Technology Brief

dr. schenk

Munich, Germany, June 2022

Particle detection as a new challenge in cell production – quality monitoring in lithium battery production

The growing need for independence from fossil energy sources sees billions invested around the world into research, development and production of lithium-ion batteries, corresponding drives and vehicles. While good solutions for many technical challenges have been found, the focus shifts increasingly to operational safety and long-term stability of the very expensive energy storage systems.
This was made clear by the maritime desaster off the Azores in February 2022, when a container ship sank, carrying some 4,000 e-cars worth approximately EUR 330 million. Whether the catastrophic fire was caused or accelerated by lithium-ion batteries has yet to be verified, but cannot be ruled out.

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SCAN ME

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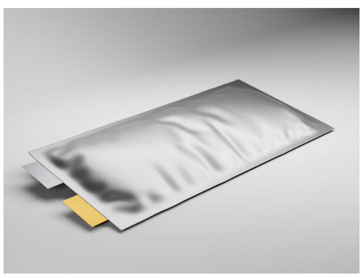
It has been modified for this technology brief.

Safety first!

How can this power source be made even safer? One way is via detection of particles on the electrode foils of the batteries. This stems from the battery design, with strongly charged energy carriers, i.e. the anode and cathode foils, kept apart by porous plastic foils of only about 5-20 µm thickness. When particles rub through these films during charging and discharging processes, a short circuit can easily occur, leading to uncontrolled discharging, high heat generation and often a battery fire that is practically impossible to extinguish.

What does Dr. Schenk offer to detect smallest particles?

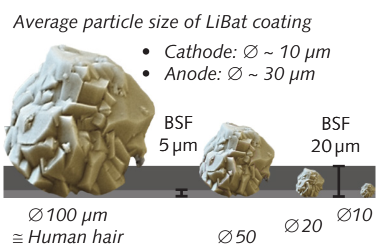
Dr. Schenk GmbH has been working on particle detection on the electrode foils of lithium-ion batteries since 2015 and has developed a dedicated inspection process for this purpose. It is now not only possible to detect smallest particles of 10 µm and possibly even smaller but to do so fully automatically and in the shortest possible time. This helps assess the quality of the surfaces or the effectiveness of the blade cleaning processes.



Why are these new solutions not implemented everywhere yet?

Reliable detection of such small objects is a joint effort. This can lead to a procurement dilemma when battery production is implemented in separate modules. Simplified, these can be divided into Coating/Drying – Calendering – Slitting – Notching – Cutting – Stacking/Winding. After each process step, optical quality control is typically provided within the respective machine modules.

At least three parties are involved in selection and procurement: The engineers of the battery manufacturer, their purchasing department and the suppliers of the modules, who are typically based in China and offer complete solutions, including inspection. The procurement dilemma results from the parties' different goals, with engineers demanding perfection and operational reliability, purchasing focused on procurement costs, and the module manufacturer pressing for rapid project completion and final acceptance.

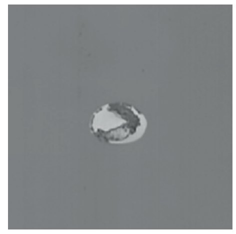


Scale representation of separator film thickness (BSF) cp. with human hair and different sized particles on lithium ion battery electrode coatings

Who is in charge of the final product's quality?

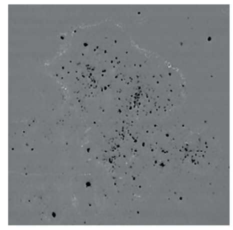
Despite their different goals, the parties reach good solutions, e.g. the module manufacturer prefers the inspection supplier with whom he has worked in the past. This guarantees smooth coordination during inspection integration and interaction during final acceptance has also already been tested. But it places considerable additional effort on his customer during production. Integration of another inspection system, possibly better suited to the battery manufacturer's tasks, could make the module more complex and more expensive from its manufacturer's point of view and could jeopardize delivery time.

The battery manufacturer's purchasing department is receptive to these points and – if necessary – the engineers can adapt the specification. During procurement and implementation an agreement is reached quickly, with shortest possible module delivery time currently being paramount. But the crucial question is: Who ultimately is responsible for the quality of the quality control and the long-term quality of the final products? The module manufacturer with his preferred inspection partner? The purchasing department, focused on timel and cost-effective procurement? The engineers, having to ensure quality and safety of the products for the final customer on behalf of the battery manufacturer?

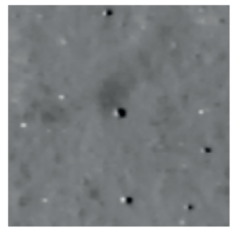


How can this potentially dangerous situation be remedied?

An alternative and strategic adaptation on the side of the customer to the steep quality requirements in lithium-ion battery production would be for the battery manufacturer to take the lead of the quality control process, selecting an inspection provider and making it mandatory for all module manufacturers to install the products of that provider, assuming he can meet the challenges of the different processes, particularly those of particle inspection.

