, 2017.
11. Mr. Y. Krishna Sarma attended the residential Programme on 'Improving Effectiveness of Private Secretaries/Personal Assistants' held at Puri, Odisha during October 09-13, 2017.
12. Dr. B. P. Saha, Mr. Anirban Bhattacharjee, Mr. G. M. Raj Kumar, Mr. A. Srinivas, Mr. B. Uday Kumar, Mr. P. Venugopal, Ms. Kamal Vaishali, Mr. P. V Ramana, Mr. Naresh Kumar, Mr. M. R. Renju, Mr. Narender K. Bhakta, Mr. Ravi Singh, Mr. B. Venkatesham, Mr. Ramavathu Ranga Naik, Mr. Sai Kishore and Mr. G. Ramesh Reddy attended the training programme on 'NIC CPPP-e Procurement for Comprehensive end to end e-Procurement' conducted by National Informatics Centre at Hyderabad on October 16, 2017.
13. Dr. E. Ganesan attended the training programme on 'TEM' held at IIT Madras, Chennai during November 20- 25, 2017.
14. Mr. V. Balaji Rao and Mrs. V. Uma attended the training programme on 'Energy Efficiency' held at Mumbai during November 23 - 24, 2017.
15. Mr. S. Arun and Mr. N. Srinivas attended the 'Road to Global Entrepreneurship Summit' held at Hyderabad during November 26- 27, 2017.
16. Mr. K. Hari Gopi and Mr. M. Rajkumar attended the training programme on 'Introduction to ANSYS Space Claim, Meshing & ANSYS Fluent' held at Chennai during December 05-08, 2017.
17. Mr. E. Anbu Rasu, attended certificate course on 'Welding Metallurgy and Weldability of Non- Ferrous alloys' at IIT-Madras, Chennai during December 11-15, 2017.
18. Mr. B. Venkatesham, Mr. R. Ranga Naik and Mr. Sai Kishore attended the training programme on 'Public Procurement' held at NIFM, Faridabad during December 18-23, 2017.
19. Mr. S. Vasu and Ms. S. Bhuvaneswari attended the ECS India Section School with the theme 'Applications of functional materials for electrochemical energy conversion' held at Coimbatore during December 25 - 29, 2017.
20. Dr. N. Rajalakshmi and Dr.R.Balaji attended the 'ECS India Section Schools on Applications of Functional Materials for Electrochemical Energy Conversion' held at Amrita Vishwa Vidyapeetham University, Coimbatore during December 26-28, 2017.
21. Dr. S.M. Shariff and Mr. N. Srinivas participated in the 'Vision Jammu & Kashmir 2018' held at Udhampur, J&K during January 29-31, 2018.
22. Ms. Priya Anish Mathews attended the training on 'Patent, Filing, Search, Drafting, Filing Process of Trademarks, GI, Copyrights, Designs' held at RGNIIPM, Nagpur during February 05-09, 2018.
23. Mr. G.M. Rajkumar attended the training programme on 'GST' held at Hyderabad during February 07-09, 2018.
24. Dr. Bhaskar Prasad Saha attended the training programme on 'Managing Technology Value Chains for Directors & Division Heads' held at Administrative Staff College of India (ASCI), Hyderabad during February 12 - 16, 2018.

Patents' Portfolio

National Patents Granted

Sl. No.	Title of Patent	Patent Number	Date of Grant	Application Number	Date of Filing
1.	A Solar Drier	184674	23/09/2000	487/ MAS/1994	08/06/1994
2.	A Solar Cooker	184675	25/05/2001	498/ MAS/1994	13/06/1994
3.	An Indirect Heated Catalytic Converter for use with Vehicles	185433	10/08/2001	809/ MAS/1994	25/08/1994
4.	A Process for the Preparation of Short Ceramic Fibres	186751	07/06/2002	537/ MAS/1994	20/05/1994
5.	A Process of Producing Chemically Treated Expanded Graphite and a Device having Such Graphite	187654	05/12/2002	562/ MAS/1994	07/06/1995
6.	A Process for Preparation of Reaction Bonded Silicon Carbide Components	195429	31/08/2006	1886/ MAS/1996	28/10/1996
7.	New Composite Material Having Good Shock Attenuating Properties and a process for the Preparation of Said Material	194524	02/01/2006	976/ MAS/1998	06/05/1998
8.	Improved Process for the Preparation of Magnesium Aluminate Spinel Grains	200272	02/05/2006	29/ MAS/1999	07/01/1999
9.	Ceramic Honey Comb Based Energy Efficient Air Heater	200787	02/06/2006	30/ MAS/1999	07/01/1999
10.	A Process for the Preparation of Improved Alumina Based Abrasive Material, an Additive Composition and a Process for the Preparation of the Composition	198068	16/02/2006	122/ MAS/2000	18/02/2000
11.	A Process for the Production of Dense Magnesium Aluminate Spinel Grains	198208	16/02/2006	520/ MAS/2000	06/07/2000
12.	An Improved Method for Making Honeycomb Extrusion Die and a Process for Producing Ceramic Honeycomb Structure using the Said Die	198045	13/01/2006	538/ MAS/2001	03/07/2001
13.	Device for Gas Dynamic Deposition of Powder Materials	198651	25/01/2006	944/ MAS/2001	22/11/2001
14.	An Evaporation Boat useful for Metallization and a Process for the Preparation of Such Boats	201511	01/03/2007	882/ CHE/2003	31/10/2003
15.	Process for Carbothermic Reduction of Iron Oxide in an Immiscible Flow with Constant Descent in Vertical Retort of Silicon Carbide	205728	16/04/2007	546/ CHE/2003	01/07/2003
16.	A Process for Preparing Ceramic Crucibles	207700	20/06/2007	806/ MAS/2000	26/09/2000
17.	A Process for Forming Coatings on Metallic Bodies and an Apparatus for Carrying out the Process	209817	06/09/2007	945/ MAS/2001	22/11/2001
18.	A Method and a Device for Applying a Protective Carbon Coating on Metallic Surfaces	211922	13/11/2007	719/ MAS/1999	08/07/1999

Sl. No.	Title of Patent	Patent Number	Date of Grant	Application Number	Date of Filing
19.	An Improved Boronizing Composition	220370	27/05/2008	289/ MAS/2001	03/04/2001
20.	Titanium Based Biocomposite Material useful for Orthopedic and other Implants and a Process for its Preparation	228353	03/02/2009	2490/ DEL/2005	14/09/2005
21.	An Improved Method of Forming Holes on a Substrate using Laser Beams	239647	29/03/2010	3205/ DEL/2005	29/11/2005
22.	A Method of and an Apparatus for Continuous Humidification of Hydrogen Delivered to Fuel Cells	247547	19/04/2011	670/ CHE/2007	30/03/2007
23.	An Improved Process for the Preparation of Doped Zinc Oxide Nanopowder useful for the Preparation of Varistors	254913	03/01/2013	1669/ DEL/2006	20/07/2006
24.	A Device for Controlling the On & Off Time of the Metal Oxide Semi Conductor Field Effect Transistor (MOSFET), A Device for Spark Coating the Surfaces of Metal Workpiece Incorporating the said Control Device and a Method of Coating Metal Surfaces using the said Device	262189	05/08/2014	1610/ DEL/2005	21/06/2005
25.	An Improved Catalyst Ink useful for Preparing Gas Diffusion Electrode and an Improved PEM Fuel Cell	277778	30/11/2016	680/ DEL/2008	18/03/2008
26.	An Improved Process for the Preparation of Exfoliated Graphite Separator Plates useful in Fuel Cells, the Plates Prepared by the Process and a Fuel Cell Incorporating the Said Plates	281504	20/03/2017	1206/ DEL/2006	17/05/2006
27.	Improved Method of Producing Highly Stable Aqueous Nano Titania Suspension	282988	28/04/2017	730/ DEL/2009	09/04/2009
28.	A Process for the Preparation of Nanosilver and Nanosilver-Coated Ceramic Powders	284812	30/06/2017	2786/ DEL/2005	19/10/2005
29.	An Improved Method for Preparing Nickel Electrodeposited having Predetermined Hardness Gradient	285178	14/07/2017	1455/ DEL/2009	15/07/2009
30.	An Improved Method for the Generation of Hydrogen from a Metal Borohydride and a Device Therfor	285257	17/07/2017	1106/ DEL/2007	23/05/2007
31.	Improved Process for the Preparation of Stable Suspension of Nano Silver Particles having Antibacterial Activity	289543	14/11/2017	1835/ DEL/2010	04/08/2010
32.	Improved Method for Producing Carbon Containing Silica Aerogel Granules	290370	07/12/2017	2406/ DEL/2010	08/10/2010
33.	An Improved Composition for Coating Metallic Surfaces, and a Process for Coating Such Surfaces using the Composition	290592	14/12/2017	620/ DEL/2010	17/03/2010
34.	Improved Catalyst Ink for Catalyst Coated Membrane of Electrode Membrane Assembly and the Process Thereof	290765	18/12/2017	631/ DEL/2008	13/03/2008

