Application Note

Instruments: Met and Optical Overview

Metallography of Lithium-Ion Battery Coated Foils

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Introduction

As the demand for renewable energy and green technologies accelerates, companies are prioritizing powerful, efficient, and reliable energy storage solutions. Lithium-ion batteries have rapidly become the leading clean energy choice across automotive, defense, and stationary storage applications. Most lithium-ion cells use a graphite anode paired with either a Lithium Iron Phosphate (LFP) or Lithium Nickel Manganese Cobalt (NMC) cathode. During manufacturing, the anode and cathode slurries are coated onto thin metal foils, which makes metallographic inspection a critical quality control step. Metallography enables precise evaluation of key battery performance factors, including adhesion, coating and foil thickness, and porosity. These characteristics directly influence charge-discharge efficiency, energy density, and overall safety, helping manufacturers prevent defects that could otherwise lead to performance loss or hazardous failures.

Understanding Battery Foil Coating

Thickness measurements of anode and cathode coatings are essential for preventing downstream issues such as reduced battery efficiency, shortened battery life, and the risk of thermal runaway. Irregular coatings can generate localized hotspots that worsen with every charge–discharge cycle. To minimize manufacturing waste and maintain quality, it is recommended to check coating thickness at multiple stages of the production process.

These measurements reveal uniformity and flatness across the foil. The material should be evenly distributed with homogeneous particle dispersion and be free of defects such as holes, cracks, delamination, or scratches. By monitoring thickness in real time, manufacturers can adjust parameters, such as coating speed or calendering gaps, to optimize performance and improve overall process efficiency.

Sample Sectioning

With any metallographic sample, the most critical step of sample preparation is sectioning. The goal of sectioning is to remove a suitable-sized sample from a larger component with the least amount of deformation. As the coated foils are incredibly thin, a sharp pair of scissors is sufficient to cut a representative piece (Figures 1 and 2). The foils should be handled with care to prevent any premature smearing or delamination of the coating.

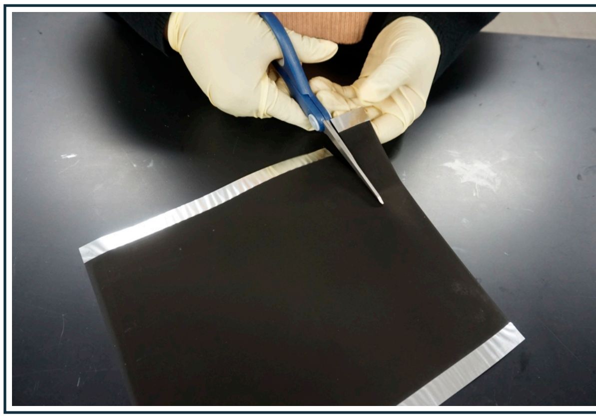

Figure 1. Sectioning the foil with scissors.

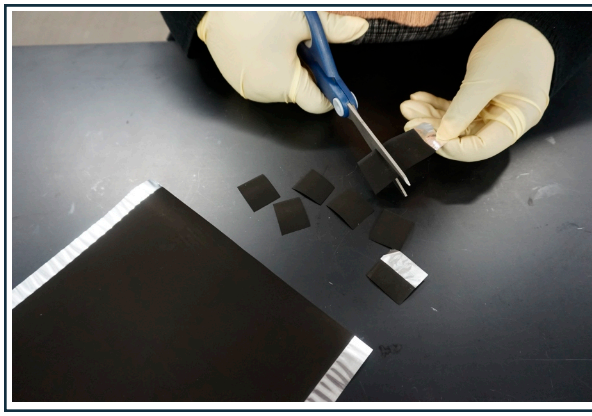

Figure 2. Sectioning representative pieces for the mold.

Mounting

Mounting the sample for grinding and polishing enables automated handling, protects edges from rounding, and ensures a flat, uniform surface for microstructure analysis. Given the thickness of the coated foils, proper handling is required, as improper handling can cause the coating to detach from the foil or crush the foil.

These foils can be temperature and pressure-sensitive, so cold mounting is recommended for this application. To achieve a flat, representative foil for image analysis, start by mixing LECOSET 7008 and pouring a thin base layer into the mold. Stack one or more foils on top of this initial layer, then pour the remaining LECOSET solution to fully encapsulate the foils (Figures 3 and 4). A pressure vessel can be used in the curing process to remove air bubbles and promote edge retention (Figure 5).

Note: it is helpful to allow the initial small layer to cure before placing the layers atop. This will result in a hard surface to carefully position the layers with tweezers. The force of the additional LECOSET should aid in flattening the foils and keeping them in place.