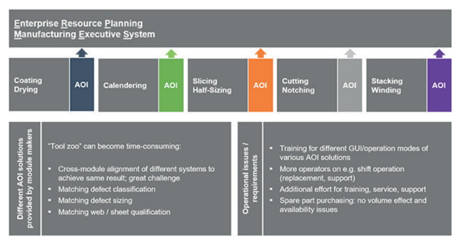


While the module manufacturer is an expert in his own process, this is not true when it comes to inspection. From the modular, complete solutions mentioned earlier with included inspection, it follows that optical quality control in the production of lithium batteries has not yet been established as a cross-module independent process. The module manufacturer in effect checks his own process, which may lead to a lack of clarity. And the battery manufacturer faces the operating problems of a diversified system landscape.

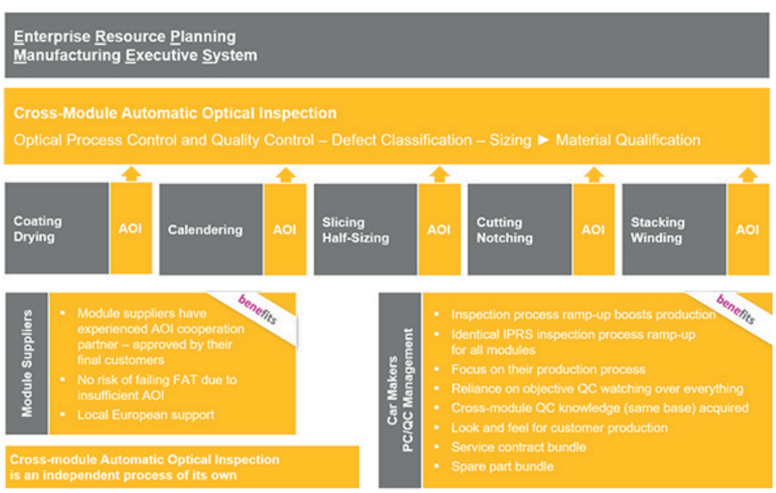


What makes the detection of debris particularly challenging?

Battery manufacturers are noticing the importance of particle detection on electrode foils. These particles (in the order of magnitude of the respective composition of the coatings, ~ 10-30 µm) are created by sheet separation cutting processes. Mechanical and laser-based tools cut individual sheets out of the layered electrode foils (active coating – metal – active coating), resulting in debris mostly near the cut edge. Lack of material contrast makes it difficult to detect the particles on the microcrystalline, optically noisy substrates. Compared with the release film, the debris is enormous, can easily penetrate the film and poses a serious threat to the function and long-term stability of lithium batteries.



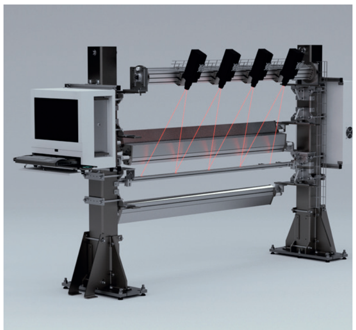
Possible negative effects of inconsistent quality assurance systems in lithium battery production



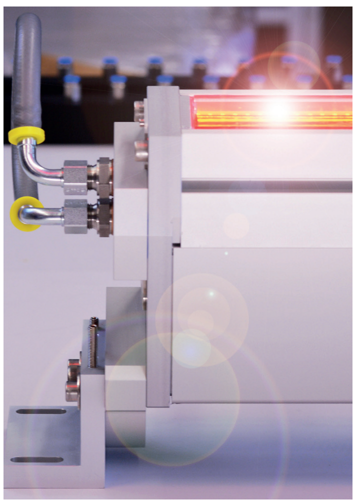
What an alternative fitting of production modules with inspection could look like.

From a quality assurance perspective, optical process and quality control are established within battery production as an independent, cross-module and harmonizing production process, serving its true purpose of final, independent inspection authority even better. Battery quality and long-term stability are ensured independent from module manufacturers and in accordance with the criteria set forth by the engineers.

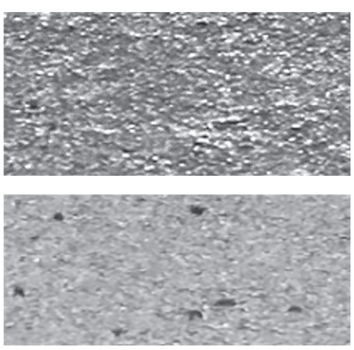
Leading technology



A Dr. Schenk EasyInspect solution (exemplary image of a 4-camera configuration as may be used in plastic film inspection)



Dr. Schenk Sirius Light Technology (SLT) delivers more light to the material surface



Same particles on crystalline LiBat electrode surface

Above with conventional illumination, below with Dr. Schenk SLT illumination. The resolution required to detect particles shows the optically noisy microcrystalline structure of the foil. Only a dedicated optical configuration can clearly distinguish particles from foil surface structure.

What does a Dr. Schenk AOI solution look like?

