Research Themes

ECPS@CECRI is currently working on six thematic areas as follows:

- Lead Acid Battery
- Lithium ion Battery
- Flow & Metal Air Batteries
- Sodium-ion Battery
- Lithium-Sulfur Battery
- Supercapacitors

1 Lead Acid Battery

Lead acid batteries are one of the oldest electrochemical storage systems that still find widespread applications in various avenues ranging from car batteries to grid storage. The battery chemistry is simple and straightforward, where during discharge, produces lead sulphate ($PbSO_4$) from a metallic lead (on the negative electrode (Pb)) and from lead dioxide (on the positive electrode (PbO_2)) by consuming sulphuric acid (that acts as an electrolyte). The main advantage of this battery is its low cost, 99 % effective recycling, abundance of raw material, relatively safety, low temperature performance and high specific power.However, many newer applications (like e-Rickshaw, mild hybrids and solar PV application) require lead batteries to operate at high rate and partial state of charge (PSoC) cycling condition. The main issue duringpartial state of charge operation is so called negative plate sulfation, as these operating conditions allow for an easier generation of big lead sulphate crystals. Bigger crystals have a lower surface area relatively to their volume and are more difficult to reduce during the recharge of the battery. This leads to a drop in its capacity and battery premature failure. This phenomenon happens mostly on negative plate as positive plate with relatively high specific surface area is less prone to sulfation.The role of carbon in negative plate is of prime importance especially for batteries operating under partial state of charge regime.The carbon in NAM increases the electroactive surface area of an electrode, thereby increasing the conductivity of NAM, physically restrict the growth of lead sulfate crystals, and improves the capacitance of the NAM.

The lead acid battery group is led by scientist/staff with extensive experience in the lead acid battery research/development/testing. For more than five decades, battery industries in India have depended on our group to help ensure the quality and reliability of their products and systems. Currently, we have been working on variety of Nano carbons additives (for negative plate) to suppress sulfation. Adding suitable Nano carbons reduces the formation of lead sulfate crystals, charges faster, and cycles more than the conventional lead-acid battery.

Nano Carbons studied at CSIR-CECRI for lead acid battery Negative plate

- **Zero-Dimensional Carbon Additives** – Philips Carbon Black, Cabot Carbons, Activated Carbons

- **One -Dimensional (1-D) Carbon Additives** – Multiwalled & Single walled Carbon nanotubes of varying length and diameter.

- **Two -Dimensional (2-D) Additives** – Expanded graphite, Graphene nano fibres, Graphene, Graphene nano platelets, Boron carbon nitride, Molybdenum di sulfide.

CSIR-CECRI has given know-how for more than 30 licensees all over the country in lead acid battery manufacturing technology. Many MSME lead acid batteries industries have been established and running successfully for more than two decades with CECRI know-how technology (eg. Jas Battery Calicut, AVM Batteries, Pudukottai, Gowell Industries Hyderabad, etc.). CSIR-CECRI has been an integral part towards development of high performance lead acid battery systems for electric vehicle, solar, telecom and stationary applications.

Battery testing

CSIR-CECRI has created CSIR-BPTEC (Battery Performance Testing and Evaluation Centre) which was NABL accredited in 2014 and BIS recognized in 2018, a unique facility for assisting battery industries in quality management.

NABL Scope of Accreditation

- IS 13369: 1992 (Tubular Positive)
- IS 14257: 1995 (Motor Vehicles)
- IS 1651:2013 (Tubular Positive)
- IS 7372: 1995 (Motor Vehicles)
- IS 15549: 2005 (VRLA Stationary)
- IRS 88/2004 (LM LAB Railways S&T)
- IRS - S 93/96 (VRLA Indian Railways)
- JIS C 8702-1: 2009 (Small sized VRLA)

BIS Scope of Recognition

- IS 16270:2014 - Secondary cells and batteries for solar photovoltaic application - general requirements and methods of test

We go beyond testing, inspecting and evaluating batteries; we are a ONE-STOP TOTALSERVICE PROVIDER to battery and allied industries in India. Through our state-of-the-art instrumentation and testing facilities and industry-leading technical expertise we provide a systemic approach to supporting our customers' in each of the areas of their operations including R&D, Performance Testing, Consulting & advisory services, Failure analysis, New additive evaluation, Battery resources, etc. Till now, more than 100 industries (both MSME & large scale) including TVS Motors, Kinetic engineering, Exide Industries, Livguard Batteries, MNRE, Duracell India, Microtek, RDSO, Indus Towers, Reliance Industries, etc,. have benefitted from the facility.

