In-line metrology solutions to improve the quality and sustainability of electric vehicle batteries

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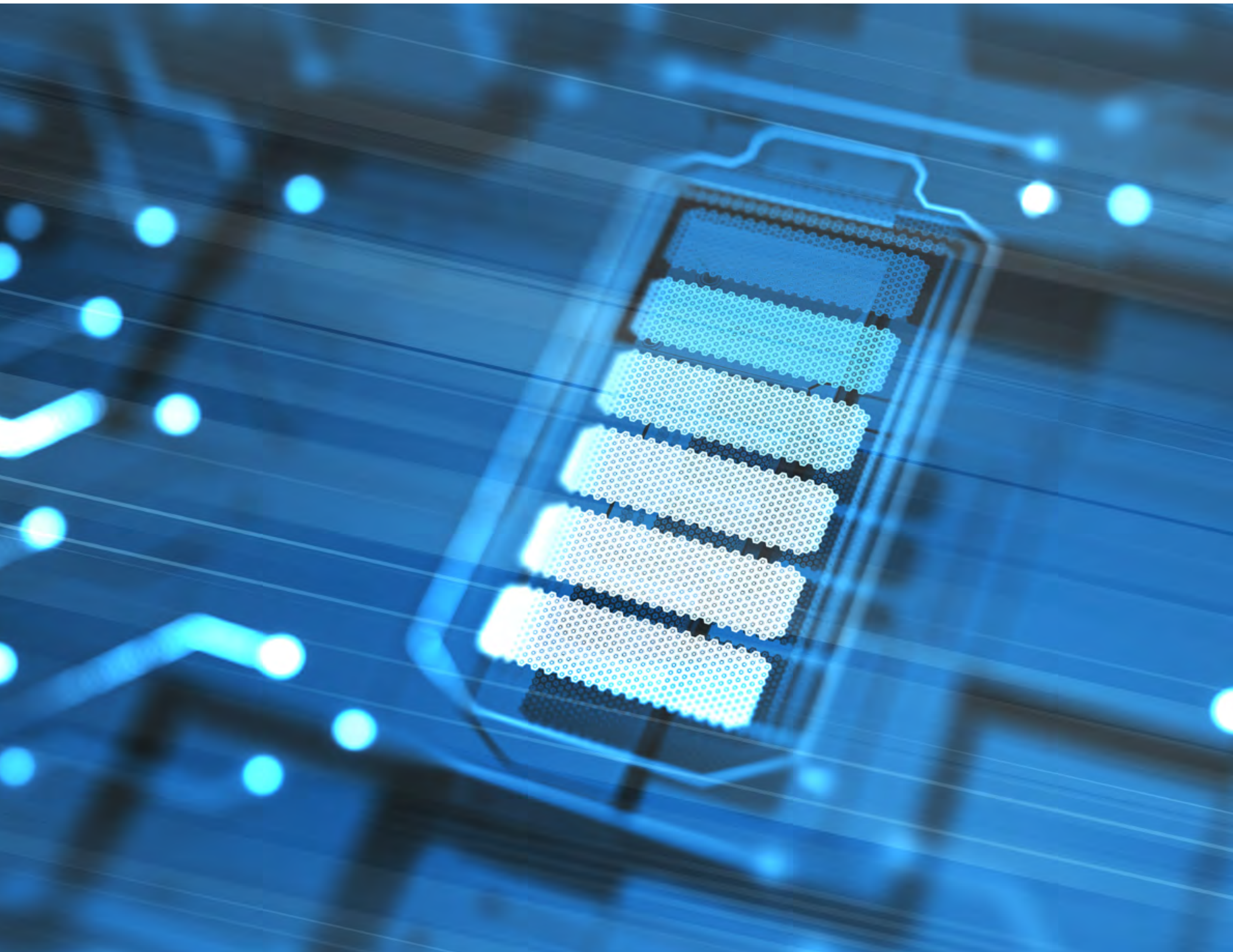

The electric vehicle sector has seen remarkable growth in recent years, putting lithium-ion battery manufacturers under increasing pressure to scale up their operations in order to keep pace with current and predicted future demand.

However, as battery cell production ramps up, it is critical to implement strict quality control measures to ensure that products can withstand the thousands of recharge cycles necessary for electric vehicles, as well as satisfying strict automotive safety standards. It is also important that the environmental benefits realised through the adoption of electric vehicles are not compromised by inefficient manufacturing processes; minimising both raw material waste and out-of-spec product scrap is vital in creating a sustainable operation. This article looks at how defects and product irregularities can affect battery performance and safety and discusses the in-line metrology solutions that can identify these issues early in the manufacturing process.