Sl. No.	Title of Patent	Patent Number	Date of Grant	Application Number	Date of Filing
35.	Improved Process for the Preparation of Bi-Functional Silica Particles useful for Antibacterial and Self Cleaning Surfaces	291408	04/01/2018	3071/ DEL/2010	22/12/2010
36.	A Hydrophilic Membrane based Humidifier useful for Fuel Cells	291871	18/01/2018	95/ DEL/2007	16/01/2007
37.	An Improved Method for Producing ZnO Nanorods	293775	05/03/2018	2759/ DEL/2010	19/11/2010
38.	Improved Scratch and Abrasion Resistant Compositions for Coating Plastic Surfaces, a Process for their Preparation and a Process for Coating using the Compositions	295221	28/03/2018	2427/ DEL/2010	12/10/2010

National Patent Applications Awaiting Grant

Sl. No.	Title of Patent	Patent Application Number	Date of filing
39.	Novel Ceramic Materials Having Improved Mechanical Properties and Process for their Preparation	3396/DEL/2005	19/12/2005
40.	An Improved Process for Preparing Nanotungsten Carbide Powder useful for Fuel Cells	81/DEL/2007	12/01/2007
41.	Improved Fuel Cell having Enhanced Performance	606/DEL/2007	21/03/2007
42.	Improved Cylindrical Magnetron Cathode and a Process for Depositing Thin Films on Surfaces using the said Cathode	21/DEL/2008	03/01/2008
43.	A Process for Continuous Coating Deposition and an Apparatus for Carrying out the Process	1829/DEL/2008	01/08/2008
44.	An Improved Gas Flow Field Plate for use in Polymer Electrolyte Membrane Fuel Cells (PEMFC)	2339/DEL/2008	13/10/2008
45.	Novel Copper Foils having High Hardness and Conductivity and a Pulse Reverse Electrodeposition Method for their Preparation	1028/DEL/2009	20/05/2009
46.	An Improved Gas and Coolant Flow Field Plate for use in Polymer Electrolyte Membrane Fuel Cells (PEMFC)	1449/DEL/2010	22/06/2010
47.	An Improved Method of Preparing Porous Silicon Compacts	912/DEL/2011	31/03/2011
48.	An Improved Process for Preparation of Nanosilver Coated Ceramic Candle Filter	1249/DEL/2011	28/04/2011
49.	An Improved Abrasion Resistant and Hydrophobic Composition for Coating Plastic Surfaces and a Process for its Preparation	1278/DEL/2011	02/05/2011
50.	An Improved Method for Making Sintered Polycrystalline Transparent Sub-Micron Alumina Article	1358/DEL/2011	10/05/2011
51.	An Improved Hybrid Methodology for Producing Composite Multilayered and Graded Coatings by Plasma Spraying Utilizing Powder and Solution Precursor Feedstock	2965/DEL/2011	17/10/2011
52.	An Improved Composition for Solar Selective Coatings on Metallic Surfaces and a Process for its Preparation and a Process for Coating using the Composition	3324/DEL/2011	22/11/ 2011
53.	A Process and a Multi-Piston Hot Press for Producing Powder Metallurgy Component, such as Cerametallic Friction Composite	3844/DEL/2011	28/12/ 2011

Sl. No.	Title of Patent	Patent Application Number	Date of filing
54.	A novel Process for Produced IR Transparent Polycrystalline Alumina Article and the Article so Produced	365/DEL/2012	08/02/2012
55.	A Process for Preparing Nanocrystalline Olivine Structure Transition Metal Phosphate Material	405/DEL/2012	14/02/2012
56.	A Device for and A Method of Cooling Fuel Cells	1408/DEL/2012	08/05/2012
57.	An Improved Aqueous Method for Producing Transparent Aluminium Oxy Nitride (ALON) Articles	1409/DEL/2012	08/05/2012
58.	An Improved Solar Selective Multilayer Coating and a Method of Depositing the Same	1567/DEL/2012	22/05/2012
59.	A Multi Track Laser Beam Process of Surface Hardening of a Full size Steel Blank of Low Carbon Steel for Producing Automotive Components	600/KOL/2012	25/05/2012
60.	A Novel Method for the Synthesis of Tungsten Disulphide Nanosheets	1703/DEL/2012	04/06/2012
61.	Laser Surface Nitrided Titanium Alloy For Light Weight Automobile Disk Brake Rotor Application	2285/CHE/2012	07/06/2012
62.	Enhanced Thermal Management Systems for Fuel Cell Applications Using Nanofluid Coolant	1745/DEL/2012	07/06/2012
63.	Process for Producing Anti-Reflective Coatings with Scratch Resistance Property	1777/DEL/2012	11/06/2012
64.	Improved Method of Manufacturing Copper-Indium-Gallium Diselenide Thin Films by Laser Treatment	2084/DEL/2012	05/07/2012
65.	Electronically and Ionically Conducting Multi-Layer Fuel Cell Electrode and a Method for Making the Same	2198/DEL/2012	17/07/2012
66.	Fuel Cell System Equipped with Oxygen Enrichment System Using Magnet	2985/DEL/2012	25/09/2012
67.	A High Thermal Stable Selective Solar Absorber layer with Low Emissive Barrier Coating over a Substrate and a Process of Producing the Same	3312/DEL/2012	29/10/2012
68.	A Polymer Electrolyte Membrane (PEM) Cell and a Method of Producing Hydrogen from Aqueous Organic Solutions	3313/DEL/2012	29/10/2012
69.	Catalytically and Chemically modified Carbon Nanostructures for Storage of Hydrogen	405/CHE/2013	30/01/2013
70.	An Improved Test Control System useful For Fuel Cell Stack Monitoring and Controlling	269/DEL/2013	31/01/2013
71.	A Novel Laser Surface Modification Technique for Hardening Steel	337/DEL/2013	06/02/2013
72.	An Improved Solar Selective Absorber Coating with Excellent Optical Absorptance, Low Thermal Emissivity and Excellent Corrosion Resistance Property and a Process of Producing the Same	1129/DEL/2013	16/04/2013
73.	An Improved Composition for Coating Anodizable Metal Surfaces and a Process of Coating the Same`	1310/DEL/2013	03/05/2013
74.	A Method of Preparation of Supported Platinum Nano Particle Catalyst in Tubular Flow Reactor Via Polycol Process	1571/DEL/2013	24/05/2013
75.	An Improved Composition for Antireflective Coating with Improved Mechanical Properties and a Process of Coating the Same	2330/DEL/2013	05/08/2013

