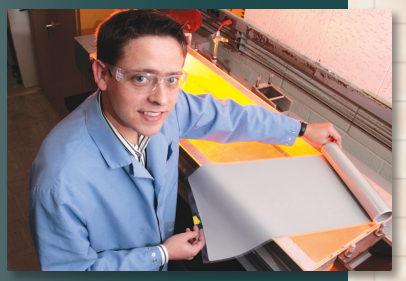
Batteries for a New Generation of Vehicles

Innovations to help satisfy America's demand for hybrid-electric and electric vehicles that are safe, affordable, and go the extra mile.

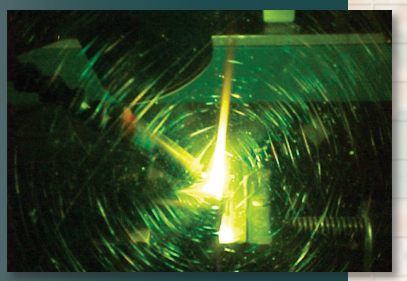
OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Materials & Processing for Ad

High performance batteries are projected to be an energy storage le
ing stationary storage solutions for the effective use of renewable ener
not yet sufficient, and costs are too high. To help meet these challeng
concentrating their expertise in **materials characterization**, **materials**
performance and lifetime limitations and develop revolutionary techno
facturing processes.



Advanced Coatings – *ORNL develops low-cost high-yield processing technologies for electrode deposition and other coatings for advanced energy storage devices.*



Advanced Joining – *Laser welding is a low heat joining technique that protects active battery materials from welding heat damage.*

In Situ Fatigue Testing – *An x-ray diffractometer is used to evaluate how battery materials change during charges and discharges.*

In Situ Microscopy – *Transmission electron microscopy for in situ characterization studies evaluates the stability of battery electrode materials during rapid charge-discharge cycling.*

Advanced Coating Technologies and Processes – The development of low-cost high-yield coating technologies is one of the most important ingredients for reducing manufacturing costs and increasing the reliability of batteries. ORNL's research on wet and dry coating technologies could reduce the time and energy needed for typically used formation procedures after the battery is assembled. ORNL scientists and engineers are also looking into scaled melting and advanced powder fabrication and laser processing techniques to fuse amorphous iron-based powders into ultrahard nanocomposite coatings many times harder than conventional steel tools.

Advanced Computational Modeling – Advanced computational modeling provides an unprecedented capability to study and optimize the overall performance and safety of the batteries by enabling rapid prototyping and screening of battery materials and configurations as well as accurate lifetime predictions (see cover image of an animated growth simulation of lithium dendrites).

Advanced Joining – Low thermal impact joining is of very high importance for advanced batteries because such devices are filled with thermally sensitive materials prior to joining and sealing. Ultrasonic joining, a candidate for such applications, is just one of many advanced joining techniques ORNL is currently researching.

Advanced Materials – Much recent research on lithium batteries has focused on the use of composite materials to improve both performance and safety. Scientists at ORNL are exploring the use of carbon, graphite, and carbon fiber composites to improve the thermal and electrical conductivity of battery materials.

In Situ Fatigue Testing – Acoustic emission spectroscopy and in situ x-ray diffraction stress analysis help characterize microscopic crack initiation, crack growth, fracture of grains and particles, and loosening of particles during cycling to establish the first ever in situ fatigue testing of electrode materials for lithium ion batteries. This will result in a deeper understanding of the mechanical behavior of electrode materials being used in lithium ion batteries.

User Fa

ORNL's battery research currently takes place within several highly sophisticated U.S. Department of Energy (DOE) National User Facilities, serving staff scientists and engineers, as well as researchers from universities, industry, foreign institutions, and other government laboratories.

- *Center for Nanophase Material Sciences* houses tools and expertise for the synthesis of high performance materials and nanostructures.
- *High Temperature Materials Laboratory* conducts world-class analysis and testing of materials structure and properties.
- *National Center for Computational Sciences* provides the world's most powerful computing resources for researching how the physical world works and

vanced Battery Development

eapfrog technology for electrifying automotive drivetrains and provid-rgy sources. However, technology safety is still a concern, service life is es, Oak Ridge National Laboratory (ORNL) scientists and engineers are **processing**, and **materials and systems simulations** to identify battery logies and low-cost processing for next-generation batteries and manu-

In Situ Microscopy – In situ microscopy or liquid scanning transmission electron microscopy is a new technique developed by ORNL scientists and colleagues at Vanderbilt University that uses a microfluidic device with electron transparent windows to enable the investigation of materials in a liquid using electron microscopy. It will be used for in situ studies of energy storage materials and battery cells.

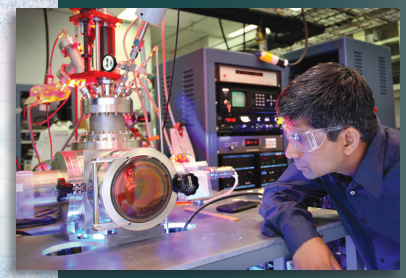
Materials Synthesis – Materials synthesis includes the study of complex, new, or improved material systems and the structure-property relationships that develop from starting materials, processing, and resulting properties. Through studying material synthesis, ORNL researchers hope to identify industrially viable technologies for the large-scale application of electrochemical double-layer capacitors for electrical energy storage.

