Technology Networks

Achieving Coating Uniformity in Battery Electrode Production

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Credit: iStock

The global drive towards greener energy sources to help combat the climate crisis has accelerated the growth of the lithium-ion battery manufacturing sector. All lithium-ion batteries, regardless of the end geometry, have a base structure of a cathode, separator film and anode. Each of these are made as individual sheets and are rolled or folded into their final form, whether as a prism, pouch or cylindrical battery. Strict control of the thickness and coating uniformity of these materials is crucial to the battery manufacturing process, making it essential to identify quality concerns at an early stage to avoid material waste and the inclusion of non-compliant materials in the end product. In-line metrology systems can help to ensure the consistency and quality of battery electrodes, and this article discusses how this technology can contribute to the manufacture of quality lithium-ion batteries.

Factors to consider in metrology selection and setup

In-line metrology systems can be used to verify that battery base components comply with design parameters before final assembly, ensuring the resulting product meets the desired energy densities, recharge rates and physical dimensions. Even small irregularities early in the production process can significantly impact the function and efficiency of the final product, making early identification of these defects critical. There are several factors to consider when selecting and setting up in-line metrology.

Sensor choice

There are many types of sensors available, and the optimal choice will depend on the material and properties to be analyzed (Table 1). For example, low-density materials – such as polypropylene or polyethylene, which are commonly used for separator films – are best measured using infrared, beta or very low-energy X-ray sensors. For the electrode substrates themselves, X-ray or beta radiation sensors are the optimal choice, while confocal laser sensors are well suited to measuring the overall thickness of the electrode after the calendering process. Sensor resolution and precision must also be taken into consideration. This is especially important in battery electrode production, where reliable, high-resolution measurement of edge defects is crucial.

Table 1: Metrology overview by sensor type.

Process	IR	Beta	X-ray	Laser	Capacitance	Ultrasonic
Substrate	⊙	+	++	+	-	--
Separator film	+++	++	-	--	⊙	⊙
Anode coating line	⊙	+++	-	+	-	⊙
Cathode coating line	⊙	+++	++	+	-	⊙
Press line	⊙	⊙	⊙	+++	⊙	+
Dynamic range	Good for non opaque material	Excellent for all battery materials	Excellent for cathode battery materials	Excellent for all battery materials	Limited	OK
Resolution	Very good	Very good	Excellent	Very good	Not good	Bad
Composition sensitivity	Calibrated to be insensitive	Density based compensation	Chemical based compensation	Excellent	Bad for conductors	Good
Environmental sensitivity	Excellent	Good	Very good	Excellent	Very good	Not good

Scan speed

Scan speed is another important parameter to consider when setting up an in-line measurement system. Since the gauge moves perpendicularly relative to the processing direction, the sensor will traverse the material in a zigzag pattern, allowing some defects to pass undetected. The scanning speed will therefore determine the percentage of the material that is measured. Although the obvious solution might be to increase the scan speed, this can lead to a decrease in accuracy. If the scan speed is too high, the response time of the sensor may be insufficient to generate a precise representation of the material surface, blurring the data and increasing the risk of poorly resolved defects. Ultimately, this becomes a balancing act between measurement accuracy and the amount of material measured.

Beam size

The beam size should be defined at a certain location between the source and detector. The further away it is from the source, the larger the beam size will be.

When looking at the edge of a patch, or a scratch, a narrow beam achieves better visualization of the defect.

Environmental and geometric considerations

It is important to make sure that the sensor frame itself is not contributing to any measurement errors. For example, flutter due to tension variations in the battery production line can cause a vertical displacement of the material between the source and detector that can lead to inaccuracies. Additionally, the rails that the source and detector ride should be well aligned to avoid measurement errors. External influences, such as changes in temperature and pressure, can change the density of the air column between the source and detector and therefore influence sensor performance. These effects all need to be measured and compensated for.

Measurement opportunities throughout battery electrode production

The chemical and material properties of the different constituents used in battery electrode production influence the in-line metrology required for the process, and these systems must be correctly positioned to achieve optimal monitoring and control.

