

Development of materials for lithium batteries

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Batteries are a key technology in today's society. They are used to power electric and hybrid electric vehicles and to store wind and solar energy in smart grids. Since the "lithium-ion" configuration using intercalation reaction has been widely accepted, significant efforts have been devoted to attain high energy and power densities to produce an excellent energy storage system without any safety issue. In the presentation, several topics on our recent battery research will be shown. (i) To improve the power characteristics, deep insights into the interfacial reactions are necessary. (ii) To improve the safety issue of battery technology, all solid-state from is the most favorable. Materials aspects of these subjects are reviewed and future direction of the batteries will be discussed.

Intercalation reactions are chemical reactions in which guest ions are inserted in and extracted from gaps in a host lattice without significantly modifying the lattice itself. They form the basis of lithium battery operation, which is driven by electrochemical reactions. Although there are minimal changes to the lattice during intercalation, restructuring of the lattice is often accompanied by a phase transition, which is one of the factors that determine the kinetics and reversibility of lithium batteries. Structural studies of intercalation materials provide valuable information for developing lithium batteries.

However, little is known about the electrochemical reaction at the electrode surface.

Although electrochemical and spectroscopic studies have emphasized the importance of surface reactions on the power and calendar-life characteristics, the surface reaction mechanism still remains unclear. In particular, no experimental techniques have been developed for detecting the surface structure during battery operation.

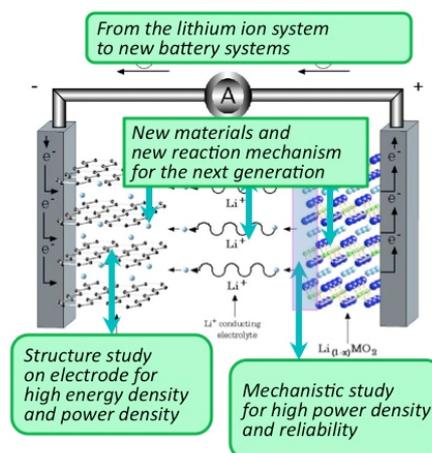


Fig. 1 Research issues for advanced batteries.

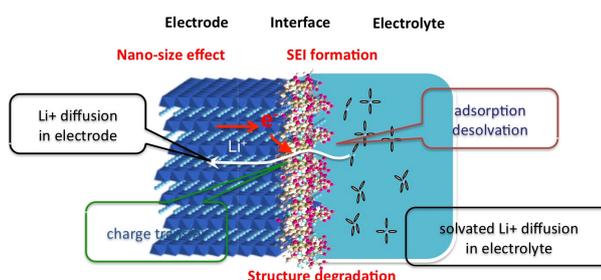


Fig. 2 Electrode reaction in batteries.

Gaining a thorough understanding of the reactions on the electrode surfaces of lithium batteries is critical for designing new electrode materials suitable for high-power, safe, long-life operation.

A technique for directly observing surface structural changes has been developed that employs an epitaxial thin-film model electrode and surface X-ray and neutron scattering techniques[1-3]. In situ scattering studies have revealed dynamic structural changes at the electrode surface during the electrochemical reaction. The surface structural changes commence with the formation of an electrical double layer, which is followed by surface reconstruction in the charge-discharge process. Surface reaction, nano-effect of the electrode reaction, and degradation mechanism of battery reaction will be discussed.

Batteries of an all solid-state provide reliability and stability for lithium batteries. Lithium superionic conductors, which can be used as solid electrolytes, promise the potential to replace organic liquid electrolytes and thereby improve the safety of next-generation high-energy batteries. Although the advantages of nonflammable solid electrolytes are widely acknowledged, their low ionic conductivities and low chemical and electrochemical stabilities prevent them being used in practical applications. In an effort to overcome these problems, there has been an ongoing search over the past few decades for new materials for solid electrolytes. The great demand for batteries with high power and energy densities promotes the need for solid electrolytes. The present study also shows the material development of lithium solid electrolyte and its application to all solid-state batteries[4].

References

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