Career Advancement

Ph.D. Opportunity: Lead acid battery group have very intimate connection with leading industry (TVS Motors, Kinetic engineering, Exide Industries, Livguard Batteries, Duracell India, Microtek, Indus Towers, Reliance Industries and so on), institutes and universities (KAIST, UniSA, TIFR, NIT and so forth). If you are a JRF/SRF/Gate Qualified candidates and have any interest in the research related to lead acid battery and Nano carbons for lead acid batteries, feel free to contact us. As proved by our recent publications and industrial projects, we're trying to compete with world-best groups in this area.

2 Lithium ion Battery

CSIR - CECRI has been the pioneer in Li-ion battery in India since 1995 and involved in the development of electrode materials, separator, polymer electrolytes for lithium ion battery. CSIR has recently completed a mission project on the Technology and Products with Sun Utilization Network (TAPSUN)under National Solar Mission Programme. CSIR - CECRI spearheaded the Store Solar theme under this mission project by networking with NPL, CGCRI, IICT, NCL and CMERI. The project has generated not only global IPR's in Li-ion battery technology but has also successfully installed India's first pilot manufacturing plant for Li-ion cell configurations viz., 18650 and prismatic competing with global benchmark.

CSIR-CECRI has successfully demonstrated the targeted prototypes with contributions from CSIR-CECRI (new cathode material, WO2012052810A1; EP 2630686; US 2014/0087257 A1; JP5707499; JP5765644), CSIR-NPL (new carbon paper, US2014/0087257A1,US2015/0364750 A1), CSIR-CGCRI (new separator, patented) and CSIR-IICT (liquid electrolytes, to be patented) which are under various stages of validation and field trials. The advanced development stage merits to be taken forward in this direction and need a facility creation for safety testing. Based on the Technology developed by CECRI, 18650/ pouch type cells have been fabricated and demonstrated in various applications like Solar Lantern, Power Bank, LED Flash lights etc. Recently, CSIR-CECRI has also demonstrated E-Cycle powered by Li-Ion battery pack of 18650 cells and E-Scooter by Li-Ion battery pack of prismatic cells (48 V/ 15 Ah). Furthermore, CSIR-CECRI has been actively involved in sponsored research projects funded by viz., DST, MNRE, Indo-French centre, Royal Society, UK, Japan Science and Technology, Tokyo, Godfrey Phillips, IOCL, Faridabad, Tata Chemicals etc., and also carry out Battery performance testing and safety testing of lithium ion batteries for several Industrial clients.

Presently, CSIR-CECRI is involved in a CSIR funded mission mode Project CSIR Innovation Centre for Next Generation Energy Storage Solutions (ICeNGESS) to set up 100 MWh Lithium ion Battery manufacturing plant.

3. Lithium Sulfur Batteries

The lithium–sulfur (Li–S) battery system has been identified as a potential alternative to the state-of-the-art lithium-ion batteries owing to its high theoretical energy density of 2600 Wh kg-1 and theoretical capacity of 1672 mAh g^{-1}. The abundance of elemental sulfur, low cost, and environmental benignity also identify this as a futuristic system for the applications in hybrid electric vehicles and stationary energy storage systems. Despite these advantages, the efficient utilization of Li–S batteries is yet to be realized due to several challenges including the poor electronic conductivity of sulfur (5×10^{-27} S cm^{-1} at 30 °C) and rapid deterioration of the lithium anode surface due to repeated deposition and stripping, as well as the formation and subsequent shuttling of polysulfides between electrodes.

