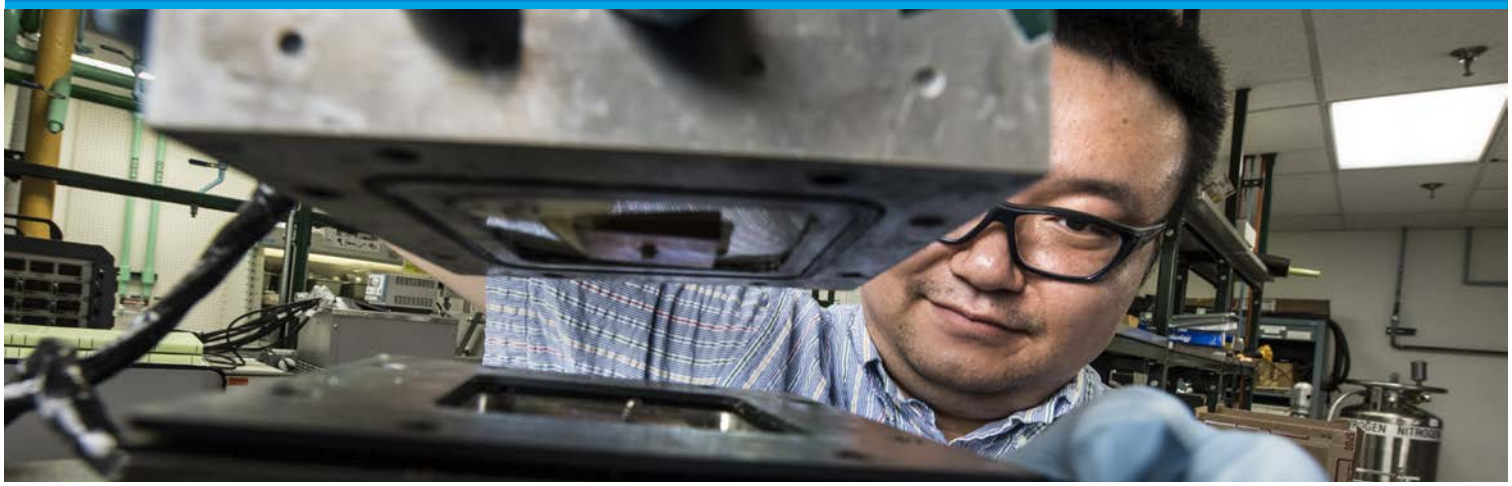
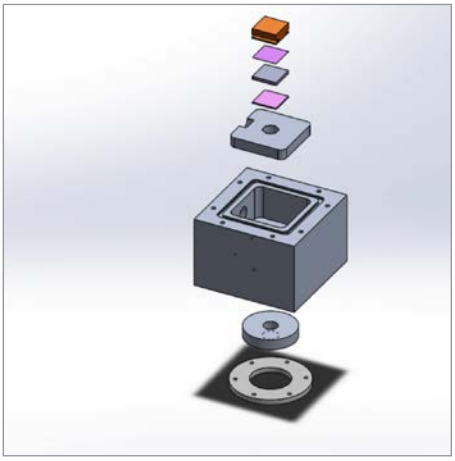
Micro Calorimeter for Batteries



A researcher prepares the Micro Calorimeter for coin cell battery evaluation. The unique busbar design allows for the assessment of battery cells under load. *Photo by Dennis Schroeder, NREL 44055*

Thermal Characterization for Coin Cell Batteries

As battery technology forges ahead and consumer demand for safer, more affordable, high-performance batteries grows, the National Renewable Energy Laboratory (NREL) has added a patented Micro Calorimeter to its existing family of R&D 100 Award-winning Isothermal Battery Calorimeters (IBCs). Lithium-ion batteries of all sizes—from single cells used in watches and medical devices to pouches used in mobile phones and packs installed in electric vehicles—must operate at maximum efficiency and perform at optimal temperatures in a wide range of climates through numerous charging cycles. The Micro Calorimeter examines the thermal signature of battery chemistries early on in the design cycle using popular coin cell and small pouch cell designs, which are simple to fabricate and study.



NREL's patented single-chamber design enables measurement of heat signals down to a few microwatts by minimizing measurement noise. *Illustration by Aron Saxon, NREL*

Fundamental analysis of material limitations at the coin-cell level gives engineers, materials researchers, manufacturers, innovators, labs, research and development (R&D) organizations, and universities the ability to experiment with a wide range of chemistries and determine which variations and combinations work best in an actual battery setting. As many new materials are being developed and integrated into battery designs, it is important to thoroughly understand their compatibility, safety, durability, production cost, and endurance before integrating components into more elaborate battery designs for larger applications or investing in production at scale.