Separator film extrusion

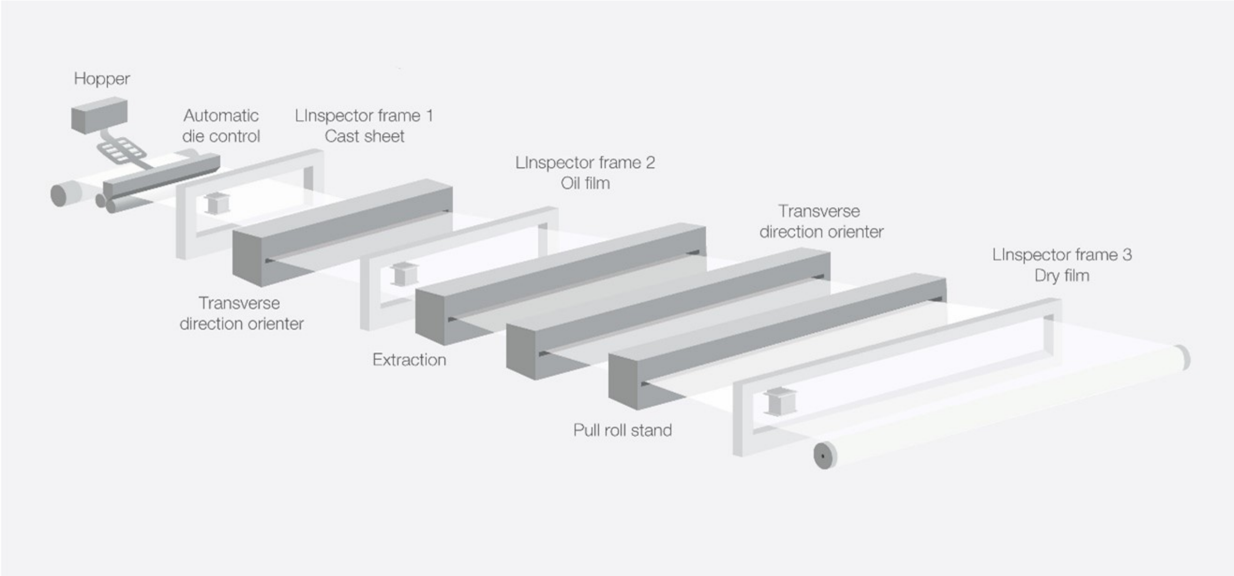

Figure 1: Measurement opportunities during separator film manufacturing. *Credit: Thermo Fisher Scientific.*

A typical battery separator film will be made up of layers of polypropylene, polyethylene or a combination of both, and it is important to be able to determine the thickness of the individual layers to ensure they are providing the properties that the end battery requires. During the manufacturing process, the raw materials are mixed and then extruded out through a die (Figure 1). An initial measurement directly after the exit from the die ensures that the first step is well monitored. After that, the material is cooled down and stretched to the required thickness and porosity. A second measurement, at the end of the production process, provides an accurate assessment of the final quality – including the correct thickness and the absence of holes – before the material is incorporated into the battery electrode. Because the material used is a low-density polymer, the radiation from most X-ray-based systems will pass through it very quickly. To overcome this, infrared or beta measurements are needed to achieve the required measurement resolution.