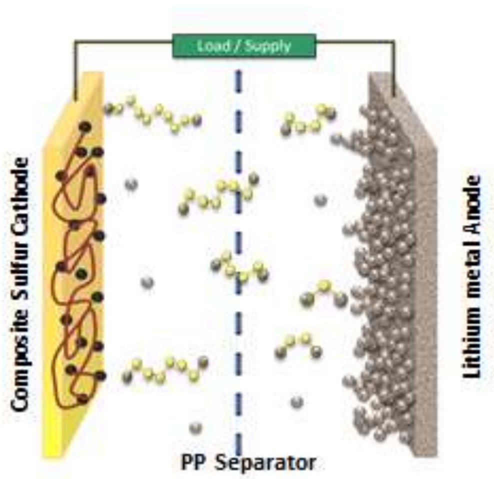

Figure 1 Architecture of a typical Lithium Sulfur Cell

Presently, CSIR- CECRI has been involved in the development of alternative anode materials (SiO_2/S/C) for lithium sulfur batteries and optimization of non-aqueous liquid electrolytes with different additives. CSIR-CECRI has also developed permselective membranes capable of retaining open circuit voltage for more than 240 hours and lithium sulfur pouch cells (2.1 V 800 mAh g^{-1} for 100 cycles)

4 Sodium- ion Batteries

Sodium ion batteries (NIBs) are operable at ambient temperature, consists of two sodium insertion materials, positive and negative electrodes, which are electronically separated by electrolyte (in general, electrolyte salts dissolved in aprotic polar solvents) as a pure ionic conductor as shown in Figure 2. The battery performance depends on battery components selected, and many different NIBs for different purposes can be assembled.

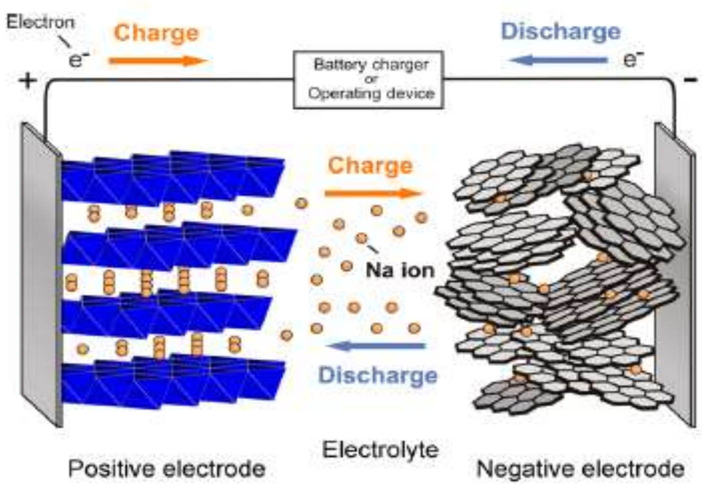

Figure 2 The working principle of a typical sodium-ion battery Adopted from: Chemical Reviews 114 (2014) 11636

The advantages of sodium-ion batteries are (i) low cost (ii) abundance of sodium on earth's crust however the bottlenecks such as high ionic radius of sodium ion and low mobility still hamper this system from commercialization. CSIR-CECRI is involved in the development of high performing cathode and anode materials for sodium ion batteries. CSIR-CECRI has already developed 1Ah sodium-ion batteries with 600 cycles for portable electronic devices.

5. Flow and Metal Air Battery

India has very high solar installation and wind energy possibly for generation of electricity in bulk. However, there are no viable, cheaper and proper storage systems available in the country. Redox flow batteries (RFB) are most appealing electrical energy storage systems for the utilization of renewable energies like solar and wind due to their high energy efficiency, deep discharge ability, low self-discharge and long cycle life. A unique advantage of RFB is the decoupling of energy capacity and power density which is not possible with the other existing conventional batteries such as lead acid, nickel cadmium, Li-ion batteries. Energy density of RFBs can be altered by tuning the concentration and volume of the electrolytes, while power density is related to the number of cell stacks. RFB utilizes circulation of electrolytes stored in external reservoirs/tanks into battery cell stack which consists of a serious of bipolar electrodes and separators (Fig.1). Based on the redox couple utilized for energy storage, RFBs are referred as iron−chromium, all-vanadium, bromine polysulfide, zinc halides and organic redox flow batteries.

