Chapter

Introductory Chapter: Lithium-Ion Batteries - Thin Film for Energy Materials and Devices

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1. Thin film lithium-ion battery

In 2019, the Nobel Prize in Chemistry has been awarded to John B. Goodenough, M. Stanley Whittingham, and Akira Yoshino for their research in improving battery technology. It is the invention of lithium-ion battery (LIB). The energy density of LIB with high discharge voltage (3.6 V) is nearly twice that of Ni-Cd batteries, and excellent cycle life and higher level of intrinsic safety have been demonstrated. The LIB has revolutionized our lives and is widespread from small-scale devices such as mobile phone to emergency distributed power supply, electric vehicle, etc. Lithium-ion batteries are evolving even now. Many current types of research for LIB focus on life extension, energy density, safety, cost reduction, and charging speed.

Thin film LIB is one of the forms of LIB. It has attracted much interest for use as power sources of smart cards, implantable medical devices, micro-sensors, and so on. The thin film LIB is composed of the anode, cathode, and electrolyte with thicknesses on the order of microns. As the demands for safety, higher energy density, and other performance metrics increase, research into anode, cathode, and electrolyte materials has been rapidly progressing. Cathode materials are often mixed metal oxides involving lithium ion such as $LiCoO_2$ and $LiMn_2O_4$. Anode materials are lithium metal, carbon-based materials, and inorganic compounds. Both the cathode and anode materials are film, chosen for their ability to intercalate, and de-intercalate lithium ion while maintaining their structural integrity. The current research of electrolyte, whose form is preferable to be solid in thin film batteries, trends toward ceramics such as lithium lanthanum zinc oxide (LLZO) and lithium lanthanum titanium oxide (LLTO). The optimal electrolyte should be an efficient ion-conductor and a good electrical insulator allowing the battery to operate safely. The optimal combination of these materials can yield a battery that is light, thin, long-lasting, and safe.

2. The structure of this book

This book includes four categories: (1) method for thin film fabrication, (2) cathode, (3) anode, and (4) solid electrolyte, written by world authorities in these fields. The chapter of "Methods of Fabricating Thin Films for Energy Materials and Devices" describes the overview of the methodology for thin film fabrication. Thin film fabrication techniques can be categorized into two procedures representing dry and wet processes. Methods such as magnetron sputtering, pulsed laser, and chemical vapor deposition have been found to be capable of forming thin films of good quality and are well established across the coatings' industry. Alternative fabrication procedures such as the molecular precursor, electrospray deposition, and sol-gel method have been devised to ensure the thin film fabrication at a low cost with no complicated equipment.

Chapters 3 and 4 are related to cathode materials. The chapter 3 "Cathode Electronic Structure Impact on Lithium and Sodium Batteries Parameters "is based on her own investigations of A_xMO_2 cathode materials (A=Li, Na; M=3d) and demonstrates that the electronic structure of these materials plays an important role in the electrochemical intercalation process. The proposed electronic model of intercalation is universal and has outstanding significance with regard to tailoring the properties of electrode materials to the most efficient application in Li-ion and Na-ion batteries. The chapter reveals several correlations between electronic structure, transportation of cations, and electrochemical properties of layered Li_xCoO_2, $Li_xNi_{1-y-z}Co_yMn_zO_2$, and Na_xCoO_2 cathode materials and explains the apparently different character of the discharge/charge curve in Li_xCoO_2 and Na_xCoO_2 systems. Chapter 4 "Cathode for thin film lithium-ion batteries" describes an overview of cathode materials including lithium-containing cathode for LIB, in terms of specific capacity, energy density, working voltage, cycling life, and safety. Furthermore, some modification strategies for these cathode materials are also discussed for improving electrochemical performance. Of course, the thin film Li-ion battery applications of these cathode materials are summed up toward next-generation flexible and high-energy devices.

Chapters 5 and 6 are written regarding anode materials. The chapter 5 "Flexible Porous Carbon Nanotube Films Intercalated with Active and Functional Materials for Lithium-ion Batteries" focuses on several new carbon nanotube films for improving and enhancing the energy/power density and cyclic performance of LIB. Meanwhile, different carbon nanotube films have their own additional advantages in conductivity, strength, toughness, or thermal conductivity to meet various functional requirements of LIB. The chapter 6 "TiO_2 Nanoparticles Prepared by Sol-Gel Method for Anode Application in Lithium-Ion Batteries" describes TiO_2 electrochemical performances as anode material in LIB, which are investigated by cyclic voltammetry, galvanostatic cycles, and rate capability measurements.

The chapter 7 focuses on the solid-electrolyte interface between anode materials. The chapter 7 "Surface Chemical Analysis of Solid-electrolyte Interphase Layer on Germanium Thin Films and the Effect of Vinylene Carbonate as Electrolyte Additive" focuses on germanium thin-film anodes for LIB applications. As part of this chapter, they review briefly the use of germanium thin-films in LIB and, subsequently, new results pertaining to the effect of vinylene carbonate (VC) as electrolyte additive on the electrochemical performance are presented.

3. Conclusion

The worldwide demand for energy requires that various improved technologies for sustainable production, conversion, and storage of energy are developed. Energy materials as well as their assembled devices are urgently demanded, which are the key and foundation to realize the new energy. The reconstruction and collaboration among various disciplines of energy materials based on physics, chemistry, materials, mechatronics, and electricity are necessary to create novel thin film devices. We sincerely hope this book, which aims to develop and create innovative thin film energy devices, will be useful for the development of next-generation energy devices.

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