Preface

This decade has witnessed rapid development in the global quest for clean, sustainable energy and an outburst in new technologies, such as smart phones and electric vehicles. These developments have stimulated intense research interest in advanced electrical energy storage systems. Every market analysis continues to predict that advanced batteries, most notably lithium-ion batteries, and supercapacitors (also known as ultracapacitors) will dominate electrical energy storage technologies for a plethora of applications, ranging from portable electronics to next-generation environmentally friendly technologies such as electric vehicles and smart grids. Batteries and supercapacitors are complementary electrochemical energy storage systems; the former are characterized by high-energy density, while the latter are known for high-power density. Supercapacitors are most suited for applications that require energy pulses during short periods of time, such as in emergency doors, escalators, regenerative braking energy recovery systems in vehicles and metro-rails, and "stop-start" applications in modern cars. In addition to their applications in electric vehicles and portable electronics, batteries and supercapacitors are proving extremely useful in utility-scale energy storage, offering services such as: (i) price arbitrage (i.e., storing 'cheap' electricity during the off-peak periods when the cost of electricity generation is usually low and using it during the expensive peak times), (ii) industrial peak-shaving or demand charge reduction (i.e., using stored energy during peak periods in order to avoid penalties for breach of contractual peak demand), (iii) balancing power or frequency regulation (i.e., compensating for excess electricity generation and utilization from the grid), (iv) island and off-grid storage (i.e., to augment the electricity generated from the variable renewable energy sources such as solar and wind), (v) transmission and distribution (T&D) upgrade deferral (i.e., in a situation where the existing grid's capacity is barely enough to meet the required peak demand in a given area or to store the peak power supply from distributed variable renewable energy sources), (vi) voltage control/support (i.e., mainly to improve power quality and local grid congestion), and (vii) security of electricity supply (i.e., mainly as power backup or to avoid the socioeconomic problems arising from load shedding).

Despite the growing interests in research and technological applications of batteries and supercapacitors, these energy storage systems still fall short of some critical requirements, such as energy density, power density, cycle life, and safety. Nanostructuring or nanoscale engineering of electrode materials has emerged as one of the most elegant research and development strategies to improve the performance of batteries and supercapacitors and revolutionize their applications.

Nanomaterials in Advanced Batteries and Supercapacitors is unique in that it provides an authoritative source of information on the use of nanomaterials to enhance the electrochemical performance of existing electrode materials for lithium-ion batteries, magnesium-ion batteries, and supercapacitors. The book covers the state-of-the-art design, preparation, and engineering of nanoscale functional materials as effective electrodes for advanced batteries and supercapacitors, as well as perspectives and challenges in future research. Contributing authors are world experts in the field and carefully chosen to ensure an in-depth coverage of the various topics related to advanced battery and supercapacitor systems. The 15 chapters cover the critical components of the energy storage systems that are the cathode, anode and separators.

Chapters 1 and 2 describe the developments in nanostructured cathode materials for the development of high-performance lithium-ion batteries (LIBs). Chapter 1 deals with the three most important structures (spinel, layered, and olivines), while Chap. 2 focuses on the manganese-based orthosilicates.

Chapters 3, 4, and 5 describe the developments in nanostructured anode materials for LIBs, ranging from metal oxides and lithium alloys to the titanates.

Chapter 6 is the only chapter dedicated to magnesium batteries, which is an excellent example of the emerging multivalent battery systems. The interest in magnesium electrochemistry is due to its ability to deliver much higher volumetric energy density (3833 mAh cm^{-3}) than Li (2061 mAh cm^{-3}). A high volumetric energy density is more desirable for mobile devices than for stationary energy storage.

Chapters 7, 8, 9, 10, and 11 deal with various aspects of supercapacitor electrode systems, including metal oxides (notably the low-cost manganese oxides), carbon nanostructures, and suspension electrodes for flowable large-scale energy storage.

Chapters 12 and 13 discuss separators and solid polymer electrolytes used in LIBs and supercapacitors.

Chapters 14 and 15 focus on the computational/mathematical modeling and simulation of electrode materials as essential value additions to LIBs and supercapacitors, enriching our understanding of the energetics, reaction mechanism of electrode processes, and providing useful insights critical to achieving science-based rational design of better electrode materials.

Enlarging on the theme of electrochemical energy, this book has a companion volume organized by the same editors entitled *Fuel Cell Catalysis Based on Engineered Nanomaterials*. We sincerely thank the authors and reviewers, without whose support these books would have been impossible. We hope that the readers will be greatly enriched by the contents of this work. Enjoy reading!

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