Sl. No.	Title of Patent	Patent Application Number	Date of filing
76.	Process for Producing Anti-Reflective Coatings With Anti-Fogging (Super Hydrophilic), UV, Weather and Scratch Resistance Properties	2919/DEL/2013	03/10/2013
77.	An Improved Process for Obtaining a Transparent, Protective Coating on Bi-Aspheric / Plano-Convex Lenses made of Optical Grade Plastics for use in Indirect Ophthalmoscopy	3072/DEL/2013	17/10/2013
78.	Exfoliated Graphite Separator based Electrolyzer for Hydrogen Generation	3073/DEL/2013	17/10/2013
79.	Multi-Track Laser Surface Hardening of Low Carbon Cold Rolled Closely Annealed (CRCA) Grades of Steels	1411/KOL/2013	13/12/2013
80.	A Super Hydrophobic Coating with High Optical Properties having Easy to Clean Property, UV and Corrosion Resistance Properties, a Process of Preparation and Application of the Same	402/DEL/2014	12/02/2014
81.	High Temperature Polymer Electrolyte Membrane Fuel Cells with Exfoliated Graphite based Bipolar Plates	494/DEL/2014	20/02/2014
82.	Method of Deposition of Double Perovskite of Sr-Fe Niobium Oxide Film on a Substrate by Spray Coating Technique and the Coated Substrate Thereof	1151/DEL/2014	29/04/2014
83.	An Improved Process to Make Coating Compositions for Transparent, UV Blocking on Glass and a Process of Coating the Same	1152/DEL/2014	29/04/2014
84.	Method of Producing Multifunctional Self Assembled Mixed Phase Titania Spheres	3777/DEL/2014	19/12/2014
85.	Method of Producing Porous MgF2 Nanoparticles, Antireflection Coating Suspension and Coatings for Solar Optical UV and IR Transparent Window Applications	4041/DEL/2014	31/12/2014
86.	A Novel Electrochemical Method for Manufacturing CIGS Thin Film Containing Nanomesh Like Structure	426/DEL/2015	16/02/2015
87.	An improved performance of Nanocomposite Oxide Selective Absorber Coating with excellent optical and thermal resistant properties and method of manufacturing the same	1111/DEL/2015	22/04/ 2015
88.	Process and apparatus for protection of structural members from wear, corrosion and fatigue damage	1839/DEL/2015	22/06/ 2015
89.	A Method of Preparing of Anti Tarnishing Organic-Inorganic Hybrid Sol-Gel and Coating The Same	2049/DEL/2015	07/07/2015
90.	An Improved Process for Producing Silica Aerogel Thermal Insulation Product with Increased Efficiency	2141/DEL/2015	15/07/ 2015
91.	Solar Selective Coating For Solar Energy Collector / Absorber Tubes with Improved Performance and a Method of Producing the Same	2142/DEL/2015	15/07/ 2015
92.	Method of Producing High Performance Visible-Light-Active Photocatalytic Materials for Self-Cleaning Applications	2625/DEL/2015	25/08/ 2015
93.	Production of Graphene-Based Materials by Thermal Spray	2626/DEL/2015	25/08/ 2015
94.	Method of Preparation of High Performance ZnO Varistors and Improved Compositions	2765/DEL/2015	03/09/ 2015
95.	An Improved Coating Composition to Provide Prolonged Corrosion Protection to Anodizable Metal Surfaces and Process of Preparing the Same	3082/DEL/2015	28/09/ 2015

Sl. No.	Title of Patent	Patent Application Number	Date of filing
96.	A Method and an Apparatus for Preparing Nickel Tungsten based Nanocomposite Coating Deposition	201611001190	13/01/2016
97.	A Process for In-Situ Carbon Coating on Alkali Transition Metal Oxides	201611007451	03/03/2016
98.	An Improved Process for the Preparation of Stable Nano Silver Suspension having Antimicrobial Activity	201611027145	09/08/2016
99.	A Laser-based Surface Processing Apparatus and a Method to Process Metallic Materials and Components	201611034362	07/10/2016
100.	An Improved Process of Carbon - Metal Oxide Composites Prepared by Nano Casting of Wood and the Product Thereof	201611034531	07/10/2016
101.	A Method for Producing Inorganic Bonded Silica based Eco-Friendly Artificial Marble Articles and the Product Thereof	201611036479	25/10/2016
102.	An Improved Coating Composition to Provide Flame Retardant Property to Fabrics and Process of Preparing the Same	201611040091	23/11/2016
103.	Method of Producing Hollow MgF2 Nanoparticles, Anti-reflection Coating Sols and Coatings for Optical and Solar Applications	201611041804	07/12/2016
104.	A Method of Producing High Performance Lithium Titanate Anode Material for Lithium Ion Battery Applications	201711006147	21/02/2017
105.	Method of Producing Graphene like Structured Nanoporous Carbon Material from Jute Stick based Bio-waste for Energy Storage Applications and the Product Thereof	201711006697	24/02/2017
106.	An Improved Gas Dynamic Cold Spray Device and Method of Coating a Substrate	201711006749	26/02/2017
107.	A Novel Equipment to Accomplish Power Metallurgy Processing Starting From The 'Raw Materials' to Finished Product	201711011552	30/03/2017
108.	An Improved Process for Preparing Durable Multifunctional Coatings On Metal/Alloy Substrates	201711020529	12/06/2017
109.	A System for Treating a Surface of Bearing Components and a Process Thereof	201711046511	23/12/2017
110.	Method Of Producing Nano Structured C-TIO2 Composite Material for Visible Light Active Photocatalytic Self-Cleaning Applications	201811011478	28/03/2018

International Patents Granted and Awaiting Grant

Sl. No.	Title of Patent	Country	Patent Number / Application Number	Date of Grant	Date of filing	Indian /Family Patent Details
1.	Process for Forming Coatings on Metallic Bodies and an Apparatus for Carrying out the Process	USA	US6893551B2	17/05/2005	02/08/2002	209817
2.	A Device for Controlling the On & Off Time of the Metal Oxide Semi Conductor Field Effect Transistor (MOSFET), A Device for Spark Coating the Surfaces of Metal Workpiece Incorporating the said Control Device and a Method of Coating Metal Surfaces using the said Device	USA	US8143550B2	27/03/2012	20/03/2006	262189

Sl. No.	Title of Patent	Country	Patent Number / Application Number	Date of Grant	Date of filing	Indian /Family Patent Details
3.	A Process for the Preparation of Nano Silver and Nano Silver-Coated Ceramic Powders	South Africa	2006/8591	30/04/2008	13/10/2006	284812
		Sri Lanka	14258	02/11/2011	17/10/2006	
		Indonesia	IDP000044402	06/02/2017	18/10/2006	
4.	A Process for Continuous Coating Deposition and an Apparatus for Carrying out the Process	South Africa	2009/06786	26/05/2010	30/09/ 2009	1829/DEL/2008
		UK	2464378	15/05/2013	02/10/2009	
		USA	8486237	16/07/2013	14/10/2009	
		Japan	2009-237921	27/12/2013	15/10/2009	
		France	2937342	18/12/ 2015	12/10/2009	
5.	Method of Depositing Electrically Conductive Electrode Material onto the Surface of an Electrically Conductive Work Piece	USA	US8674262B2	18/03/2014	12/08/2011	1610/DEL/2005; Divisional Patent of US81435 50B2
6.	Improved Process for the Preparation of Stable Suspension of Nano Silver Particles having Antibacterial Activity	United Kingdom	GB2496089	18/06/2014	19/07/2011	1835/DEL/2010
		Hong Kong	13107076.7	---	18/06/2013	
7.	A Process for Continuous Coating Deposition and an Apparatus for Carrying out the Process	USA	US9365945B2	14/06/2016	14/06/2016	1835/DEL/2010; Divisional patent of US8486237 B2
8.	An Improved Hybrid Methodology for Producing Composite, Multilayered and Graded Coatings by Plasma Spraying Utilizing Powder and Solution Precursor Feedstock	South Africa	2012/02480	---	05/04/2012	2965/DEL/2011
		Canada	2784395	16/09/2014	31/07/2012	
		Brazil	102120221209	---	31/08/2012	
		Germany	102012218448.1	---	10/10/2012	
		France	1259820	---	15/10/2012	
9.	A Device for Controlling the On & Off Time of the Metal Oxide Semi Conductor Field Effect Transistor (MOSFET), A Device for Spark Coating the Surfaces of Metal Workpiece Incorporating the said Control Device and a Method of Coating Metal Surfaces using the said Device	USA	14/190581	---	26/02/2014	262189; Divisional Patent application of US81435 50B2 and US86742 62B2
10.	Multi-Track Laser Surface Hardening of Low Carbon Cold Rolled Closely Annealed (CRCA) Grades of Steels	USA	15/103343	---	10/12/2014	1411/KOL/2013
		Australia	AU2014362928A	---	10/12/2014	
11.	An Improved Process for Producing Silica Aerogel Thermal Insulation Product with Increased Efficiency	To be decided	WO/2017/ 009858	---	04 /07/2016	2141/DEL/2015; PCT/ IN2016/ 000176
12.	A Method of Producing High Performance Lithium Titanate Anode Material for Lithium Ion Battery Applications	Yet to decide	PCT/ IN2018/050080	---	17/02/2018	201711006147
13.	An Improved Gas Dynamic Cold Spray Device and Method of Coating a Substrate	Yet to decide	PCT/ IN2018/050087	---	21/02/2018	201711006749

