Battery manufacturing

Monitoring critical parameters during battery electrode manufacturing

Authors

Palani K Shanmugam, Thermo Fisher Scientific, Rugby, United Kingdom

Chris Burnett, Thermo Fisher Scientific, Tewksbury, MA, USA

Keywords

Battery manufacturing, battery electrode, lithium-ion batteries, in-line metrology

Introduction

Demand for Lithium-ion (Li-ion) batteries for applications such as electric vehicles and long-duration energy storage intensifies the pressure on battery manufacturers to improve both product quality and process efficiency. The manufacture of Li-ion battery electrodes is a key link in the battery supply chain and options for monitoring the electrode coating processes are steadily expanding. Thermo Fisher Scientific has developed new technology, the Thermo Scientific™ LInspector™ Edge In-line Mass Profilometer, to measure the critical parameter of electrode coating weight. The high resolution of LInspector Edge In-line Mass Profilometer is able to detect manufacturing defects efficiently and precisely, assuring the quality of the coating in real time. This application note considers the metrics that can be measured, their application and associated opportunities for advanced process control.

A foundation for modern manufacturing

For battery manufacturers, the pathway to smart manufacturing, digital transformation and Industry 4.0 is dependent on embracing new solutions for process monitoring. There is a need is for tools that provide the advanced analytics, real-time data, and interconnectivity required for decentralized and fully automated decision-making.

LInspector Edge Inline Mass Profilometer uses an innovative new metrology – in-line mass profilometry – to measure the entire surface of coated electrodes in real-time, delivering coating weight profiles in milliseconds. The result is a rich information stream that supports efforts to:

- Confidently classify defects during coating and develop appropriate remedial and management strategies to minimize their impact.
- Enhance process control.
- Establish robust end-to-end traceability for every battery.
- Derive multi-physics and data-driven models to enable more predictive design and electrode manufacturing.
- Create digital twins that can predict the outcome of alternative operational strategies for advanced process optimization.

In this way in-line mass profilometry can help battery manufacturers to tackle longstanding issues such as scrap rates, which are currently estimated to be in the order of 5% and 30%, and relatively high levels of unplanned downtime, while simultaneously helping to improve battery quality and safety.

Data analysis 1: Coating weight uniformity

Figure 2 shows a 2D heat map of coating weight uniformity in both the Cross Direction (CD) and Machine Direction (MD). It is a true, live graphical representation of coating weight data that uses a system of color coding to represent the magnitude of different values across the coated surface. The traces below and to the right of the heat map show the numerical variability associated with each emerging electrode.

In-line mass profilometry delivers 100% coating weight measurement, a statistically significant real-time dataflow for responsive decision-making. By providing complete surface inspection at full production speed it eliminates the limitations of scanning gauges and other traversing frame technology which can miss significant areas of the coating, especially at high production speeds.

The simplicity of the heat map allows process engineers, production managers, and analysts, to readily identify and investigate defective regions. For example, it allows engineers

Figure 1. LInspector Edge In-line Mass Profilometer.

