Rechargeable lithium-ion (Li-ion) batteries have advanced considerably since their introduction in the early 1990s and are now an integral part of the portable electronics industry. Li-ion batteries (LIBs) are key components of a variety of electronic devices including mobile phones, laptop and tablet computers, and personal gaming and music devices. These batteries are particularly well-suited for mobile applications due to long lifetimes and high power densities (W/kg), which result in compact, light-weight batteries.

Basic principles and conventional materials

Li-ion batteries, like other batteries, are constructed from three primary materials: two electrodes (anode and cathode) and a conductive electrolyte. In the case of Li-ion batteries (Figure 1), monovalent lithium cations migrate to the negative electrode (anode) during charging cycles and to the positive electrode (cathode) during discharge cycles.\(^1\)\(^2\)

![Figure 1. Schematic representation of a typical Li-ion battery.](image)

Conventional cathode materials generally fall under two structure types. Materials like LiCoO\(_2\), adopt a layered, rhombohedral structure with two dimensional Li\(^+\) diffusion parallel to the planar sheets of metal cations. Other materials, such as LiMn\(_2\)O\(_4\), adopt the spinel structure and allow Li\(^+\) diffusion in three dimensions.\(^3\) LiCoO\(_2\) and mixed metal analogs (Ni- and Al-substitutions) are currently the most widely used cathode materials because of superior properties and well-studied behaviors. Mn-based spinels have slightly decreased performances relative to LiCoO\(_2\) but are less expensive to produce, finding applications in niche markets with large-scale battery use. LIB anodes are typically fabricated from carbonaceous materials. Common electrolyte materials include LiBF\(_4\) and LiPF\(_6\).\(^4\)

Materials for Next Generation Li-ion Batteries
Judicious selection of cathode and anode materials allows for cell optimization, making the pursuit of new materials with superior properties a paramount issue for LIB research. Promising cathode materials include mixed metal oxides, such as LiMn$_{1.5}$Ni$_{0.5}$O$_4$, and metal phosphates, such as LiCoPO$_4$. Oxides such as Li$_4$Ti$_5$O$_{12}$ and SnO$_2$ are also of interest as alternative anode materials.

In conjunction with exploratory synthetic work identifying new LIB materials, much effort has been devoted toward developing new methods of device fabrication. One of the recent advances in Li-ion technology is the fabrication of battery components from nanoscale or sub-micron scale powders, such as LiMn$_2$O$_4$ and LiCoPO$_4$. Sub-micron LIB materials display several interesting properties owing to their high surface-to-volume ratios and large surface areas. Two distinct advantages are observed in this case:

1. higher areas of contact at the electrode-electrolyte interfaces and
2. decreased diffusion distances for Li$^+$ migration from the center of the grain (particle) to the grain boundary. From a mechanical standpoint, fine-grain composites may also yield superior fatigue resistance, tolerating a higher amount of induced strain from volumetric changes during charge/discharge cycles.

References


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