Journal Publications

1. S. Pavithra, N. Rajender, M.V. Reddy, K.Murugan and K.I. Suresh, "Effect of Graphene Oxide (GO) Size and Structure on Synthesis and Optoelectronic Properties of Hybrid GO-Poly (3-Hexylthiophene) Nanocomposites", Polymer Composites, Vol.38 (5), p 852-862, 2017.
2. N. Ravi, R. Markandeya and S. V. Joshi, "Effect of Substrate Roughness on Adhesion and Tribological Behaviour nc- TiAlN/a-Si3N4 Nano Composite Coatings Deposited by Cathodic Arc PVD Process", Surface Engineering, Vol. 33(1), p 07-19, 2017.
3. S.Kumar, S.K. Reddy and S.V.Joshi, "Microstructure and Performance of Cold Sprayed Al-SiC Composite Coatings with High Fraction of Particulates", Surface & Coatings Technology, Vol.18, p 62-71, 2017.
4. G.A. Sundaram, M.H. Yang, K. Nomura, S. Maniarasu, G. Veerappan, T. Liu, and J.H. Wang, "Sn-119 Mossbauer and Ferromagnetic Studies on Hierarchical Tin- and Nitrogen-Codoped TiO2 Microspheres with Efficient Photocatalytic Performance", Journal of Physical Chemistry, Vol. 121(12), p 6662-6673, 2017.
5. K. Kaushik, T.N. Rao and A. Subrahmanyam, "Studies on the Disorder in DC Magnetron Sputtered Cu2ZnSnS4 (CZTS) Thin Films Grown in Sulfide Plasma", Surface & Coatings Technology, Vol. 314, p 85-91, 2017.
6. V. Manikandan, A. Vanitha, E.R. Kumar and S. Kavita, "Influence of Sintering Temperature on Structural, Dielectric and Magnetic Properties of Li Substituted CuFe2O4 Nanoparticles", Journal of Magnetism and Magnetic Materials, Vol. 426, p 11-17, 2017.
7. R.Dom, H.G. Kim, and P.H. Borse, "Photo Chemical Hydrogen Generation from Orthorhombic CaFe2O4 Nanoparticles Synthesized by Different Methods", Chemistryselect, Vol. 2(8), p 2556-2564, 2017 .
8. R. Dom, L.R. Baby, H.G. Kim, and P.H. Borse, "Fe Controlled Charge-Dynamics in ZnO for Solar Hydrogen Generation", International Journal of Hydrogen Energy, Vol. 42(9), p 5758-5767, 2017.
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11. S. Kumar and A. Arjuna Rao, "Influence of Coating Defects on the Corrosion Behavior of Cold Sprayed Refractory Metals", Applied Surface Science, Vol. 396, p 760-773, 2017.
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13. N. Islavath, D. Das, S.V. Joshi and E. Ramasamy, "Seed Layer-Assisted Low Temperature Solution Growth of 3D ZnO Nanowall Architecture for Hybrid Solar Cells", Materials & Design, Vol.116, p 219-226, 2017.
14. B. Syed, S.M. Shariff, G. Padmanabham, S. Lenka, B. Bhattacharya and S. Kundu, "Influence of Laser Surface Hardened Layer on Mechanical Properties of Re-Engineered Low Carbon Steel Sheet", Materials Science and Engineering A-Structural Materials Properties Microstructure and Processing, Vol.685, p 168-177, 2017.
15. K. Zhang, S. Ravishankar, M.Ma, G. Veerappan, J. Bisquert, F. Fabregat-Santiago and J.H. Park, "Overcoming Charge Collection Limitation at Solid/Liquid Interface by a Controllable Crystal Deficient Overlayer", Advanced Energy Materials, Vol. 7(3), Article No. 1600923, 2017.
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3. K.C.Yogananda, E.Ramasamy, S.Kumar, S.V.Kumar, M.N.Rani and D.Rangappa, "Novel Rice Starch Based Aqueous Gel Electrolyte for Dye Sensitized Solar Cell Application", Materials Today-Proceedings, Vol. 4, (11), p 12238-12244, 2017.
4. B.S.Yadav, S.R.Day and Sanjay R.Dhage, "Chalcopyrite CIGS Absorber Layer by Inkjet Printing for Photovoltaic Application", Materials Today-Proceedings, Vol. 4, (14), p 12480-12483, 2017.
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6. U.Anusree, N.Rajalakshmi, and V.M.Janardhanan, "Electrochemical Modeling of HTPEM Fuel Cells using Elementary Step Kinetics", Polymer Electrolyte Fuel Cells 17 (PEFC 17)- ECS Transactions, Vol.80(8), p 57-64,2017.
7. A.Das, S. Sarkar, Malobika Karanjai and G. Sutradhar, "RSM based Study on the Influence of Sintering Temperature on MRR for Titanium Powder Metallurgy Products using Box-Behnken Design", Materials Today: Proceedings, Vol. 5(2), p 6509-6517, 2018.
8. Sanjay Bhardwaj, G.Padmanabham, Karuna Jain, R.Vijay and R.S. Johnson, "Technology Transfer from Public-funded R&D Laboratory to an Industrial Organisation in the Indian Business Environment", Proceedings of the 4th International Conference on Management of Intellectual Property Rights and Strategy (MIPS2018), Mumbai, p 30-39, 2018.
9. M.Vijaykumar, D. Sri Rohita, A.Jyothirmayi, T.N. Rao and M. Karthik, "Biomass Derived High Surface Area Activated Carbon as High Energy Storage", Proceedings of National Conference on Electric Mobility – Opportunities and Challenges NCEM, Vol. 1, p 145-149, 2018.
10. R.Gopalan,S.Harish,B.Jayachandran,B.Priyadarsani, B. Manjusha, D. Sivprahasam and G. Sundararajan, "Thermoelectric (TE) Materials with High ZT and TE Generator System Development", Proceedings of Indo-UK Workshop on Thermoelectric Materials for Waste Heat Harvesting, p 5, 2018.
11. M.Battabyal, V.Trivedi and R. Gopalan, "Enhanced Thermoelectric Properties in Ni doped CoSb3 Skutterudites Processed by Spark Plasma Sintering", Proceedings of Indo-UK Workshop on Thermoelectric Materials for Waste Heat Harvesting, p 23, 2018.
12. B.Priyadarshini, M. Battabyal, D. Sivaprahasam, A. Chandra Bose and R. Gopalan, "Investigation of Microstructure and Thermoelectric Properties of n-type Mg2Si", Proceedings of Indo-UK Workshop on Thermoelectric Materials for Waste Heat Harvesting, p 26, 2018.

Books and Book Chapters

1. A chapter on "Detonation Sprayed Coatings for Aerospace Applications" authored by D. Srinivasa Rao, L. Rama Krishna and G. Sundararajan in the book on 'Aerospace Materials and Material Technologies' – Part of Indian Institute of Metals Series book series (IIMS)., (ed.) N. Eswara Prasad and RJH Wanhill., Springer, Vol.1, p 483-500, 2017.
2. A chapter on "Nano Manufacturing for Aerospace Applications" authored by S. Anandan, Neha Hebalkar, B. V. Sarada and Tata N. Rao in the book on 'Aerospace Materials and Material Technologies' – Part of Indian Institute of Metals Series book series (IIMS)., (ed.) N. Eswara Prasad and RJH Wanhill., Springer, Vol.2, p 85-101, 2017.
3. A chapter on "Hydrogen from Water" authored by P. H. Borse in the book on 'Sustainable Utilization of Natural Resources', (ed.) P. Mondal, A.K. Dalai., Taylor & Francis Group, CRC Press USA., p 441–457,2017.
4. A chapter on "Aerogels for Energy Conservation and Saving" authored by A. Yamini, S. Keerthi and Neha Hebalkar, in the book on 'Nanotechnology for Energy Sustainability' (ed.) Baldev Raj, Marcel Van De Voorde and Yashwant Mahajan, Wiley-VCH Verlag GmbH, Germany., Published Online:2017, Vol.2. Chapter 38, by Wiley DOI: 10.1002/9783527696109.ch38
5. A chapter on "Nanomaterials for Li-Ion Batteries: Patents Landscape and Product Scenario" authored by Md. Shakeel Iqbal, C.K.Nisha, Vivek Patel and Ratnesh K. Gaur in the book on 'Nanotechnology for Energy Sustainability', (ed Baldev Raj, Marcel Van De Voorde, and Yashwant Mahajan,, Wiley-VCH Verlag GmbH, Germany., Chapter 41., Published Online: 2017, DOI: 10.1002/9783527696109.ch41