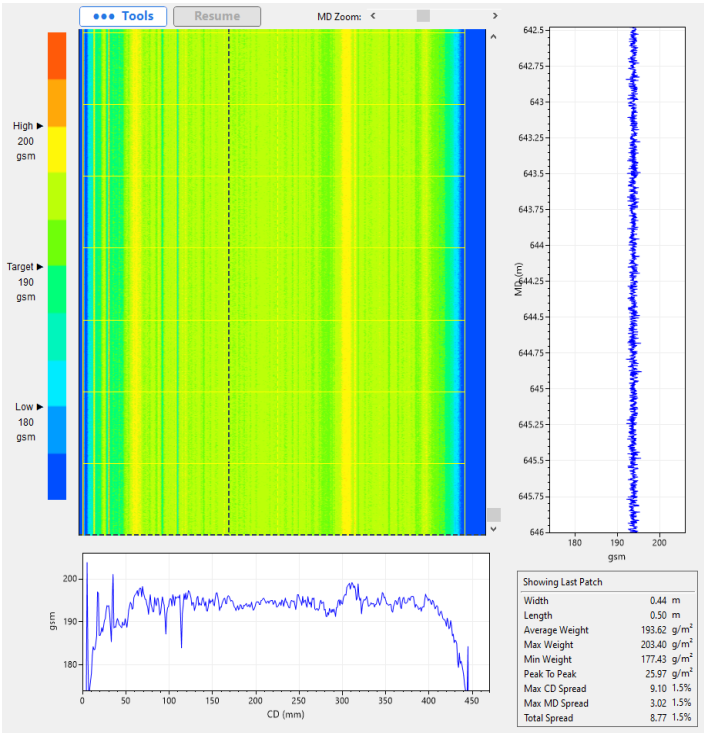


Figure 2. 2D heat map, high-resolution CD and MD profiles

to identify low/high spots, which can then be scrutinized to view the magnitude of individual values and assess the extent of variability across the electrode.

Data analysis 2: Defect detection and tracking:

At higher magnifications heat maps are highly effective in highlighting defects as shown in Figure 3. Small areas of red indicate discrete patches of excess coating such as might be seen with agglomerates or bubbles, and there are more generalized striations in blue across the surface indicating a general lack of loading uniformity across the sample.

Battery manufacturers concern themselves with a wide range of defect types including:

- Coating weight defects relating to either average weight or high / low points
- Uniformity defects such as CD spread, MD spread, total spread, Cp and CpK
- Dimensional defects – width or length
- Edge defects - shallow edge slopes or high edge slopes (bunny ear) on any of the four edges
- Scratches / streaks
- Voids/bubbles
- Agglomerates
- Contaminants
- Chatter/ribbing

Defects can be full-width, affecting a specific length of the electrode roll, or discrete and confined to a very small area.

Figure 4 shows a heat map stripe profile display highlighting edge defects (in red). Stripe edge zoom profiles for these samples are shown in Figure 5, helping to increase visibility and assessment of the issue. These show the side edges of coated stripes across CD web profiles. Together these figures illustrate some key features of the system software for defect monitoring including the ability to:

- Display a minimum of 4 stripe profiles per page and up to 16 scrollable stripes or full-width profiles
- See coated (white) and uncoated (light blue) zones in real time
- Set-up sub-zoom windows for the left and right edges of each stripe for up to 16 stripes

Statistical values and set up options are customizable for various aspects of the chart display, to meet individual processing needs. For example, in the sub-zoom window users can set the X-axis edge zoom display size (mm) and zoom width (%), with a 75/25% bias towards the coating around the target edge position. The Y-axis can be similarly modified.

Here, the red areas indicate the coating has drifted out of the defined specification creating a trigger for remedial action that can help to minimize the amount of coated electrode that will be lost to scrap. In contrast, with conventional scanning technology far more out-of-specification product is likely to be made before action can be taken to address the problem, simply because scanning systems are slower and can miss sub-standard areas of the electrode. Crucially all the data shown, while making it easier for manual decision provides a secure foundation for advanced, automated process control.