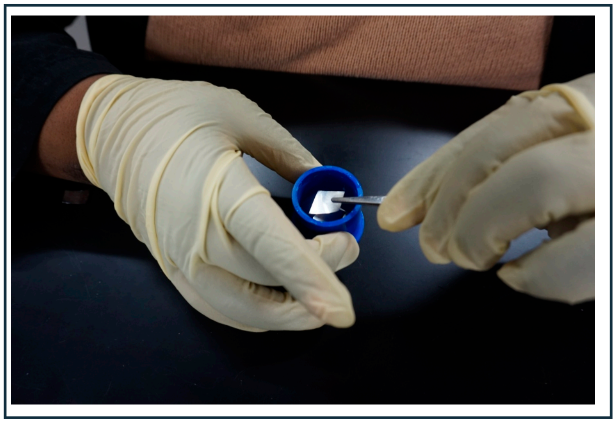

Figure 3. Placing foils on the hardened layer.

Figure 4. Pouring LECOSET 7008 atop foils.

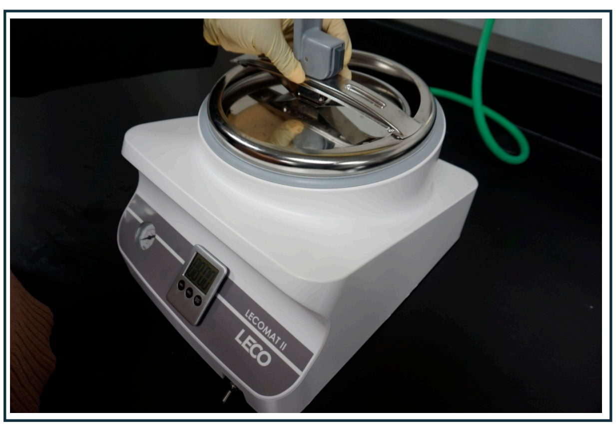

Figure 5. LECOMAT II Pressure Vessel for curing.

After the mount has cured, it is then cut in half transversely to reveal the region of interest for image analysis. If utilizing an automated grinder/polisher carousel, the halves can be placed face down in the mold cup, and additional LECOSET can be used to remount the sample for ease of handling in a carousel (Figure 6).

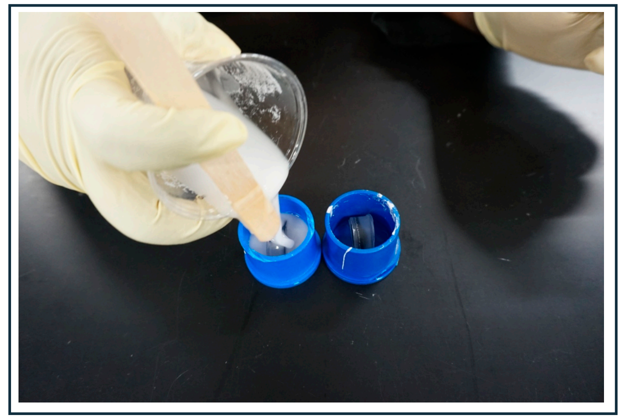

Figure 6. Pouring LECOSET 7008 around the sectioned pieces.

Grinding & Polishing

The goal of grinding is to remove any deformation caused by previous preparation steps and produce a uniform surface with minimal scratches. In this step, it is very important to avoid any pull-outs, thermal damage, or foreign elements that could cause additional surface deformation. LECO recommends Premium Silicon Carbide (SiC) Papers for sample preparation due to its high hardness, sharp cutting action, and friable nature, allowing for rapid material removal with minimal deformation on soft metals. Since the foils are delicate and susceptible to deformation, using overly aggressive or improper abrasives can introduce artifacts that compromise the microstructure. Water should be used as a lubricant to minimize heating, prevent abrasive loading, and flush away debris. Any scratches or foreign materials introduced on the surface could cause inaccurate results and microstructure observations.

Polishing is conducted in metallography to create a deformation-free surface, removing scratches and damage left by grinding. This critical step ensures that the true microstructure is visible, allowing for accurate microscopic analysis and interpretation without artifacts, which could distort the results. LECO recommends two fine polishing steps to achieve the desired result: 3 μm and 1 μm. These steps will properly remove any scratches that may have been introduced in grinding and reveal the coating layer for accurate measurement. Both steps utilize a diamond suspension or paste and an extender. The use of a polishing lubricant/extender is advised to decrease friction, facilitate heat dissipation, prevent abrasive clogging, and promote uniform distribution of diamond compounds or suspensions. It also keeps the polishing cloth moist, improves material removal efficiency, prevents sample damage, and ensures consistent surface finishes.

Table 1. Grinding/Polishing Guidelines (Central Force)

	Time (Minutes:Seconds)	Head Direction	Head Pressure (lbf)	Head Speed (RPM)	Wheel Direction	Wheel Speed (RPM)
240 grit SiC / H_2O	1:00	CCW	40	100	CCW	200
400 grit SiC / H_2O	1:00	CCW	40	100	CCW	200
600 grit SiC / H_2O	1:00	CCW	40	100	CCW	200
Gold Technotron / 3 µm Diamond Suspension / Extender	3:00	CCW	30	100	CCW	200
Red Felt Cloth / 1 µm Diamond Suspension / Extender	1:00	CCW	30	100	CCW	200

Image Analysis for Coating Thickness Measurements

LECO's image analysis software, PAX-it, provides users with an enhanced user interface to automate and generate reports based on common metallographic inspections for coated foils, including coating and layer thicknesses. Samples in the as-polished condition are suitable for observation and these measurements (Figure 7).