Despite these advantages and favourable features, commercialization of RFB has impeded due to (i) poor kinetic reversibility, (ii) self discharge associated with electrolytes crossover to counter comportment, (iii) solubility of active species and (iv) short circuit happening due to metal dendrites. With these challenges in the RFBs, CSIR-CECRI focuses on the development of high performance and environmentally benign RFBs systems. CECRI's efforts are centred on low cost electrode materials/separators, improving the cell performance by reducing ion crossover and light weight electrode fabrication to increase the energy density.

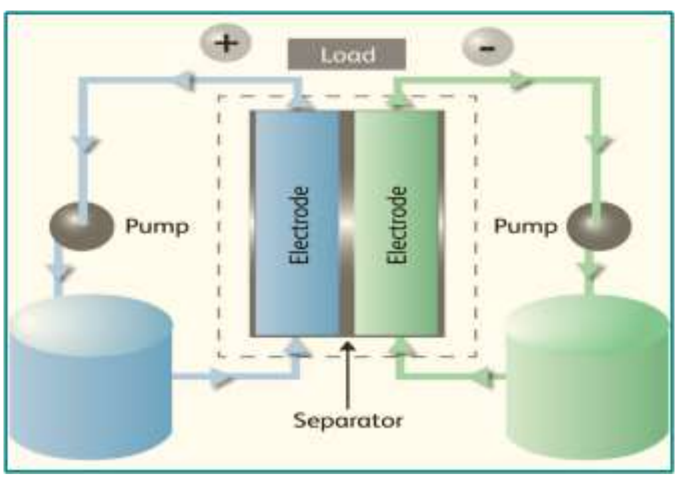

Fig.1 Schematic representation of RFB.

Metal halides (Fig. 2), all vanadiumand metal-metal hybrid redox flow systems (Fig.3) are the prime focus at CSIR-CECRI.