Reliable Readings to Fine-Tune Cell Design

Battery performance and lifespan are affected by temperature—low temperatures can lead to shorter battery life, while high temperatures can cause overheating, which can lead to thermal runaway, a potential safety risk. The Micro Calorimeter can identify different heat generation mechanisms within cells and track the performance of individual cell components by measuring heat generated at multiple temperatures.

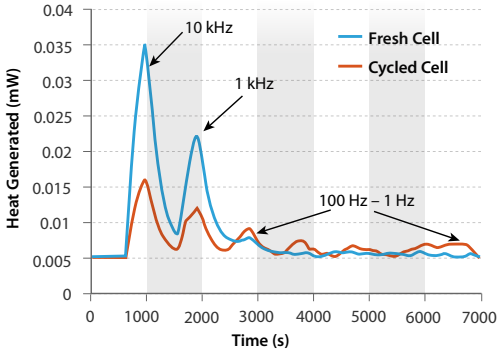
With cutting-edge sensors, low thermal mass, and short response times, the Micro Calorimeter captures precise thermal signatures in just minutes, including measurements to pinpoint instances where cells under load are losing tiny amounts of energy and are only giving off weak heat signals. By exciting multiple cell processes that have different thermal signatures, the response from different materials within a battery, such as electrolytes, salts, additives, anodes, and cathodes, can be isolated.

**NREL is a national laboratory of the U.S. Department of Energy,
Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.**

Evaluation of Battery Degradation Mechanisms

Degradation of components due to cell aging leads to differences in heat generated across the spectrum. The Micro Calorimeter measures thermal performance of the cell across the full spectrum of frequencies so that individual performance of materials within a battery can be isolated and evaluated.

Battery aging studies conducted with the Micro Calorimeter allow researchers to measure battery performance at different stages of life, under different operating conditions, and over varied periods of time. By comparing the thermal response of aging batteries concurrently with new ones, researchers can track individual failure modes. The Micro Calorimeter simultaneously measures the thermal response as a function of frequencies in addition to the electrical impedance of the cell. This functionality helps the user to obtain a comprehensive understanding of changes to component-level properties with cell aging when building new material chemistries and cell design.



Degradation of different components due to cell aging leads to differences in heat generated across the spectrum: the high-frequency heats are likely from a lack of adequate contact, whereas the low-frequency heats are likely from a loss of porosity. The Micro Calorimeter can detect very small heat signals (+10 µW) and has response times less than a millisecond: both are necessary features to isolate different degradation mechanisms within the cell. *Illustration by Aron Saxon, NREL*

Specialized Software for Materials Analysis

The Micro Calorimeter comes with NREL's proprietary software to analyze frequency response data for physical insights into degradation mechanisms. The software enables researchers to identify material compatibility across different cell components that will enhance battery life. The accurate sensing of small heat signals combined with powerful analytical capabilities minimizes development costs by enabling battery scientists to build a small, targeted set of design of experiments for rapid screening of new chemistries.

Micro Calorimeter Highlights and Capabilities

- Examines new chemistries in small format cells, small electronics, wearable devices, and sensors
- In *operando* measurement of reaction heats within individual cells under actual load cycles
- Flexible chamber design accommodates testing of different cell sizes at a consistent, known pressure
- Evaluates kinetic and thermal properties from frequency response analysis
- Powerful tool for early-stage materials R&D to assess material stability and compatibility across multiple cell components
- Analyzes cell abuse kinetics mechanisms, as well as thermal limitations under normal operation
- Ideal for studying engineering modifications (coating effects, thermal interfaces, contact impedance at interconnects, porosity changes, wetting, binder adhesion)
- U.S. Patent #14/855,538; software for post-processing: NREL-SWR-13-15

NREL's Sustainable Transportation R&D

A recognized leader in battery thermal management R&D, NREL drives research at the materials, cell, battery, pack, and systems levels. NREL spearheads R&D to accelerate widespread adoption of high-performance, energy-efficient passenger and freight vehicles, as well as fuels and related infrastructure. The laboratory's innovative and integrated approach helps government, industry, and other partners develop the components and systems needed for market-ready, next-generation vehicles.

For more information on NREL's transportation R&D capabilities and successes, go to: *nrel.gov/transportation*

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NREL/FS-5400-68532 • August 2017