The danger of defects

Defects that are not discovered during the production process can be detrimental to performance, with even small deviations in electrode coating uniformity or separator film thickness significantly impacting the function and safety of the final product. For instance, it is essential that the coating of active material on each electrode foil is uniform to provide comparable charge storage. Unequal coating of the anode will render it unable to cope with the influx of electrons produced by the cathode during the charging process, often leading to catastrophic results. Conversely, non-uniform coating of the cathode will diminish battery capacity, restricting the distance an electric vehicle can travel on a single charge. Tiny defects – like coating flakes and chips – can also lead to safety issues, with internal failures sometimes causing fire and even explosion. This is why routine quality control checks should be in place to keep coating thickness strictly within specifications, and to identify defects before they make it into the finished product.

Manual monitoring

Quality control on an electrode coating line can be achieved through manual film thickness measurements and visual defect identification, with the operator undertaking a series of appropriate parameter adjustments to keep the process within acceptable tolerance levels. In reality, the infrequent nature of these checks, together with the subjective nature of human defect detection, can lead to products veering out of spec before any changes can take effect, resulting in high levels of product waste. However, this challenge is easily overcome with the implementation of continuous in-line metrology solutions – like the Thermo Scientific™ LInspector™ Measurement and Control System – which monitor the electrode coating process in real time, ensuring that specifications are adhered to and defects are quickly detected, ultimately resulting in a better controlled and more sustainable process.

Image 1: Metrology solutions like LInspector Measurement and Control System monitor the electrode coating process, detecting defects in real-time

Source: Thermo Fisher Scientific

Sensor selection

The use of in-line measurement systems can help to ensure that battery base structures meet the energy densities, recharge rates and physical dimensions required for demanding automotive applications. These systems are fitted with a sensor that scans back and forth across a moving reel of substrate to provide in-line thickness and coating weight measurements, as well as real-time defect detection. The ability to precisely detect coating variation is dependent on several factors, the first being how well the sensor type matches the application. For example, while confocal laser sensors are perfectly suited to measuring the thickness of calendered electrodes, coating weight is best determined using X-ray or beta technologies. Conversely, optical inspection methods and the analysis of infra-red emissions are better suited to separator film thickness measurements. Choosing a sensor with a suitable beam shape and size is also important. Narrow slot sources, for example, can identify streaks, wrinkles, scratches and edge defects in far more detail than wider sources, which are prone to image blurring.

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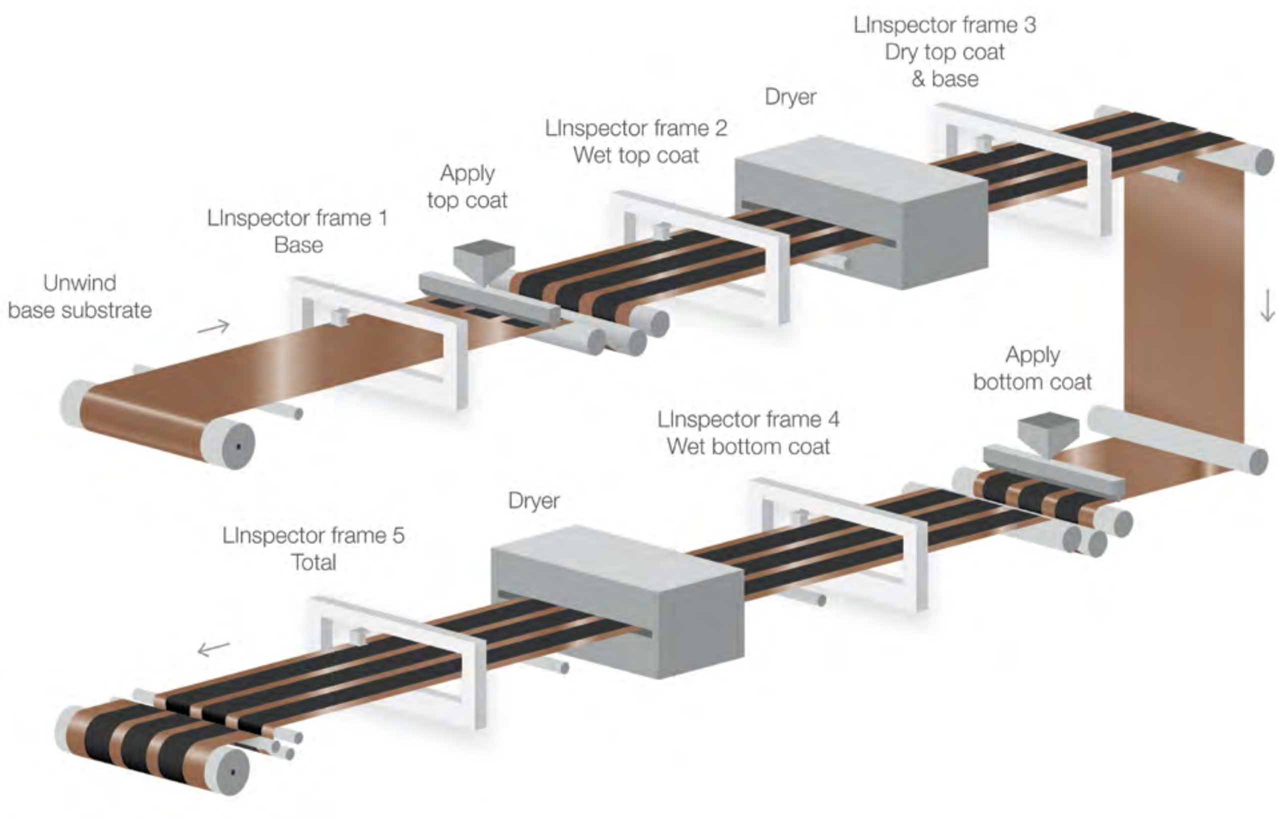
Image 2: The end-to-end electrode coating process monitored and controlled at all stages.