6. A chapter on "Nanotechnology in Fuel Cells: A Bibliometric Analysis" authored by M. Sinha, Ratnesh .K. Gaur and H. Karmarkar in the book on 'Nanotechnology for Energy Sustainability', (ed.) Baldev Raj, Marcel Van De Voorde, and Yashwant Mahajan,, Wiley-VCH Verlag GmbH, Germany., Chapter 42, Published Online: 2017, DOI: 10.1002/9783527696109.ch42
7. A chapter on "Techno-Commercial Opportunities of Nanotechnology in Wind Energy" authored by V. Patel and Y.R. Mahajan in the book on 'Nanotechnology for Energy Sustainability' (ed.), Baldev Raj, Marcel Van De Voorde and Yashwant Mahajan, Wiley-VCH Verlag GmbH, Germany. Chapter 43, Published Online: 2017, DOI: 10.1002/9783527696109.ch43
8. A chapter on, "Nanomaterials for the Conversion of Carbon Dioxide into Renewable Fuels and Value Added Products" authored by I. Ganesh in the book on 'Nanotechnology for Energy Sustainability' (ed.) Baldev Raj, Marcel Van De Voorde and Yashwant Mahajan,, Wiley-VCH Verlag GmbH, Germany. Chapter 44, Published Online: 2017, DOI: 10.1002/9783527696109.ch44
9. A chapter on "Research Advancements in Low-Temperature Fuel Cells" authored by N. Rajalakshmi, R. Imran Jafri and K.S. Dhathathreyan in the book on 'Electrocatalysts for Low Temperature Fuel Cells: Fundamentals and Recent Trends', (ed.) T. Maiyalagan and V. S. Saji., Wiley-VCH Verlag GmbH & Co. Germany. doi: 10.1002/9783527803873.ch2, 2017.
10. A chapter on "Pulsed Electrochemical Deposition of CuInSe2 and Cu(In,Ga)Se2 Semiconductor Thin Films" authored by M.Sreekanth, B. V. Sarada, Suhash R. Dey and S.V. Joshi, in the book on 'Semiconductors: Growth and Characterization', (ed.) Rosalinda Inguanta and Carmelo Sunseri., Techopen, ISBN no: 978-953-51-5589-8, p 109-132, 2018.
11. A chapter on "Hole Conductor Free Perovskite Solar Cells", authored by S. Maniarasu, V. Manjunath, E. Ramasamy and V. Ganapathy, in the book on 'Perovskite Photovoltaics-Basic to Advanced Concepts and Implementation'. (ed.) S.Thomas, A.Thankappan, ISBN No.: 9780128129159, Elsevier, p 289-321,2018.
12. A chapter on "Perovskite Solar Cell Architectures" authored by V. Manjunath, Ramya Krishna, S. Maniarasu, E. Ramasamy, S. Sakthivel and V. Ganapathy, in the book on 'Perovskite Photovoltaics-Basic to Advanced Concepts and Implementation', (ed.) S.Thomas, A.Thankappan,ISBN No.: 9780128129159, Elsevier, p 89-121, 2018.
13. A chapter on "Flexible Perovskite Solar Cells" authored by V. Manjunath, S. Maniarasu, V. Ganapathy and E. Ramasamy, in 'Perovskite Photovoltaics-basic to Advanced Concepts and Implementation' (d.) S.Thomas, A.Thankappan, ISBN No.: 9780128129159, Elsevier, p 341-371, 2018.
14. A chapter on "The electrochemical conversion of carbon dioxide to carbon monoxide over nanomaterial based cathodic systems: measures to take to apply this laboratory process industrially", authored by I. Ganesh in the book on 'Applications of Nanomaterials: Advances and Key Technologies in the Micro and NanoTechnologies Series', Elsevier Book, (ed) O. Samuel, S. Thomas, N. Kalarikkal, & S. Mohan, Chapter 4, Volume III, p 83-131,2018.
15. A chapter on "Corrosion and Wear Protection through Micro Arc Oxidation Coatings" in 'Aluminum and its Alloys' authored by L. Rama Krishna and G. Sundararajan in the book 'Encyclopedia of Aluminum and its Alloys', (eds.): George E. Totten, Olaf Kessler, Murat Tiryakioglu., Taylor & Francis Publishers. Chapter 25, doi:10.1201/9781351045636-140000207, 2018.
16. A chapter on "Thermal Spray Coatings: Al Alloy Protection", authored by P. Suresh Babu, D.Srinivasa Rao, L. Rama Krishna, G.Sundararajan and Aravind Agarwal in the book 'Encyclopedia of Aluminum and its Alloys', (ed.) George E. Totten, Olaf Kessler, Murat Tiryakioglu, Pubs: Taylor & Francis, Chapter 155, doi:10.1201/9781351045636-140000232, 2018.
17. A chapter on "Economical and Highly Efficient Non-Metal Counter Electrode Materials for Stable Dye-sensitized Solar Cells" authored by V. Ganapathy, E. Ramasamy, B. Gowreeswari, in the book on 'Dye-sensitized Solar Cell Mathematical Modelling, Optimization and Design'. (Ed.) S.Thomas, A.Thankappan,ISBN No.: 9780128145418, Elsevier (2018). (In Press)
18. A chapter on "Applications of Sol-Gel Coatings: Past, Present and Future" authored by R. Subasri, K.R.C. Soma Raju and K. Samba Sivudu, in the 'Hand book on Modern Coating Technologies: Applications, V4', (ed) M. Aliofkhazraei, Elsevier Publishers. (In Press)
19. A chapter on "Mechanical and Corrosion Protection Properties of Hybrid Sol-Gel Coatings on Aluminium: Effect of Plasma Surface Treatment" authored by R. Subasri in the book on 'Encyclopedia of Aluminum and its Alloys', (ed.): George E. Totten, Olaf Kessler, Murat Tiryakioglu, Taylor & Francis Publishers. ISBN-13:978-14665100807. (In Press)
20. A chapter on "Polymer Electrolyte Membrane based Electrochemical Conversion of Carbon dioxide from Aqueous Solutions" authored by P. Suresh, K. Ramya, and K. S. Dhathathreyan, in the book on 'Polymeric and Nanostructured Materials', (ed.) A.Thankappan, N.Kalarikkal, S.Thomas and A.Padinjakkara, Apple Academic Press, 2018. (In Press)

Awards and Honours

1. Aswin Bob Ignatius (Dr. R. Subasri) received the 'Best Paper Award' for the paper entitled "Effect of Shot-Peening on the Adhesion of Chitosan-Based Multifunctional Sol-Gel Coatings on SS 304", at the National Conference on Advances in Micro and Nano Electronics "NCAMNE 2017", held at PSG College of Technology, Coimbatore during 27-28 April, 2017.
2. Dr. S. Sakthivel received the 'Mother Theresa excellence Award' for his Meritorious service, outstanding performance & remarkable role in his research field at 'National Seminar on Economic Growth & National Integration' held at New Delhi, on May 27, 2017.
3. Sumit Ranjan Sahu received the "Best Session Paper" award for the paper presentation on "Synthesis of Graphene Sheets from Single-walled Carbon Nanohorns" at the In-house Symposium held at Indian Institute of Technology-Madras during 29-30 July 2017.
4. Ms. G. Sai Spandana (Dr. Joydip Joardar), received the 'Best Paper Award' for presenting a paper on "Development of 2D-nanolayered WS2 reinforced aluminum nanocomposites" at the '3rd International Conference on Recent Challenges in Engineering and Technology (ICRCET-17)' held at Tirupati during September 12-13, 2017.
5. Dr. Nitin P. Wasekar was felicitated by Indian Institute of Metals Hyderabad Chapter for EMCR Fellowship during Annual General Body Meeting held at Hyderabad September 14, 2017.
6. Dr. Manjusha Battabyal received the 'Outstanding Reviewer Recognition Award from Fusion Engineering and Design journal (Elsevier publication group) during November, 2017.
7. Dr. Srinivasan Anandan was conferred the "Outstanding Scientist Award" for his contribution and achievement in the field of Nanomaterials by Venus International Foundation during '3rd Annual Research Meet' held at Chennai on November 11, 2017.
8. Dr. Sanjay Bhardwaj received the "Bharat Vikas Award" for loyalty, diligence and outstanding performance in the field of Science and Technology based Entrepreneurship at Bhubhaneshwar on November 19, 2017.
9. Dr.N.Rajalakshmi received the "Bharat Vikas Award" for her outstanding performance in the field of Clean Energy Conversion from Institute of Self Reliance at Bhubhaneshwar on November 19, 2017.
10. P. M. Pratheeksha (Dr.S.Anandan) won the 'Best Poster Award' for the poster presentation on "Large Scale Synthesis of High Performance Zero Strain Lithium Titanate for High Energy Density Li-ion Battery Application" at the '9th Bengaluru India Nano Conference' held at Bengaluru on December 08, 2017.
11. Dr. R. Gopalan received 'National Award for Excellence in Science and Technology (2017)' from India Society of Analytical Scientists on February 08, 2018.
12. Ms. Reshma Dileep (Dr. V. Ganapathy), received the 'Best Poster Presentation' Award for the poster presentation on "Hole Conductor and Metal Cathode-Free Stable

Dr. Anandan Srinivasan receiving the 'Outstanding Scientist Award'

Ms. PM Pratheeksha receiving the 'Best Poster Award'

Sumit Ranjan Sahu receiving the 'Best Session Paper' Award

Dr. R. Gopalan receiving the ISAS Award of Excellence in S&T-2017

Perovskite Solar Cells" at the 'National Conference on Emerging Materials for Sustainable Future' held at PSG Tech, Coimbatore on February 09, 2018.