With the "Measurement Sequence" capability, users can repeatedly measure thicknesses from a captured image (Figure 8). The Measurement Sequence is set up to prompt an operator to make measurements based on predefined parameters and locations. It is often recommended to use multiple measurements and areas of a sample for an accurate average of the entire layer of interest (Figure 9). Pass/Fail criteria can be established to alert a user if any of the measurements don't meet quality standards. This can also be used to observe any coating inconsistencies, like porosity or inclusions, that could lead to failure. Users also have the option to customize and print out Excel reports for traceability purposes.

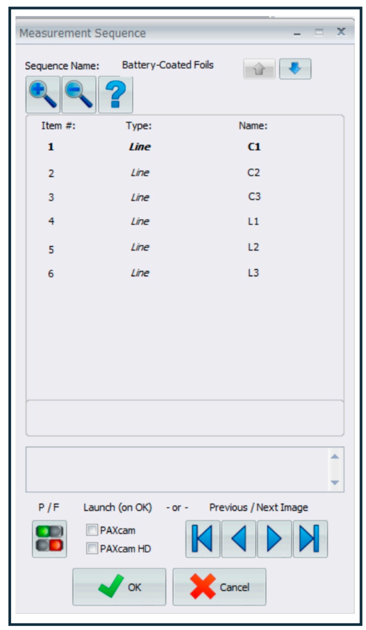

Figure 8. Measurement sequence for thickness.

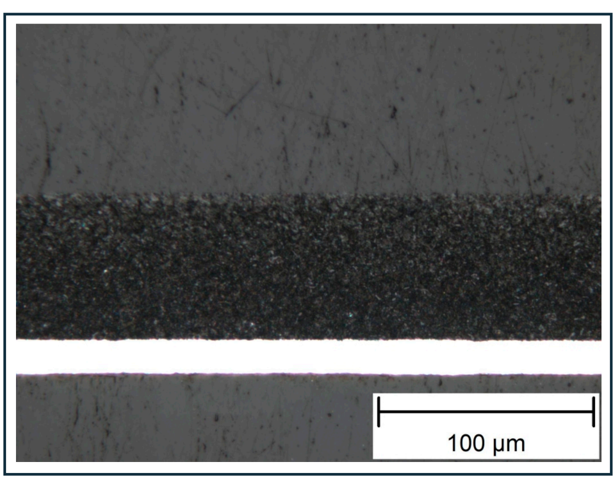

Figure 7. LiFePO$_4$ coated aluminum foil (LECO VX4, 50X objective).

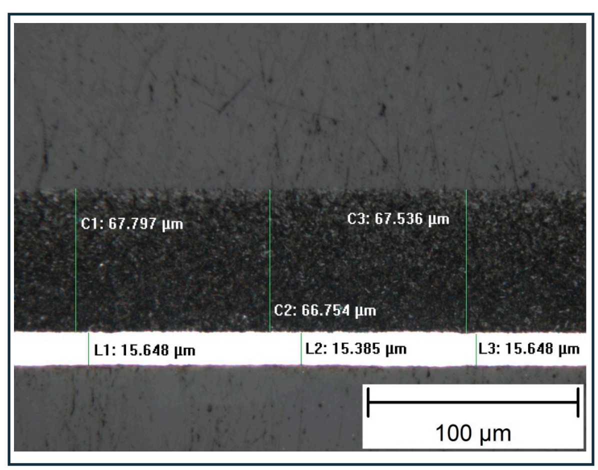

Figure 9. LiFePO$_4$ coated aluminum foil with measurements (LECO VX4, 50X objective).

Conclusion

Metallographic inspection is a critical quality control tool in lithium-ion battery manufacturing, directly impacting performance, safety, and reliability. Accurate evaluation of coating thickness, adhesion, and uniformity on anode and cathode foils helps prevent efficiency losses, premature failure, and safety risks such as thermal runaway. Because these foils are highly sensitive to deformation, careful sectioning, delicate cold mounting, and controlled grinding and polishing are essential to preserve the true microstructure. LECO's recommended preparation methods and consumables enable consistent, deformation-free surfaces suitable for precise analysis. When combined with PAX-it image analysis software, manufacturers can reliably measure coating and foil thickness, detect defects, and generate traceable reports. Overall, a well-controlled metallographic workflow supports optimized process control, reduced manufacturing waste, and the production of safer, higher-performing lithium-ion batteries.

LECO Metallographic Solutions

CX300 Series

MX Series

PX Series

VX4

PAX-it

PAXIT
BY MIS

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