Source: Thermo Fisher Scientific



Scanning speed

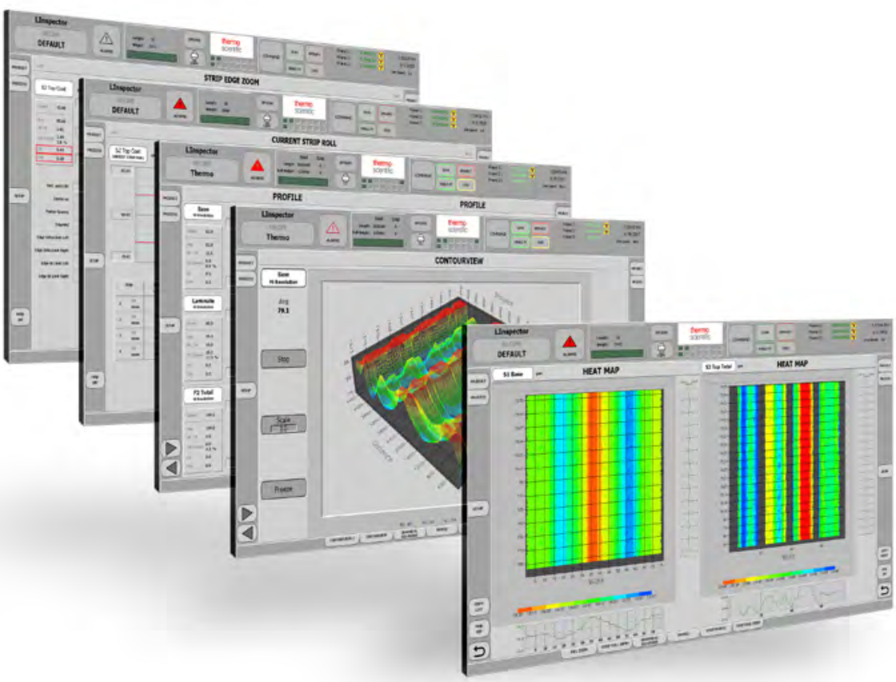
In addition to a suitable sensor type, the scanning speed of the system – the pace that the sensor traverses the material – should also be taken into consideration, since this determines the amount of coating measured in a given time-frame. Because the sensor moves perpendicularly relative to the processing direction, it traces a zig-zag measurement path across the material, inevitably allowing some defects to slip by undetected between passes. Intuitively, it may seem like the best way to avoid this would be to increase the scanning speed, however, the response time of the sensor may not be fast enough to generate an accurate representation of the surface due to blurring, which increases the risk of poorly resolved defects. In the end, it becomes a compromise between measurement accuracy and the amount of material measured, balancing the scanning speed against the response time of the sensor.

Accurate automation

Acquiring precise measurement data is only part of the story, and the next consideration is how to use this information. For instance, automatic profile control can be used to process the data generated by a metrology system, creating a feedback loop between process measurement and adjustment to keep the coating thickness within specified limits. This significantly reduces both raw material and product waste, creating a more sustainable process. Additionally, this data can provide a valuable reference in the event of a downstream issue – like a vehicle charging problem or safety concern – with everything from CPK values to time-stamped images accessible at a moment's notice for traceability, quality control and troubleshooting.

Image 3: Example reporting capabilities available with an in-line metrology system, including specific displays for battery manufacturing.

Source: Thermo Fisher Scientific



The electric era

The number of electric vehicles on our roads is undoubtedly set to increase even further over the coming years, and lithium-ion battery manufacturers must resolve quality and throughput issues to have any chance of meeting the demands of this fast-moving sector. Eliminating manual measurements and implementing in-line metrology is an ideal solution that will allow manufacturers to produce consistently high-quality products at the scale required to service the automotive industry. Continuous monitoring solutions are key to reducing both raw material and product waste, steering lithium-ion battery production towards a more sustainable future.