13. Ms. Shaik Mubina (Dr. B.P. Saha) received the 'Best Paper Award' for the paper presentation on "Effect of Processing Parameters on the Properties of Silicon Carbide and its Composites used for Harsh Environments" at the 'International Conference on Engineering Materials, Metallurgy & Manufacturing' held at Chennai during February 15-16, 2018
14. K. Nanaji won the 'Best Poster Award' for the poster presentation on "Graphene Sheets like Nanoporous Carbon Derived from Agricultural Bio-Waste (Jute Stick) as Electrode Material for High Performing Super Capacitors" at the 'Workshop on Battery Technologies & Electric Mobility' held at Bengaluru during March 08-09, 2018.
15. Mr. Sriram K (Dr. N. Rajalakshmi) received the 'Best Presentation Award' for the poster presentation on "Enhanced Corrosion Resistance of Pt-Modified Polyaniline coated on 316L SS as Metallic Bipolar Plates for PEM Fuel Cell Application" at the 'International Conference on 5th edition of CORSYM (International Corrosion Prevention Symposium for Research Scholars)' held at the Indian Institute of Technology (IIT) Madras, Chennai, during March 23-24, 2018.
16. Ms. R. Yogapriya (Dr.R Subasri), received the 'Best Paper Award' for paper presentation on "Investigations on the Durability of Spray Deposited Super Hydrophobic Coatings on Stainless Steel AISI 304" at the 'National Conference on VLSI Design, Communication and Nano Technologies (VDCNT18)' held at PSG College of Technology, Coimbatore during March 23-24, 2018.
17. Dr. R. Gopalan received Best Citizen of India Award from International Publishing House.
18. Dr. R. Gopalan received the 'Rashtriya Gaurav Award 2017' from India International Friendship Society.
19. Dr. T.N. Rao was elected as the "Fellow of Telangana Academy of Sciences (TAS)" in recognition of his contributions to Science & Technology for the year 2017.
20. Dr. T.N. Rao was elected as the "Fellow of Andhra Pradesh Academy of Sciences" in recognition of his contributions to Science & Technology for the year 2017.
21. Dr. Sanjay Bhardwaj was elected as the Honorary Secretary of Indian Institute of Chemical Engineers-Hyderabad Regional Centre (IIChE-HRC) and Co-Chairman of Industrial Visit Committee, IIChE-HRC for the year 2017-18.

Ms. Shaik Mubina receiving the 'Best Paper Award'

Ms. R Yogapriya receiving the 'Best Paper Award'

K. Nanaji receiving the 'Best Poster Award'

Dr. T. N. Rao being elected as the 'Fellow of Telangana Academy of Sciences'

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Mahender Peddi, Project Junior Scientist (TRC)
Bheesetti Gowreeswari, Project Junior Scientist (TRC)
V. Tarun Kumar, Project Junior Scientist (TRC)
J.A. Prithi, Project Junior Scientist (TRC)
P. Vijaya Durga, Project Junior Scientist (TRC)
G. Mohan, Project Junior Scientist (TRC)
Md. Ayub Shareef, Project Junior Scientist (TRC)
Minati Tiadi, Project Junior Scientist (TRC)
S. Ganesh, Project Junior Scientist (TRC)
Saubik Datta, Project Junior Scientist (TRC)
V. Sai Krishna, Project Technical Assistant (TRC)
R. Vasudevan, Project Technical Assistant (TRC)
N. Kannadasan, Project Technical Assistant (TRC)
Karnam Chandra, Project Technical Assistant (TRC)
Debendra Nath Kar, Project Technical Assistant (TRC)
V. Durga Mahesh, Project Technical Assistant (TRC)
Tanmoy Shee, Project Technical Assistant (TRC)
G. Uday Bhaskar, Project Technical Assistant (TRC)
Shaik Nagur Baba, Project Technical Assistant (TRC)
Priya Vikas Suresh, Project Technical Assistant (TRC)
Golu Kumar Jha, Project Technical Assistant (TRC)
Krishna Kumar Pathak, Project Technical Assistant (TRC)
K. Velmurgan, Project Technical Assistant (TRC)
U. Gowtham, Project Technical Assistant (TRC)
K. Shanmugam, Project Technical Assistant (TRC)
T.P. Sarangan, Project Technical Assistant (TRC)
A. Sivaraj, Project Technical Assistant (TRC)
D. Vigneshwaran, Project Technical Assistant (TRC)
D. Srirohita, Project Technical Assistant (TRC)
N. Ramesh, Project Technical Assistant (TRC)

TRC: Technical Research Centre on 'Alternate Energy Materials and Systems'
SPHD: Sponsored Technology Development Programme

Financial Report

ANANT RAO & MALLIK
CHARTERED ACCOUNTANTS
B-310, Kushal Towers
Khairatabad
Hyderabad - 500 004

Date: 25/09/2018

INDEPENDENT AUDITORS' REPORT

The Governing Council, **INTERNATIONAL ADVANCED RESEARCH CENTRE FOR POWDER METALLURGY & NEW MATERIALS (ARCI),** Hyderabad

REPORT ON THE FINANCIAL STATEMENTS

We have audited the accompanying financial statements of International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI) ("the Society"), which comprises the consolidated statement of affairs as at March 31, 2018, the Consolidated Income and Expenditure Account and Consolidated Receipts and Payments Account for the year then ended and a summary of Consolidated significant accounting policies and other explanatory notes and Standalone Statement of Affairs, Standalone Income and Expenditure Account, Standalone Receipts and Payments Account and Standalone significant accounting policies and other explanatory notes of the following funds :

i. Operational Fund;
ii. Technology Demonstration and Transfer (TDT) fund; and
iii. Sponsored Project Fund

Management's Responsibility for the financial Statements:

Governing Body of the Society is responsible for preparation of these financial statements of the Society in accordance with the Generally Accepted Accounting principles in India (GAAP) and the significant accounting policies stated in financial statements. This responsibility also included maintenance of adequate accounting records for safeguarding the assets of the society and for preventing and detecting frauds and other irregularities; selection and application of appropriate accounting policies; making judgments estimates that are reasonable and prudent; and design, implementation and maintenance of adequate internal financial controls, that were operating effectively for ensuring the accuracy and completeness of the accounting records, relevant to the preparation and presentation of the financial statements, that are free from the material misstatement, whether due to fraud or error.

Auditor's Responsibility:

Our responsibility is to express an opinion on these financial statements based on our audit. We conducted our examination 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 examination to obtain reasonable assurance about whether financial statements are free from material misstatements.

Examination of financial statements involves performing procedures to obtain audit evidence about the amount of 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 risks assessments, the auditor considers internal control relevant to the society's preparation and fair presentation of the financial statements in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on effectiveness 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 of the society for the year ended March 31, 2018 are prepared in all material aspects, in accordance with Generally Accepted Accounting Principles in India (GAAP) and the significant accounting policies stated in Note 24 to the Financial Statements.

Other Matters:

a) In our opinion, proper books of accounts as required by the law have been by kept the society so far as it appears from our examination of those books

b) The Statement of Affairs, the Income and Expenditure Account, and Receipts and Payments account dealt with by this report are in agreement with the books of accounts.

For **ANANT RAO & MALLIK**
Chartered Accountants
Firm's Registration No. 006266S

Sd/-
V ANANT RAO
Partner
Membership No. 022644

FORM OF FINANCIAL STATEMENTS (NON-PROFIT ORGANISATIONS)
ARC INTERNATIONAL FUND (OPERATIONAL) BALANCE SHEET AS AT 31.03.2018

(Amount in Rs.)