Electrode coating

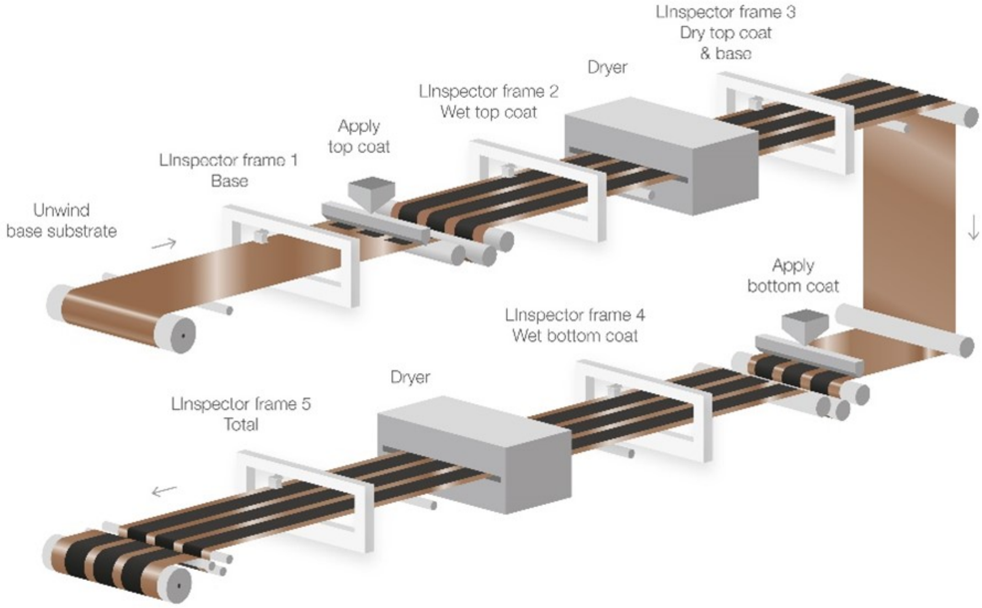

Figure 2: In-line measurement during the electrode coating process. *Credit: Thermo Fisher Scientific.*

During the electrode coating process, a topcoat and bottom coat are applied to the base substrate in a two-step process. Each coating is applied wet and then dried in a dryer (Figure 2). It is possible to measure both the top and bottom coatings for a complete overview of the coating; however, all the scanners must be synchronized to ensure they are measuring the same spot in order to provide individual layer measurements. The "substrate only" measurement scanner feeds information to the subsequent scanners to provide detailed information on the individual layers during the coating process. Due to the properties of the materials used, beta radiation provides an ideal absorption rate to distinguish the difference between the substrate and the coating. X-ray measurement is also possible, although it can be alloy sensitive considering the relative composition of the metal substrate and the coating.

Post-coating processing

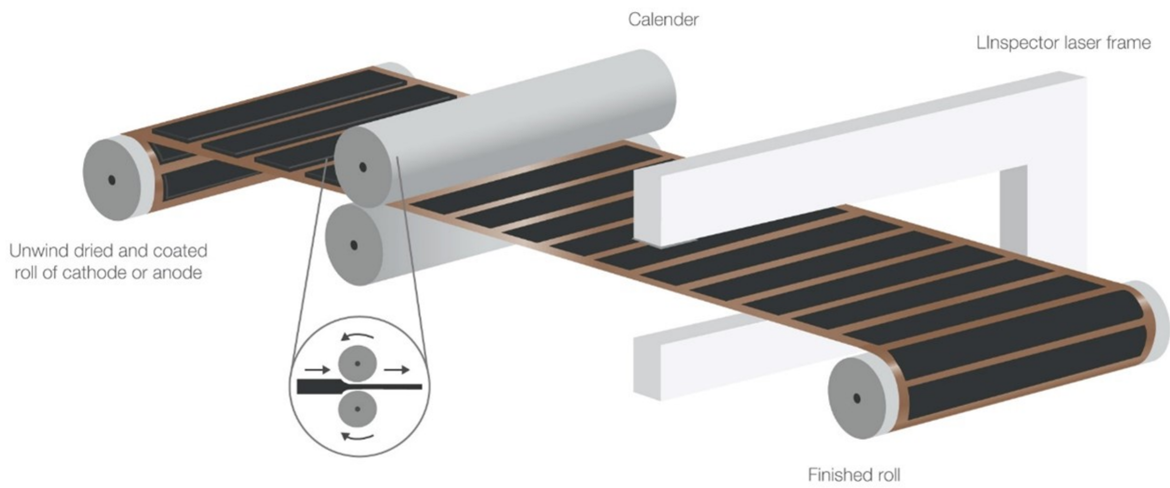

Figure 3: Thickness measurement during the calendering process for electrode materials. *Credit: Thermo Fisher Scientific.*

Once the coating line has produced electrode material with a well-defined base weight and energy density, it is fed into a calendering device to achieve the correct thickness for the battery in its final form (Figure 3). An in-line measurement system featuring two confocal laser sensors – one above and one below the material – provides a measurement of the actual thickness to sub-micron precision of the electrode following the calendering process.

Summary

Thickness and coating weight uniformity in electrode materials is crucial to maintain the quality and safety of lithium-ion batteries, and in-line metrology systems help manufacturers to meet specifications while maximizing process efficiency. Determining the right system for each application allows continuous analysis in real time without compromising throughput, reducing the risk of defects and increasing overall productivity.

About the author:

Chris Burnett has held a number of positions at Thermo Fisher Scientific, including Director of Sensor Development and Manager of Systems Integration for the flat-sheet gauging business. He currently drives solutions for the battery industry in his role as Senior Manager, Applications. He studied physics at Worcester Polytechnic Institute, USA.