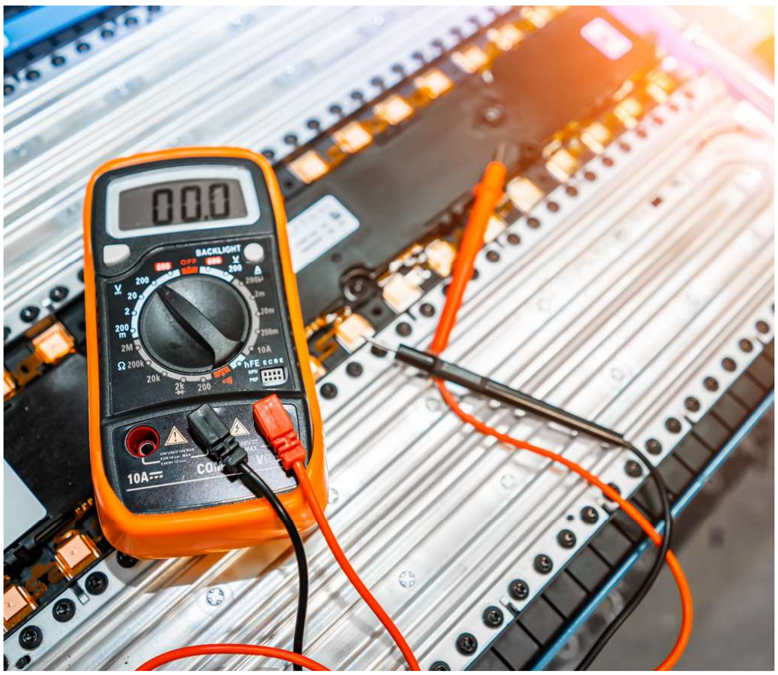
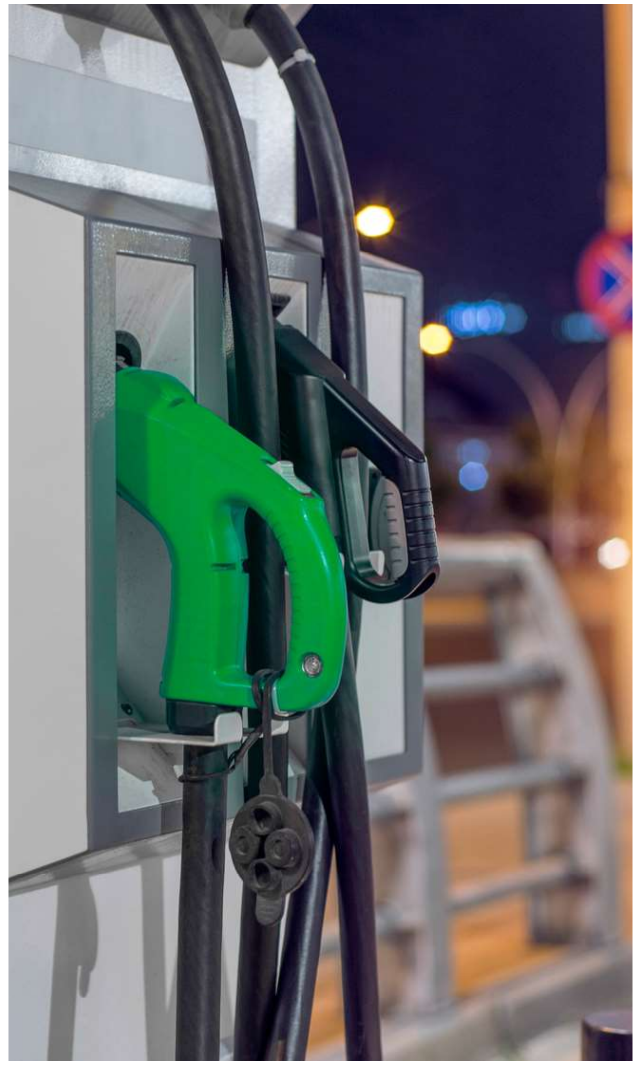
Lithium-ion Battery Chemistry

THE FRONT RUNNER

For Electric Vehicles





When it comes to powering electric vehicles (EVs), lithium-ion batteries (LIBs) are the front runners globally. They offer higher specific energy (energy stored per unit mass) and longer lifetimes compared to other battery technologies available on the market. The storage demand for the EV sector in India is expected to reach 900–2,300 GWh (for two-wheelers, four-wheelers, and buses) by 2030—considering a 30% EV penetration. It is thus essential to understand the existing and emerging LIB technologies available today, especially considering the Government of India's (GoI's) Make in India initiative.

