Energy Storage Materials and Processing

Advanced Characterization and Process Development for Energy Storage Materials

Background

Lithium ion battery technology is projected to be one of the energy storage leapfrog technologies for the electrification of automotive drivetrains and providing stationary storage solutions to enable the effective use of renewable energy sources. This technology is already in use for low-power applications such as consumer electronics and power tools. Extensive research and development (R&D) has enhanced the technology to a stage where it seems very likely that safe and reliable lithium ion batteries will soon be on board hybrid electric and electric vehicles and connected to solar cells and windmills. However, safety of the technology is still a concern, service life is not yet sufficient, and costs are too high.

Technology

Oak Ridge National Laboratory (ORNL) has performed a thorough technical assessment of materials and processing for energy storage devices and developed partnerships with leading battery developers, the automotive industry, and utility companies. In this assessment ORNL worked together with many battery developers, original equipment manufacturers, automotive suppliers, and automotive companies. Parts of the assessment and cost estimates have been published in an overview article.[1] Based on the assessment, ORNL has identified characterization and process development as the key components of a new, enabling R&D program at ORNL.

Status

To benchmark our newly developed materials and processes, a shared battery test laboratory has been set up and equipped with state-of-the-art characterization instruments such as a 32-channel Maccor battery cycler with temperature control chambers, an 8-channel Solartron frequency response analyzer, a portable Gamry potentiostat, and a large glove box with a video microscope. Each of these can be expanded to accommodate a larger number of test stations as demand grows. The portable potentiostats will be used for experiments at ORNL's Spallation Neutron Source and High Temperature Materials Laboratory electron microscopy, synchrotron, and X-ray diffraction laboratories. The video microscope will be

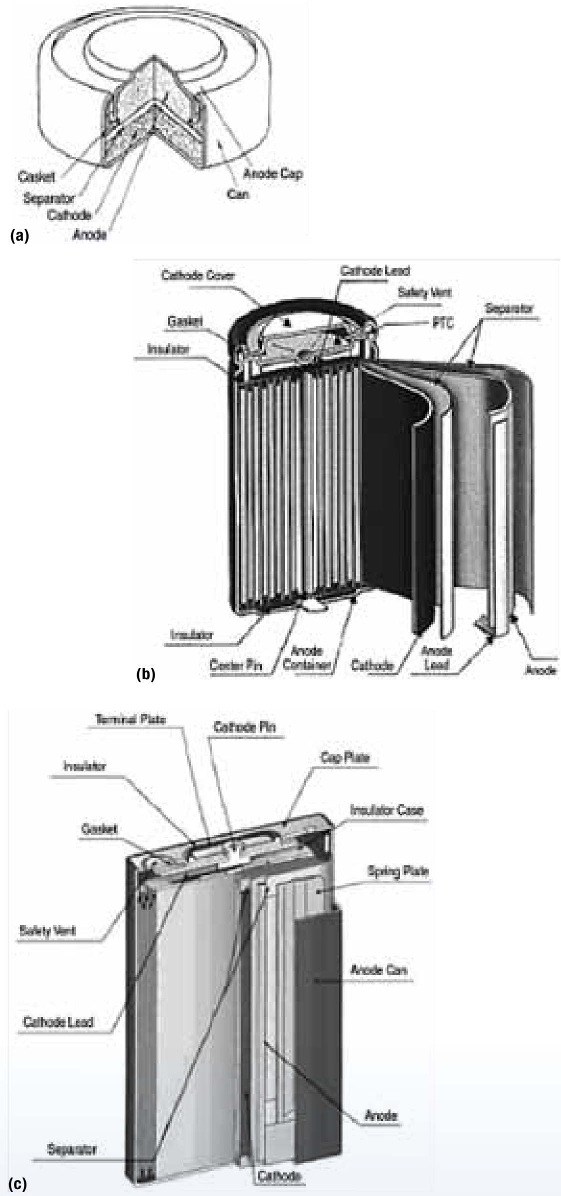

Figure 1: A schematic of cell forms as found from a multitude of sources: (a) button cell, (b) cylindrical cell, and (c) prismatic cell. [From JOM, 60 (9), 43–48.]

Benefits

- *Establish and strengthen domestic manufacturing.*
- *Reduce dependence on foreign oil imports.*
- *Increase energy security.*
- *Understand failure mechanisms.*
- *Enable the effective use of intermittent renewable energy sources.*

used to assemble liquid flow cells for transmission electron microscope and scanning electron microscope characterization of critical battery materials and interfaces. Basic battery fabrication equipment and materials, such as a coin cell crimping machine, will also be available. About a dozen likely users attended a 1.5 day training session conducted by a Maccor representative in February 2009.

For the characterization efforts, ORNL is focusing on elucidating life-limiting structural and compositional phenomena in operating batteries in order to propose new and advanced materials for the future. To this end, ORNL is developing in-situ characterization tools such as in-situ microscopy and in-situ fatigue testing.

Scientists from ORNL and colleagues at Vanderbilt University have developed a new nanoscale imaging technique for micrometer thick specimens in liquid that can be used to image whole cells in biological experiments and for the imaging of operating energy systems. The new technique–liquid scanning transmission electron microscopy (STEM)–uses a microfluidic device with electron transparent windows to enable the imaging of materials in liquid[2] and will be used for in situ microscopy of energy storage materials and battery cells. The fundamentals of the liquid STEM technique have been the basis for designing a specialized holder for the in situ microscopy testing of micrometer-size (miniaturized) batteries in the Hitachi HF-3300 high-resolution scanning/transmission electron microscope. For the in situ battery testing and the concurrent live-time observation (and recording) of the solid electrolyte interface formation (and other microstructural changes) during rapid charge-discharge events, the liquid flow cell will “contain” the liquid electrolyte as well as the battery anode and cathode materials (forming the miniature battery). Recently we started testing the holder, and the study will require chip/window (which form flow cell) redesign and extensive baseline characterization of “known” battery materials and correlation of the in situ tests with actual laboratory tests of full-size batteries.

In the coming year’s effort, we will focus on working directly with battery developers and their suppliers and customers to scale the technology, establish domestic manufacturing, and understand performance limiting barriers. In addition, ORNL has established an extensive internally funded effort on materials, processing, and modeling for electrical energy storage.

Refs:

1. Daniel, C., “Materials and processing for lithium-ion batteries,” *JOM*, 60 (9), 43–48.
2. de Jonge, N., et al., “Electron microscopy of whole cells in liquid with nanometer resolution,” *Proc. Natl. Acad. Sci*. (2009).

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A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy’s Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.