BATTERIES

Bright Future for an Old Invention

by Daniel A. Scherson

Batteries are perhaps the most ubiquitous electrical devices ever invented. Despite their two-century history, batteries have gained over the last decade an ever more important role as the power behind the explosion of the portable electronics market, including computers, cell phones, and entertainment. They are also the key to the introduction of large fleets of hybrid electric vehicles, which are crucial to helping industrialized societies, at least in the near future, to deal with the inevitable depletion of fossil-derived fuels and their adverse environmental impact. To offset their perceived lack of dazzle compared to the latest generation of music (MP3) players, for example, batteries are well hidden within the device and silently provide power based on the most elegant scientific principles.

Prompted by demands in performance, including such factors as cycle-life, durability, safety and environmental considerations—and aided by the seductive availability of funds from government and industrial sources— batteries are being investigated to a level of detail unimaginable only a few years ago. Although primary or non-rechargeable batteries continue to represent a significant fraction of the market, most of the attention in recent years has focused on lithium-ion batteries, the canonical rechargeable power source for computers and other portable electronic devices. Extraordinary progress has been achieved in terms of predicting the properties of electrode materials, particularly lithiated transition metal oxides as cathodes for lithium ion batteries, using state-of-the-art quantum mechanical calculations. These advances have been paralleled by the discovery of novel and promising compounds using ingenious combinatorial techniques and/or insightful tuning of the stoichiometry by direct synthesis.

Battery research also has served as a platform for the development and implementation of *in situ* spectroscopic and structural techniques, which have led to a better understanding of correlations between oxidation state of metal sites in the lattice and its metrical dimension and state of charge. These *in situ* tools have also shed light on the chemical nature of the passive film in high energy density anodes, which is key to the operation of the battery as a whole. The diversity and complexity of problems have helped build alliances between chemists, material scientists, and engineers—both experimentalists and theoreticians with expertise on disparate disciplines—and have led, in some cases, to the rebirth of topics for which the interest seemed to have irrevocably waned years ago. According to its charter, the ECS Battery Division fosters these interactions by stimulating research, publication, and the exchange of information relating to batteries and fuel cells, a role which it has vigorously pursued since its inception in 1947.

This present issue of *Interface* touches upon three topics that amply illustrate the multidisciplinary character of battery science and engineering. Dahn, and coworkers of Dalhousie University in Canada, describe recent progress toward the development of redox shuttle additives for Li-ion cells that can prevent damaging overcharge and

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Upcoming Battery Sponsored/Co-sponsored Symposia

Denver, Colorado • May 7-12, 2005 — Battery and Energy Technology Joint General Session; Energy Systems for the Twenty-First Century: Opportunities for Applications of Solar, Storage, and Conversion Technologies; Electrode Materials and Processes for Energy Conversion and Storage; and Direct Methanol Fuel Cells.

2006 Joint International Meeting, Cancun, Mexico • October 29-November 2, 2006 — Electrochemical Capacitors and High Power Batteries; Intercalation Compounds for Batteries and Hybrid Supercapacitors; Lithium-Ion Batteries; Metal/Air and Metal/Water Batteries; Organic Photovoltaics; Proton Exchange Membrane Fuel Cells 6; Solid-State and Solid-Electrolyte Batteries; and Multifunctional Carbon Materials for Electrochemical and Electronic Applications. (See the Call for Papers in this issue for a full description of these topics.)

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overdischarge reactions. Such strategies, as argued by the authors, may lead to Li-ion cells that are virtually indestructible and cannot be damaged in low-rate applications involving consumer-assembled batteries, making them suitable for the drugstore and supermarket shelves. A second article from the group of Nishide at Waseda University in Japan, explores the use of radical species, particularly nitroxide, which are capable of undergoing reversible electron transfer, as charge storage materials for secondary Li-ion battery electrodes; and it discusses the performance of nitroxide-grafted polymers synthesized in their laboratories as viable materials for practical cells. The final article in this issue deals with the impact of third-party software for applications of mathematical modeling to battery development and in particular for estimating battery performance. These new tools are expected to expedite customization of batteries to meet specific requirements by providing rational means of design and testing. If embraced by commercial battery developers, this approach may lead to improved device performance and better battery utilization and thus shift the paradigm from "You go to production with the battery you have, not the battery you want" to "You go into production with a rationally optimized and tested battery, and not with the battery you have."

Many of us wonder about the future of batteries a decade from now. Consensus appears to have been reached among experts in the field, that through the efforts of scientists around the world, the properties of battery materials in terms of rate, stability, and capacity, are now better understood than ever before; and as stated by Prof. G. Ceder of MIT, the ongoing hunt for new materials is very likely to pay off. Lithium-ion batteries are expected to eventually replace Ni-MH hydride batteries in hybrid electric vehicles and power tools; and to become entrenched in the primary battery market for portable, consumer electronic devices such as MP3 players and digital cameras. Key to the mission of the ECS Battery Division is to provide a venue for scientists and technologists of all disciplines to assess progress of maturing technologies as well as to promote the new revolution. The often overflowing sessions in lithium-ion batteries, battery safety and abuse tolerance, and the emerging, and indeed, tantalizing field of three-dimensional batteries, all in symposia sponsored by the Battery Division in Los Angeles this past October offer a solid demonstration of the importance of batteries in meeting the energy challenges ahead.

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