For this highly complex inspection task and all other cell production processes Dr. Schenk developed production-safe in-line and off-line solutions. The modular EasyInspect from Dr. Schenk comprises a mounting beam with precisely aligned 8K dual line CMOS cameras, ultra-bright LED illuminations of the same width as the material featuring dynamic cooling, an all-in-one electronics box and an operator terminal box including screen, computer, keyboard and mouse.

Ultra-bright LED lamps illuminate a narrow strip of material across the entire width of the machine. The cameras focus on this area and scan the web or cut-sheet material line by line – without gaps. The optical resolution is determined by the number of cameras (resolution across machine direction) and the number of scans per second (resolution in machine directiontion). Video signals above an adjustable threshold are considered local deviations (defects) and evaluated in detail.

How important is the correct classification of defects?

Dr. Schenk pays particular attention to the classification of defects. It is primarily through correct classification that causes of defects can be determined and eliminated. In addition to simple threshold and feature-based classification, Dr. Schenk uses neural network-based classification. The latter can segment and classify even low-contrast defects from their surroundings in the gray image – independent from the threshold. Special defects and critical defect accumulations within defined areas trigger events such as alarms or a signal to a marker.

Why is the synchronization of illuminations and cameras so important?

AOI configurations dedicated to the inspection of different battery foils take the respective optical properties of the base material and of the defects to be detected into account in equal measure. The primary goal is their distinction from the base material through an optimized defect signal, thus ensuring production-safe quality monitoring.

For this purpose, up to six different illuminations can be clocked synchronously with one row of cameras. Observation angle, illumination direction, specific distribution of light, wavelength and light intensity can be varied individually. In this way defects are detected according to their contrast effect (light absorption), light deflection (distortion), and orientation or a mix of these properties.

Up to six independent optical channels operate on a single scan line. They detect typical coating defects, lumps, scratches and particles on electrodes as well as black spots, gels, dents and low-contrast defects on separator and pouch-pack films. With this MIDA (Multiple Image Defect Analysis) inspection configuration all six channels can be switched up to 140,000 times per second. The results of the channels are evaluated together, enabling comprehensive material control through the best possible defect detection.

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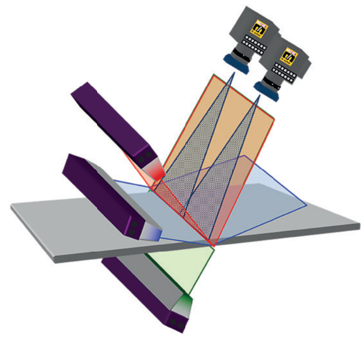
The combination of fast cycle times and high web speeds requires particularly high levels of light, provided by LED illuminations with Sirius Light Technology. Even monitoring of coated foils with an optical density of up to 3.3 with transmission optics is possible using SLT.

Can the Dr. Schenk solutions detect large-area changes in the material?

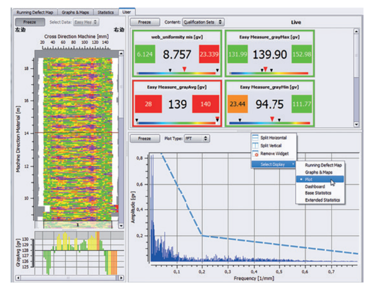
They certainly can – with EasyMeasure. EasyMeasure provides optional simultaneous area analysis using the EasyInspect hardware. While inspection detects local deviations (i.e. defects) in the material and evaluates only these, EasyMeasure uses all camera pixels as individual brightness sensors. All signals are used in their entirety for analysis of the area. They are recorded numerically with high precision and repeatability, as thickness or reflection changes over the complete material width and length, and then interpreted using statistical functions.

Surface tiles consisting of tenthousands of pixel signals are evaluated in real time. The size of the tiles can be adapted to the respective material. Unauthorized deviations from the target value allow immediate initiation of countermeasures on the production line.

In addition to thickness or reflectance monitoring, the optional integrated Fast Fourier Transformation calculates unwanted regularities in the product, providing indications of interfering periods and frequencies. These can be caused, for example, by deflection rollers, extruder screws or poorly-tuned process parameters.



Dr. Schenk MIDA configuration for battery foil inspection



Integrated Fast Fourier Transformation helps identify interfering periods and frequencies

EasyInspect

Detection, classification and qualification of local defects

EasyMeasure

Monitoring of overall material properties

About Dr. Schenk GmbH

Dr. Schenk GmbH offers inspection and measurement solutions for automated quality assurance and production process control - e.g. plastics, textile materials, nonwovens, paper, metal, or glass, for a multitude of markets such as display glass, automotive, packaging, medical, renewable energy, and many more.
Throughout the world Dr. Schenk's 300+ employees continue to set new standards for the inspection of surfaces. Over 18,000 m² of modern, cleanroom-capable production and testing facilities are available for research, development and production to apply cutting-edge optics and electronics to customer applications.
From modular standard units to highly customized systems – Dr. Schenk's solutions have your material in focus!

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