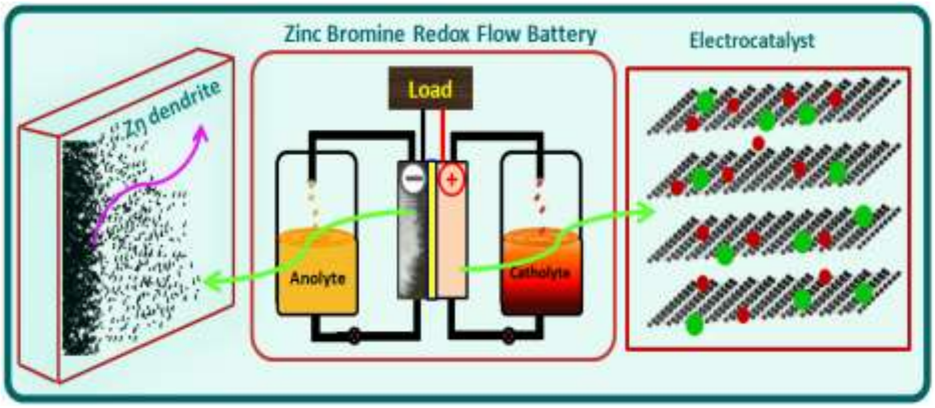

Fig. 2 Metal halides ($ZnBr_2$) redox flow battery

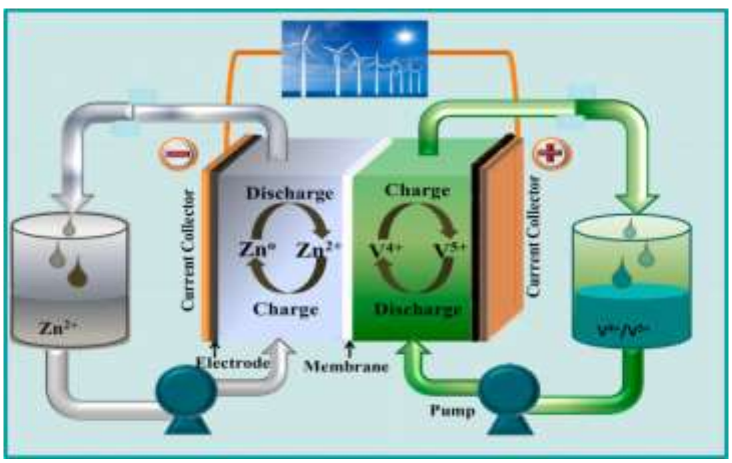

Fig. 3 Metal-Metal hybrid redox flow battery

Metal air batteries

Metal air batteries (MABs) are received significant interest for the fact that the energy density of air batteries is few times higher than the state of art Li-ion batteries. They are established on the basis of the pairing of metal anodes and oxygen-air cathodes. Compared to other batteries, especially Lithium-ion batteries, which currently dominate the market share, MABs are cheap, because the cathode source (oxygen from air) is abundant and the anode can be made using low-cost metals, such as, Al, Zn, F. To date, several metal−air batteries using alkali metals (Li, Na, and K), alkaline earth metal (Mg), and first-row transition metals (Fe, Zn) or Al as the anode have been reported.

Rational material design of the air electrode, metal electrode, electrolyte, and separator is highly desired to address various challenges associated with air batteries. In this regard, CSIR- CECRI has been involved in the development of metal air batteries with special emphasis on electro catalysts, air cathodes and separators.

Advantages

1. High energy density (few fold higher than lithium-ion batteries)
2. Abundance of elementals (various metals) on earth's crust
3. Low cost and environmental friendly

Challenges

1. The major issues with the air batteries are the lack of efficient electro catalysts and air cathodes both for the oxygen reduction reaction (ORR) and oxygen evolution reaction (OER).
2. The challenges are to keep the electrolyte and metal from the attack of H_2O and CO_2 from the ambient air, the safety concerns etc.,
3. In addition, the high reactivity of the superoxide ions formed during discharge causes a severe degradation of the electrolyte and metal dendrites growth.

On going

1. Exploration of various oxygen electrocatalysts (transition metal oxides, perovskites, carboneous materials etc., for air batteries.
2. Development and demonstration of zinc and Li-air batteries.

6. Super capacitors

The energy storage from renewable energy sources receives paramount importance in meeting the ever increasing energy demands. In this direction, recent research approaches focus on enhancing the efficiency of energy conversion and storage devices like solar cells, fuel cells, batteries and supercapacitors. Among the energy storage devices, supercapacitors are emerging due to their high power density that is essential for applications in electric vehicles, heavy electric vehicles and for sustainable energy storage. Electrochemical capacitors or supercapacitors exhibit a high power density when compared to other energy storage devices. However, their poor energy density limits their potential applications in electric and hybrid electric vehicles. The energy density of supercapacitors mainly depends on the nature of the electrode materials and electrolyte used. The electrode materials need to possess a high surface area with good conductivity and the combination of composite electrode materials can increase the energy density by having contributions from pseudocapacitance and electrochemical double layer capacitance. In addition, the use of battery-type electrode materials with supercapacitor electrodes in asymmetric configuration enhances the energy density significantly. Thus, fabrication of hybrid device by suitable combination of battery (Li-ion or Lead acid-battery) and supercapacitor will serve the high energy and power demands with increased life of battery. Eventually, electric vehicle and applications with high power requirements will be benefitted due to the significant cost reduction and increased life time of the product. Fast charging and long life for electric vehicle and safe high power operation could be realized. Thus, fabrication of high energy supercapacitor device using indigenous electrode materials and fabrication technologies is highly warranted.

It is challenging to increase the energy density of the supercapacitors without compromising the power density. Enormous efforts are being made globally to resolve the issues in increasing the energy density and performance of the supercapacitors. In CSIR-CECRI, R&D activities are being carried out both at fundamental and application levels to establish supercapacitor as a viable energy storage device. At present, we have demonstrated the fabrication of 18 F symmetric supercapacitor with an operating voltage of 2.2 V at lab level using bio-derived carbon materials. Similarly, an asymmetric supercapacitor with energy density of 30 mWh and 9.6 V has been successfully fabricated using bio-derived carbon and Ni(OH)2 electrodes. Research on exploration of high energy density electrode materials, fabrication of supercapacitor devices using indigenous electrode materials and integration of supercapacitors with other energy storage devices are under progress.