GRANTS-IN-AID: FUND AND LIABILITIES	SCHEDULE	CURRENT YEAR	PREVIOUS YEAR
GRANTS-IN-AID	1	1,49,95,64,860.99	1,56,43,05,484.76
RESERVES AND SURPLUS	2	2,36,06,972.81	63,04,121.14
EARMARKED/ENDOWMENT FUNDS	3	0.00	0.00
SECURED LOANS AND BORROWINGS	4	0.00	0.00
UNSECURED LOANS AND BORROWINGS	5	0.00	0.00
DEFERRED CREDIT LIABILITIES	6	0.00	0.00
CURRENT LIABILITIES AND PROVISIONS	7	27,94,62,052.63	21,19,10,004.00
TOTAL		**1,80,26,33,886.43**	**1,78,25,19,609.90**
ASSETS			
FIXED ASSETS	8	1,25,01,28,852.73	1,25,94,19,268.84
INVESTMENTS - FROM EARMARKED/ENDOWMENT FUND	9	0.00	0.00
INVESTMENTS - OTHERS	10	0.00	0.00
CURRENT ASSETS, LOANS, ADVANCES ETC.	11	55,25,05,033.20	52,31,00,340.56
MISCELLANEOUS EXPENDITURE (to the extent not written off or adjusted)		0	0
TOTAL		**1,80,26,33,886.43**	**1,78,25,19,609.90**
SIGNIFICANT ACCOUNTING POLICIES	24		
CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS	25		

Sd/-
R. Vijay Kumar
Chief Finance & Accounts Officer

Sd/-
Dr. G Padmanabham
Director

AS PER OUR REPORT OF EVEN DATE
for **M/s. ANANT RAO & MALLIK**
Chartered Accountants
Firm Registration No. 006266S

Sd/-
V Anant Rao
Partner, Membership No. 022644

Date: 25/09/2018
Place: Hyderabad

FORM OF FINANCIAL STATEMENTS (NON-PROFIT ORGANISATIONS)
INCOME AND EXPENDITURE ACCOUNT OF ARC INTERNATIONAL FUND (OPERATIONAL) FOR THE YEAR ENDED 31.03.2018

(Amount in Rs.)

	SCHEDULE		CURRENT YEAR		PREVIOUS YEAR
INCOME					
Income from Sales/Services	12		0.00		0.00
Grants/Subsidies	13		36,48,67,000.00		54,79,00,000.00
Fees/Subscriptions	14		0.00		0.00
Income from Investments (Income on Investments from earmarked/endowment funds)	15		0.00		0.00
Income from Royalty, Publications etc.	16		0.00		0.00
Interest Earned	17		2,15,28,647.00		2,39,18,545.00
Other Income	18		5,13,30,636.00		1,31,16,722.00
Increase/(decrease) in stock of finished goods and work-in-progress	19		0.00		0.00
TOTAL (A)			**43,77,26,283.00**		**58,49,35,267.00**
EXPENDITURE					
Establishment Expenses	20		37,02,63,732.03		25,00,81,534.00
Other Expenses	21		15,93,14,262.89		15,28,52,655.15
Expenditure on Grants/Subsidies	22		0.00		27,55,984.00
Interest	23		0.00		0.00
Depreciation (Net Total at the year-end: corresponding to Schedule 8)			14,06,78,911.85		13,98,71,497.41
TOTAL (B)			**67,02,56,906.77**		**54,55,61,670.56**
Balance being excess of Income over Expenditure (A-B) Transfer to Special Reserve [specify each] Transfer to/from General Reserve			-23,25,30,623.77		3,93,73,596.44
BALANCE being Excess of Expenditure over Income - Transfer to Grants-in-Aid			**-23,25,30,623.77**		**3,93,73,596.44**
SIGNIFICANT ACCOUNTING POLICIES	24				
CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS	25				

AS PER OUR REPORT OF EVEN DATE
for **M/s. ANANT RAO & MALLIK**
Chartered Accountants
Firm Registration No. 006266S
Sd/-
V Anant Rao
Partner, Membership No. 022644

Sd/-
R. Vijay Kumar
Chief Finance & Accounts Officer

Sd/-
Dr. G Padmanabham
Director

Date: 25/09/2018
Place: Hyderabad

INTERNATIONAL ADVANCED RESEARCH CENTRE FOR POWDER METALLURGY AND NEW MATERIALS (ARCI)

BALAPUR POST. HYDERABAD

ARCI (OPERATIONAL) FUND

SCHEDULE – 24 SIGNIFICANT ACCOUNTING POLICIES

1. **Basis of preparation of financial statements :**
   The financial statements of Operation Fund of International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI/Society), Hyderabad, have been prepared on historical cost convention and on accrual basis unless otherwise stated.

2. **(1) Grants:**
   (a) Grants are recognized on receipt.
   (b) Grants received from Department of Science & Technology (DST) are treated as Income.
   (c) Expenditure incurred by the Society towards operations, maintenance and depreciation have been adjusted against these grants.
   (d) Grants received from DST and earmarked for special projects by ARCI are grouped under Sponsored Project Fund.
   (2) Reserves & Surpluses:
   (a) Net Surplus / Deficit generated from Technology Demonstration & Transfer Fund (TDT Fund) are appropriated as under:
   50% Transferred to ARCI Operational Fund & Balance 50% Remains in TDT Fund

3. **Fixed Assets:**
   Fixed assets are stated at cost. Cost includes duties, taxes, freight, insurance etc, attributable to acquisition and installation of asset.

4. **Depreciation and Amortization:**
   Depreciation on fixed assets (except Lease Hold building) is provided on written down value method as per rates stated in Income Tax Rules, 1962.
   Non-Refundable advance towards Lease Hold Building is amortized over lease period.

5. **Revenue Recognition:**
   Grants are recognized on cash basis. Interest income from bank balances/deposit is recognized on accrual basis.

6. **Research and Development (R&D) Expenditure:**
   R&D expenditure including cost of raw materials, consumables, other inputs etc. is charged off as revenue expenditure. Raw materials, consumables, stores spares and other inputs are procured on need basis and issued to end users soon after they are received. Hence values of closing stock of these materials is not recognized in the accounts.

7. **Foreign Exchange Transactions:**
   Foreign exchange transactions during the year are recorded at the exchange rate prevailing on the date of transaction.

8. **Retirement Benefits:**
   Contributions to Provident Fund and New Pension Scheme (Defined Contribution Plans) are charged to income and expenditure account as per applicable rules/statutes. Provision towards gratuity and leave encashment (Defined benefit Plan) is made on actuarial valuation carried out by Life Insurance Corporation of India as stated in AS-15 (Revised) – "Accounting for Retirement Benefits". The Society has covered its gratuity and leave encashment liability with Life Insurance Corporation of India (LIC) and contributions are made to LIC on yearly basis.

9. **Margin Money Deposits:**
   Margin Money Deposits placed with Banks towards Letters of Credit issued to the A/c of ARCI are grouped under Loans and Advances–Advances Recoverable in Cash/Kind.

AS PER OUR REPORT OF EVEN DATE
for **M/s. ANANT RAO & MALLIK**
Chartered Accountants
Firm Registration No. 006266S

Sd/-
V Anant Rao
Partner, Membership No. 022644

Sd/-
R. Vijay Kumar
Chief Finance & Accounts Officer

Sd/-
Dr. G Padmanabham
Director

Date: 25/09/2018
Place: Hyderabad

INTERNATIONAL ADVANCED RESEARCH CENTRE FOR POWDER METALLURGY AND NEW MATERIALS (ARCI)

BALAPUR POST, HYDERABAD

ARCI (OPERATIONAL) FUND

SCHEDULE – 25 NOTES TO THE ACCOUNTS

1. Department of Science and Technology (DST) sanctioned and released during the year Rs. 36,48,67,000.00 towards revenue and Rs. 16,77,90,000.00 as capital grant-in-aid under Plan (Previous year Rs. 45,62,07,000.00 and Rs. 9,16,93,000.00 towards revenue and capital respectively under Plan grant-in-aid). Under Non-Plan, Grant-in-aid sanctioned was nil.

2. Advances on capital accounts (Schedule 11) include advances to Hyderabad Metro Water Supply and Sewerage Board (HMWS&SB), Rs 3, 97, 43,048.00 paid during 2007-08 and 2008-09 for supply of Krishna water inter alia to the Society. This is an advance payment to Hyderabad Metro Water Supply and Sewerage Board (HMWS&SB) and work is executed and settlement is awaited.

3. During the year, the provision for Gratuity Liability & Leave Encashment was made based on the accrued liability furnished by LIC of India.

4. The figures of previous year have been regrouped/reclassified wherever necessary.

Sd/-
R. Vijay Kumar
Chief Finance & Accounts Officer

Sd/-
Dr. G Padmanabham
Director

AS PER OUR REPORT OF EVEN DATE

for **M/s. ANANT RAO & MALLIK**
Chartered Accountants
Firm Registration No. 006266S

Sd/-
V Anant Rao
Partner, Membership No. 022644

Date: 25/09/2018
Place: Hyderabad

FORM OF FINANCIAL STATEMENTS (NON-PROFIT ORGANISATIONS)
RECEIPTS AND PAYMENT ACCOUNT OF ARC INTERNATIONAL FUND (OPERATIONAL) FOR THE YEAR ENDED 31.03.2018

(Amount in Rs.)

