

Preface I: Introduction

This book covers selected topics in lithium-ion batteries science and technology viewed from a perspective of scientists and engineers who work in an industrial setting. The primary intent of this work was to discuss the current technology, the most pressing challenges, and the potential future developments in an unassuming yet thorough manner. Considering the large volume of publications dedicated to the energy storage in general and lithium-ion batteries in particular, our aim was to provide a “companion” publication that would discuss selected inter-disciplinary aspects of the Li-ion materials and engineering. Modern battery science and engineering often draw inspiration from other science and technology fields, such as physical chemistry, crystallography, electronics, etc. Frequently, the terms and definitions associated with these fields become carried over with an assumption of prior knowledge. Several of these concepts were explained in this publication and/or the sources were given for a more comprehensive reading, as desired by the reader.

Chapter 1 of this book discusses several main cell components: cathodes, anodes, electrolyte solutions, and separators. Typically, the commonly used syntheses methods of these materials are discussed, along with their principal properties and the requirements for successful implementation in high-end cells. The chapter concludes with the forecast of future directions in cell materials’ development.

Chapter 2 tackles fundamental aspects of electrochemistry of lithium-ion materials and their relationship with the materials’ properties. There is a strong connection between the fundamental electrochemical and physico-chemical properties of materials and the real-life behavior of battery materials. The chapter includes theoretical reasoning as well as the related practical examples.

Chapter 3 discusses optimizing lithium-ion cell materials for various high-end cell designs as well as the particular designs’ limitations. Lithium-ion cell components that were individually discussed in the first chapter are considered here as part of the complex system. The relationships between various cell components are illustrated using examples of several successful optimization efforts.

Several high-end lithium-ion applications and the related product requirements are examined in Chap. 4. The high-end batteries are contrasted with their selected

mass-produced counterparts. The applications are organized by the environment in which they are used (land, aerospace, space, and sea) with special mention given to the Li-ion batteries for implantable medical devices.

Chapter 5 examines common safety issues commonly encountered in lithium-ion cells and batteries as well as various hazard counteracting measures employed by the lithium-ion manufacturers. The surveyed safety issues pertain to multiple levels of engineering design, from the choice of active materials to full system topography.

Hybrid power sources containing lithium-ion cells or batteries are introduced in Chap. 6. In this chapter, the rationale behind hybrid systems is given, along with the advantages and disadvantages of these devices. Hybrid power systems, such as lithium-ion cell with an ultracapacitor as well as lithium-ion cell with a lithium-air battery are analyzed in this chapter, supported by specific examples of hybrid systems and their demonstrated performance.

Finally, Chap. 7 illustrates the competitive technologies landscape. This chapter assesses some of the most prominent energy storage options competing against lithium-ion batteries. The surveyed systems are organized by the application environment, namely: man portable applications, transportable and stationary applications. A socio-economic commentary is provided for the current and future situation of the selected energy storage market sectors.

This publication can be viewed as an assembly of correlated essays supported by graphs, tables, and pictures, with the common thread being the practical application of several scientific and technological disciplines. The individual chapters were written by professionals who deal with the described challenges in their everyday work. The book is also an illustration on how the high-end technology field benefits from collaborative approach and specialists in various disciplines working together towards the common goal.

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Malgorzata K. Gulbinska

Preface II: Historical Notes

Yardney Technical Products, Inc. is a speciality battery manufacturer that figures prominently in this book. This is unsurprising, since the majority of the contributors are either past or present employees of Yardney. The industrial influence was a welcome addition to the book's perspective since the underlying intention of this publication was to place the selected current topics in lithium-ion battery science and technology within the practical context. This historical note presents a few less known facts from the long and rich history of the company and its founder, Michel Yardney.

When Michel N. Yardney came to the United States from Paris in 1940, he had approximately \$500; degrees in Electrochemical Engineering and Electronic Engineering from the University of Caen and Ecole Supérieure d'Electricité; patents of a remote control device he had invented; and a personal motto "*Cherche et tu trouveras*", "Seek and you shall find". Shortly after his arrival and the start of World War II, he built a working model of the remote control unit, demonstrated the device to the U.S. Navy, and received a \$20,000 prototype development contract. That first small contract was the beginning of the Yardney Electric Corporation, which still holds hundreds of U.S. patents and world-wide patents in the field of electrochemistry. Since that time, Yardney has developed a number of battery systems that include silver zinc, silver cadmium, silver metal hydride, silver hydrogen, magnesium silver chloride, aluminum silver oxide, aluminum air, zinc-air, magnesium-air, lithium-air, cadmium-air, lithium-ion, lithium thionyl chloride, lithium manganese dioxide, and nickel cadmium and nickel hydrogen cells and batteries.

Interestingly, Yardney also developed or supported several commercial products, some that were not associated with batteries at all. These were the "Sea Watch" emergency light, commemorative silver ingots, silver powder, high intensity portable lights, 7.2 hp electric vehicle, electric motorcycle that until very recently held the world speed record for an electric powered motorcycle, a silver doped cellulosic material that was used as an antiseptic article, and other health related items such as Agosan and Eversan first aid ointments and a Como back support system.

Over the years, many of Yardney's battery systems became an integral part of the nation's most advanced spacecraft systems. Some of these products enabled significant technical milestones such as primary power for the astronauts' life support system (Extravehicular Mobility Unit or EMU) that used Yardney's 25 Ah silver zinc battery.

Yardney battery still holds the distinction of going deeper than any manned submersible with the U.S. Navy's Trieste to the bottom of the Marianas Trench using our 1000 and 5000 Ah silver zinc batteries. For many years Yardney's 12 Ah battery was used by virtually every major television network for their portable cameras. Overseas, Yardney's 16 Ah silver cadmium batteries were used by the various prime contractors which included an Italian company for the successful GIOTTO mission that monitored the passage of Halley's Comet past Earth in 1986.

In the early 1990s Yardney capitalized on the potential of lithium-ion battery technology and began the internal R&D program laid the groundwork for transforming the early laboratory work into a lithium-ion battery development program, which eventually led to Yardney becoming a leader in the technology and supporting several space applications including the Mars Rover batteries, multiple satellites, and many manned and unmanned vehicles.

Currently, Yardney is in continuous production of secondary lithium-ion batteries, primary and secondary silver-zinc batteries and primary reserve silver-zinc batteries used on various Department of Defense applications. The primary battery applications include the Navy's Trident II D5 Fleet Ballistic Missile program, the Minuteman III ICBM, and primary power for the MK 21 re-entry vehicle. In 2012, the Trident II missile has achieved 143 successful test launches since 1989—a record unmatched by any other large ballistic missile or space launch vehicle. The most prominent Li-ion batteries made by Yardney have powered the Mars Explorer Rover missions (Spirit, Opportunity, and Curiosity), the USAF B-2 Bomber and Global Hawk aircraft, and the US Navy Advanced SEAL Delivery System (ASDS). One of the future applications for Yardney's Li-ion batteries is NASA's Orion Crew Exploration Vehicle (CEV).

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