CHARACTERISTICS OF BATTERIES MANUFACTURED IN INDIA

For battery modules, the important characteristics are cost, safety, cell voltage, specific energy, lifetime, material availability, and recycling capability. Presently, the cost of different battery chemistries used in EVs is in the range of 200–800 USD/kWh. However, it is expected to drop 54%–61% by 2030 because of economies of scale.

Safety is another crucial parameter. Cobalt-free batteries are safe as they are less prone to fire.

High cell voltages reduce the number of batteries to be connected together in a module, which in turn reduces the weight and cost of batteries. In addition, batteries should have high specific energy as this would reduce their weight.

The lifetime of a battery is measured in cycle life and shelf life (when the battery is unused). One full recharge and one full discharge constitute one cycle. High cycle life is desirable as it minimizes battery replacements. India depends heavily on the import of raw materials (e.g., lithium, nickel, and cobalt) for battery manufacturing. Assuring raw material security and reducing the use of critical materials in battery chemistries are key parameters of material availability.

The use of recyclable batteries and recovered battery components should be encouraged in the EV sector as retired batteries would otherwise end up in landfills and damage the environment.

EXISTING LIB CHEMISTRIES

Some of the commercially available LIB chemistries suitable for EV applications are as follows:

- Lithium manganese oxide: It utilises manganese-based cathodes to produce cost-competitive and safe batteries but has low lifetime.
- Lithium iron phosphate (LFP): It is safe and cheap, has a long lifetime, and does not contain critical materials such as nickel or cobalt.
- Lithium nickel manganese cobalt oxide (NMC): It has high cycle life and gives high performance. Hence, EV manufacturers prefer to use this chemistry.
- Lithium nickel cobalt aluminium oxide: It has high specific energy, cycle life, and shelf life.
- Lithium titanium oxide (LTO): It uses lithium-based cathodes and LTO-based anodes. It is fast-charging compatible and safe, and has the highest cycle life (around 20,000 cycles) among all the chemistries. However, LTO-based batteries are expensive because of the high concentration of lithium in them.

EMERGING LIB VARIANTS

To enhance the performance of the state-of-the-art LIB variants, extensive research and development (R&D) activities are being conducted across the world. While promising technologies such as lithium–sulphur (LiS), solid-state lithium, lithium–metal, lithium–air, and thin-film lithium are at various stages of development, some R&D challenges persist. For example, the clustering of sulphide atoms over time is a concern with the LiS technology, resulting in efficiency reduction and usable lifetime. In solid-state LIBs, premature failure after cycling is a major issue. It is caused by dendrites—branched out lithium networks that grow through a solid ceramic electrolyte when a battery is charged, triggering a short circuit—and void formation between the lithium anode and solid electrolyte when the battery is discharged, leading to a shortened area of contact between the two parts of the battery cell.

THE WAY FORWARD

High specific energy, long cycle life, low cost, low weight, and safe operation are desirable battery characteristics for EV applications. Therefore, under the Make in India initiative, battery chemistries such as LFP and NMC should be given priority. Developing these battery technologies would enable the GoI to effectively manage the shortage of critical materials such as cobalt and nickel as LFP does not require these materials. While NMC battery systems have lower costs, LFP batteries offer the best safety features. The GoI should also incentivise the development and commercialisation of LiS among the emerging battery technologies through academia–industry partnerships because of its high cell voltage and energy density. In addition, the GoI should support R&D in next-generation LIB variants through multinational agreements and encourage recycling techniques to recover critical materials such as lithium, cobalt, and nickel.

For more details kindly refer to our technical brief: https://cstep.in/publications-details.php?id=1254

AUTHORS:

DR AMMU SUSANNA JACOB

Senior Research Engineer, Center for Study of Science, Technology and Policy (CSTEP)

DR ANJALI SINGH

Research Scientist, Center for Study of Science, Technology and Policy (CSTEP)