RECEIPTS	CURRENT YEAR	PREVIOUS YEAR	PAYMENTS	CURRENT YEAR	PREVIOUS YEAR
I. **Opening Balances**			I. **Expenses**		
a. Cash in hand	50,504.00	78,831.00	a. Establishment expenses	30,05,95,733.00	21,32,37,158.00
b. Bank Balances			b. Other expenses	15,58,09,196.39	16,04,02,157.15
i) In Current accounts	0.00	0.00			
ii) In Deposit accounts	6,50,00,000.00	0.00	**Total: Expenses**	**45,64,04,929.39**	**37,36,39,315.15**
iii) Savings accounts	62,07,895.86	62,612.51			
Total: Opening Balances	**7,12,58,399.86**	**1,41,443.51**			
II. **Grants Received**			II. **Payments made against various projects**		
a. From Government of India	53,26,57,000.00	54,79,00,000.00			
b. From State Governments	0.00	0.00	Rheological characterisation of $LiFeP0_4$ (IIT-MUMBAI)	0.00	19,80,000.00
c. From other source [details]	0.00	0.00			
d. Fund received on closed Projects	0.00	0.00			
Total: Grants Received	**53,26,57,000.00**	**54,79,00,000.00**	**Total: Payments made Against Projects**	**0.00**	**19,80,000.00**
III. **Income on Investments From**	0.00	0.00	III. **Investments and deposits made**		
a. Earmarked/Endowment Funds	0.00	0.00	a. Out of Earmarked/Endowment funds	0.00	0.00
b. Own funds (other investments)			b. Out of own funds (investments-others)	0.00	0.00
Total: Income on Investment	**0.00**	**0.00**	**Total: Investments and Deposits**	**0.00**	**0.00**
IV. **Interest Received**			IV. **Expenditure on Fixed Assets & Capital Work-in-Progress**		
a. On bank deposits	67,81,668.00	1,14,36,625.00	a. Purchase of fixed assets	12,40,08,039.00	11,01,38,538.00
b. Interest from sponsored projects	0.00	38,23,150.50	b. Expenditure on capital work-in progress	0.00	0.00
c. Loans, Advances to staff etc.	0.00	3,10,165.00			
Total: Interest Received	**67,81,668.00**	**1,55,69,940.50**	**Total: Expenditure on Fixed Assets & Capital WIP**	**12,40,08,039.00**	**11,01,38,538.00**
V. **Other Income**	1,33,65,893.00	1,18,46,250.00	V. **Refund of surplus money/loans**		
			a. To Government of India	0.00	0.00
			b. To State Government	0.00	0.00
			c. To other providers of funds	0.00	0.00
VI. **Amount Borrowed**	0.00	0.00	VI. **Finance charges (Interest)**	0.00	0.00

VII. **Any Other Receipts**			VII. **Other Payments**		
a) EMD & Security Deposits	3,09,245.00	42,10,000.00	a. Advance for Festival-Staff	66,600.00	1,23,300.00
b) Sales of Fixed Assets	0.00	39,722.00	b. Advance to Staff-HBA	14,82,400.00	0.00
c) HBA-Staff	0.00	78,619.00	c. Return of EMD & security deposits	6,30,000.00	22,94,594.00
d) Deposit Rent & others from Spppliers	0.00	14,02,719.00	d. Institutional grants	1,32,000.00	8,71,650.00
e) 7th CPC Contribution - TDT Funds	4,32,21,831.00	-	e. Deposit: Gratuity to LIC	9,20,278.00	1,69,41,856.00
f) TDT Fund contribution for Manpower Usages	1,57,294.00	15,92,756.00	f. Deposit: EL Encashment to LIC	2,74,72,773.00	99,82,484.00
			g. Advances to Delhi Cell	1,00,000.00	1,37,032.00
g) TDT Fund Contribution for Equipment Usages	8,89,739.00	41,32,994.00	i. TDS receivables	0.00	1,95,600.00
			j. Advance to Staff-Vehicle	24,000.00	1,26,343.00
h) Employees Group Insurance Scheme-LIC	58,049.00	0.00	k.Advance to Staff-Computer	2,80,970.00	2,69,915.00
i) TDS Refund	2,07,341.00	0.00	l. Deposit: Gases	10,200.00	0.00
j) Advances Others	0.00	10,43,433.00			
k) Telephone Deposit	0.00	1,150.00			
			Total : Other Payments	**3,11,19,221.00**	**3,09,42,774.00**
Total : Any Other Receipts	**4,48,43,499.00**	**1,25,01,393.00**	VIII. **Closing Balances**		
			a) Cash in hand	30,559.00	50,504.00
			b) Bank balances		
			i) In Current accounts	0.00	0.00
			ii) In Deposit accounts	0.00	6,50,00,000.00
			iii) In Savings accounts	5,73,43,711.47	62,07,895.86
			Total : Closing Balances	**5,73,74,270.47**	**7,12,58,399.86**
TOTAL	**66,89,06,459.86**	**58,79,59,027.01**	**TOTAL**	**66,89,06,459.86**	**58,79,59,027.01**

AS PER OUR REPORT OF EVEN DATE
for **M/s. ANANT RAO & MALLIK**
Chartered Accountants
Firm Registration No. 006266S

Sd/-
V Anant Rao
Partner, Membership No. 022644

Sd/-
R. Vijay Kumar
Chief Finance & Accounts Officer

Sd/-
Dr. G Padmanabham
Director

Date: 25/09/2018
Place: Hyderabad

OUR COLLABORATORS

FOREIGN

Applied Materials, USA
Advanced Mechanical Optical System
ADAMA Makhteshim Limited., Israel
Belarusian State University of Informatics and Radio Electronics
Ballard Power Systems Incorporation, USA
Corning Incorporated, USA
DesignTech Systems Limited
Deakin University, Australia
Fraunhofer Institutions, Germany
Hoganas AB, Sweden
Industrial Materials Institute of National Research Council of Canada (NRC-IMI), Canada
Institute for Problems of Materials Science (IPMS), Ukraine
International Centre for Electron Beam Technologies, Ukraine
Li-ion Technologies Limited, Russia
MPA Industrie, France
Nanomechanics, USA
REOSC, France
SLM Solutions Singapore Private Limited
The Boeing Company, USA
Toda Kogyo Corporation, Japan
Zoz GmbH, Germany

INDIAN

ABB India Limited
Advanced Surface Finishing Labs
Andhra University
Alair Coatings Private Limited
Avantek
Bharat Electronics Limited
Bharat Heavy Electricals Limited
Bhabha Atomic Research Centre
Bharat Forge Limited
Blue Fox Aerogel Development and Applications LLP
Central Scientific Instruments Organization
Central Institute of Plastics Engineering and Technology
Cyient Limited
Carborundum Universal Limited
Defense Research and Development Organization
Dover India Private Limited
DNP Global
Global Medical Education and Research Foundation
GE India Industrial Private Limited
Green Era Energy India Private Limited
Hindustan Aeronautics Limited
Hulikkal Electro (India) Private Limited
Hyderabad Eye Research Foundation
Hyderabad Electroplating Works
Indian Institute of Chemical Technology
Indian Airforce
Indian Space Research Organization
Indira Gandhi Centre for Atomic Research
Indian Institute of Technology-Bombay
Indian Institute of Technology-Madras
Indian Institute of Technology-Kanpur
Indian Institute of Technology-Kharagpur
Indian Institute of Technology-Hyderabad
Indian Oil Corporation Limited
Infinity Microsystems
JCB India Private Limited
KristalBond India Private Limited
Larsen and Toubro
LED India Private Limited
Midwest Granite Private Limited
MIC Electronics Private Limited
Mahindra and Mahindra
MVS Engineering Private Limited
National Institute of Technology-Warangal
National Institute of Technology-Thiruchirapalli
National Institute of Technology-Nagpur
National Engineering Industries Limited
Neyveli Lignite Corporation Limited
National Research and Development Corporation
Osmania University
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Roca Bathroom Products Private Limited
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Saint Gobain Ceramics and Plastics Private Limited
Sai Surface Coating Technologies
Surface Engineering and Allied Industries Private Limited
Sai Craft Limited
Silicate Glaseals
Tata Steel Limited
TVS Lucas
TVS Motor Company Limited
Tends to Infinity
University of Hyderabad
VRK Enterprises
Wipro Enterprises (P) Limited
Wissenkraft Labs Private Limited

ए आर सी आई
ARCI

EDITORIAL BOARD

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Chennai Cell
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Centre for Fuel Cell Technology
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ए आर सी आई
ARCI

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