Mechanical Testing – Through multidisciplinary project teams, often using one-of-a-kind instruments or facilities for materials characterization, ORNL scientists are mapping the mechanical properties of battery materials in the search for ways to improve the performance and cost of lithium batteries.

Thermal Runaway Characterization – Thermal runaway in batteries is a safety concern that can lead to degradation of performance and catastrophic failure. At ORNL we are using infrared imaging to better understand temperature distribution inside lithium batteries to prevent internal short circuiting and thermal runaway.

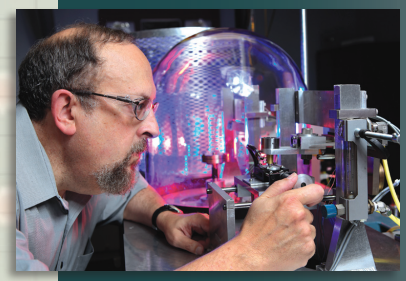
Tribology – Over the years, ORNL has led the way in friction and wear testing, including the development of ASTM standards in this area. Now we are focusing our research on eliminating or mediating the effects of internal friction in batteries.

3-D Surface Profiling
A vertical scanning interferometer is used to precisely measure fine-scale surface features and construct high-resolution 3-D surface maps. Unlike a scanning electron microscope that requires putting materials into a high vacuum chamber, the phase-shift imaging features of this system enable nanometer-resolution images to be obtained in air.

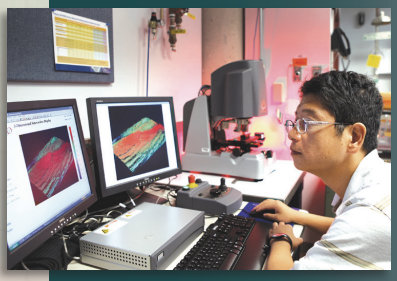


Materials Synthesis – *A sputtering technique is used to study thin film deposition of battery materials and solid electrolytes.*

Mechanical Testing – *A mechanical testing machine used to characterize the stress-strain response of various battery materials.*



Tribology – *A reciprocating tribometer is used to measure the friction forces between battery materials during repeated charging and discharging.*



3-D Surface Profiling – *A vertical scanning interferometer precisely measures fine-scale surface features of battery materials and constructs high-resolution 3-D surface maps.*

cilities

using that knowledge to address pressing national and international concerns.

- *National Transportation Research Center* focuses on fuels, engines and emissions, power electronics and electric machines, heavy vehicle safety research, transportation analysis, and high-risk/high-value packaging.
- *Shared Research Equipment User Facility* includes electron beam microcharacterization tools that are used in battery research.
- *Spallation Neutron Source* is an accelerator-based neutron source that provides the world's most intense pulsed neutron beams for scientific research.

Accelerating Commercialization

ORNL is looking to the future with plans for advanced facilities and investments in novel energy storage research initiatives. It is actively pursuing the construction of an advanced battery fabrication technology development center to accelerate development, screening, and validation of future-generation battery materials and cell designs. The envisioned facility will occupy an existing 12,000-foot space and consist of new state-of-the-art equipment as well as existing equipment relocated and consolidated from other laboratories across the site. It will house a flexible coating and fabrication line and a reconfigurable suite of modules comprising innovative processes beyond those considered to be state-of-the-art for cell fabrication today. The modules will include novel deposition systems; drying and consolidation systems; winding, folding, and stacking systems; and joining technology systems. The facility will have sufficient automation to assess and demonstrate the potential of scaling developments to commercial volumes.

The facility will be designed for open-access use by researchers from industry, universities, and other national laboratories and will also be used to train battery technicians, engineers, and researchers as part of a workforce development focus to support substantial job growth in the domestic battery industry. ORNL's extensive characterization capabilities can also be applied at the facility to assist in failure mode and effects analysis, component and process validation, in-line quality sensing and process control, and enhanced evaluation at each processing stage.

In addition to the technology center concept, ORNL has established a Laboratory Director's Research and Development initiative on energy storage that increases internal investments in projects for new scientific discoveries and game-changing concepts such as metal air, large scale all solid state, and other applications.

Supporting Sustainable Transportation

ORNL's battery research for a new generation of vehicles is aligned under the lab's Sustainable Transportation Program. Through dynamic partnerships, the program's mission is to provide innovative solutions that advance America's transportation systems. The program brings together scientists and engineers, commercialization experts, and technology transfer specialists from across laboratory directorates to address today's transportation challenges. Through partnerships with government, industry, and academia, their research and development efforts are resulting in knowledge discovery and technology development, maturation, and implementation. The program drives four broad and integrated areas of concentration to advance the mobility of people and goods within America's transportation systems: vehicle, energy, information, and infrastructure.

For more information about battery research for vehicles, contact:

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