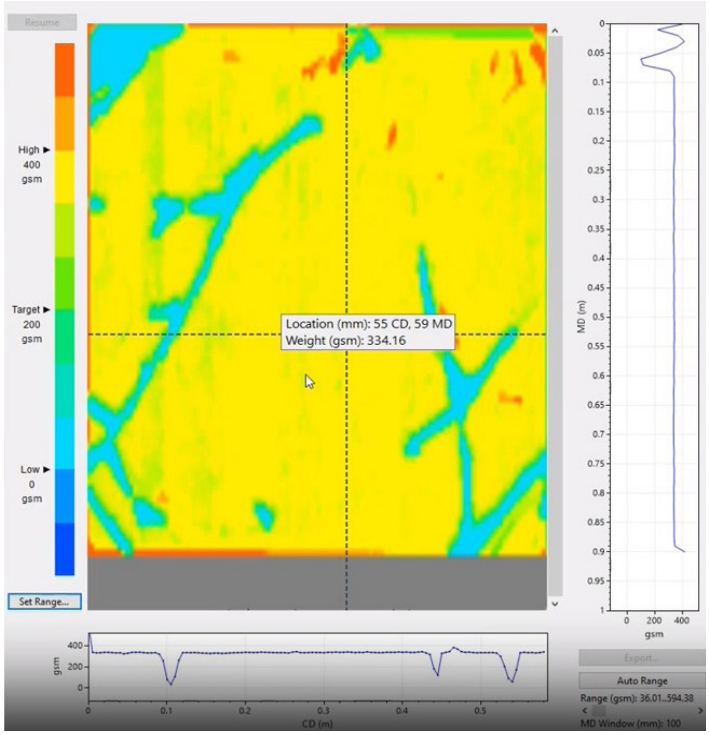
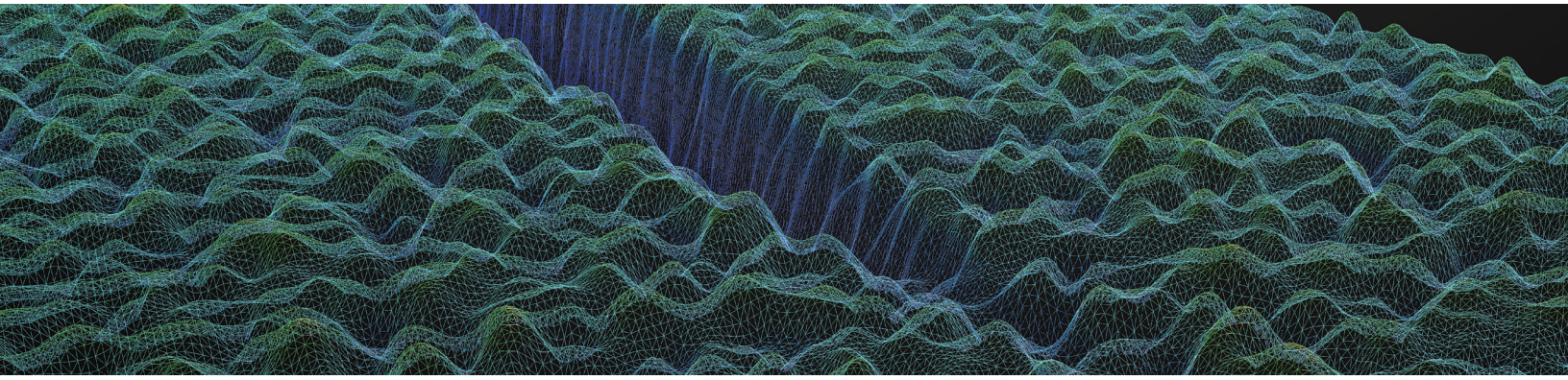


Figure 3. 2D birds eye view, high dimensional CD and MD data and defect identification

Figure 4. Heat map view with edge defect identification

Figure 5. CD stripe edge zoom profiles showing sub-zoom windows for each edge (lower half of the image)



Looking ahead

To build the smart, high efficiency processes of the future and meet increasingly stringent levels of product quality, battery manufacturers need to strengthen the knowledge that underpins production and implement advanced process control.

By capturing high resolution data at unprecedented speed and providing a versatile toolset for analysis, the LInspector Edge In-line Mass Profilometer provides a secure foundation for advancing towards this goal. Coating quality is quantified from measurements of variation in loading. Rapid, high sensitivity measurements maximize the chance of detecting and identifying defects, delivering valuable information to predict the onset of problematic effects and minimize them.

Defect-free electrodes are the foundation of high-quality Li-ion batteries, with detailed and complete quality inspection required at every production speed to reach higher productivity and quality. With the ability to measure product quality for all types of electrode coating this new technology has an important role to play in ensuring resource and cost efficiency during production and highlighting strategies for continuous improvement.

Learn more at **thermofisher.com/LInspectorEdge**

PPA-AN1010-EN_3/24