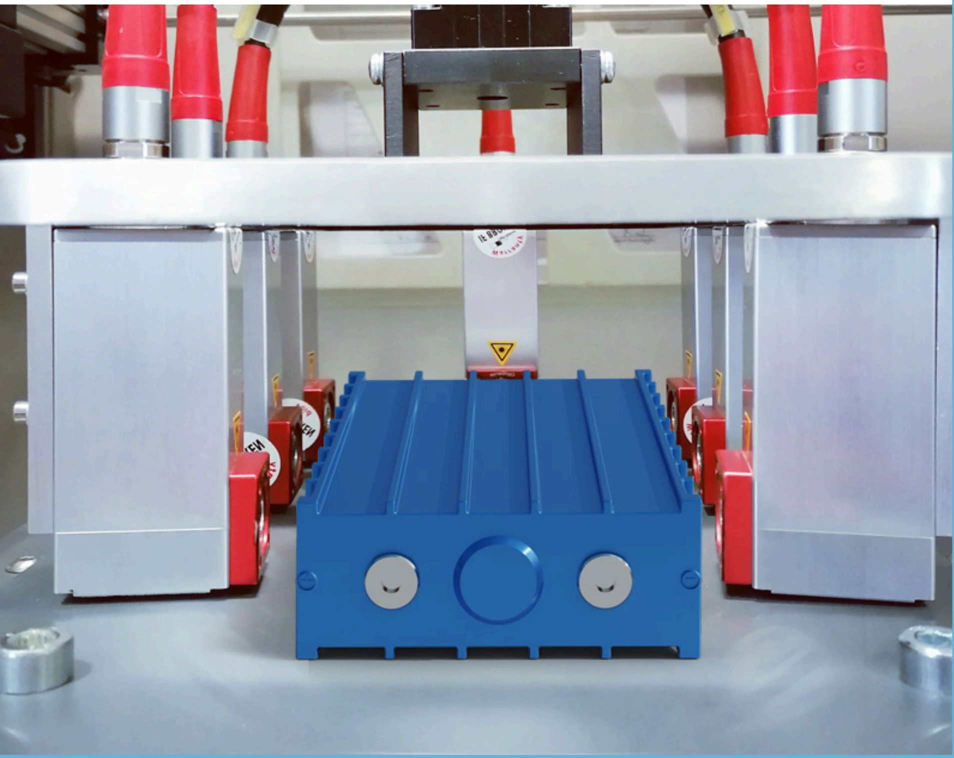
Whitepaper



OptiSense goes Battery

Over twenty years ago, OptiSense started as a spin-off from the Fraunhofer Institute. Today the manufacturer from Haltern is considered to be the market leader in miniaturized measurement solutions, whose quality and technology are widely known as "Designed and Made in Germany".

The same applies to measurements on lithium-ion battery cells. This white paper shows how a photothermal "early warning system" is created. The special testing technology developed by OptiSense is used to reduce rejects and continuously improve battery production.

Quality assurance in battery production

Inline testing technology for lithium-ion batteries

In order for a lithium-ion battery to be competitive, it must be manufactured inexpensively, have a high energy density and last as long as possible. When manufacturing battery cells in millions of units, high quality is extremely important; because faulty production can, in extreme cases, lead to self-destruction and a fire in the battery. So above all, the battery has to be safe.

Production-integrated test systems – ideally coupled with intelligent data concepts – are increasingly becoming a central element for effective quality assurance and the associated increased cost-effectiveness in battery production.

Photothermal coating thickness measurement, as offered by OptiSense, the market leader in coating thickness measurement, can make an important contribution to the aspects of cost reduction, resource saving and safety for lithium-ion batteries.

The specially developed photothermal inline testing technology continuously optimizes the quality of battery production: from slurry application to coil testing (left) to measuring the isolating paint coating thickness on the battery enclosure

High-performance and inexpensive energy storage as a key component in competition

The production of lithium-ion cells faces major challenges. Rapidly increasing demand combined with growing requirements on quality and low prices are putting cell manufacturers around the world under pressure. It is important to continuously increase process efficiency and stability and to further ensure competitiveness and sustainability over the next years.

However, existing approaches are reaching their limits when trying to to achieve these goals. For future widespread use of lithium-ion batteries for mobile or stationary energy storage, production costs of the battery cells must be further reduced. Fewer manufacturing faults and the associated low reject rates are a central requirement for economical production.

Rejection rates in battery production as a central requirement

In order to ensure the best possible quality in battery production, defects should be detected early in the manufacturing process, i.e. before further processing. So far, batteries have almost exclusively been checked for proper operation at the end of their manufacturing process in the so-called end-of-line test. And even there, hardly any test procedures are available for these demanding tasks since traditional measurement methods such as eddy current sensors would impair the process flow through direct mechanical contact. With the photothermal measurement technology developed by OptiSense, manufacturers of lithium-ion batteries now have an "early warning system" at their fingertips that can test battery components during the production process.

Photothermal test method for cell production

In order to detect manufacturing faults in the various cell formats at an early stage, the German manufacturer OptiSense developed a test system that essentially relies on photothermal energy to determine the thickness of coatings – in this case electrodes and insulation of the battery cell – in a non-contact and non-destructive manner. The different thermal properties of the coating and the substrate are used to determine the absolute coating thickness.

The surface of the coating is heated up by a few degrees with a short, intense light pulse and then cools down again by dissipating the heat into deeper areas. The thinner the coating, the faster the temperature drops. The temperature profile over time is recorded with a fast, highly sensitive infrared sensor and converted into a corresponding layer coating.

Thanks to the tiny measuring spot, corners and edges of the smallest components can be precisely measured. The data obtained in this way is aggregated, structured and evaluated using an intelligent concept. This enables battery manufacturers to recognize fault patterns, optimize production processes and establish holistic production data management. This paves the way to completely new quality criteria and standards in battery cell production.

The battery manufacturing process

In the battery manufacturing process stages shown below, the cells can be tested in the different production phases using the OptiSense measuring approach. Thanks to the inline inspection system, coating thickness faults can be detected during production without touching the sensitive surface.

Measurement of the slurry coating

In the first step, the powdery raw materials of the electrodes are mixed with water and solvent.

For the anode, this is primarily graphite, i.e. carbon. For the cathode it is a metal oxide consisting of nickel, cobalt, manganese and lithium. The materials are used to create electrode pastes called slurries. The slurries are applied to thin, metallic carrier foils. The cathode slurry is put on aluminum foil, and the

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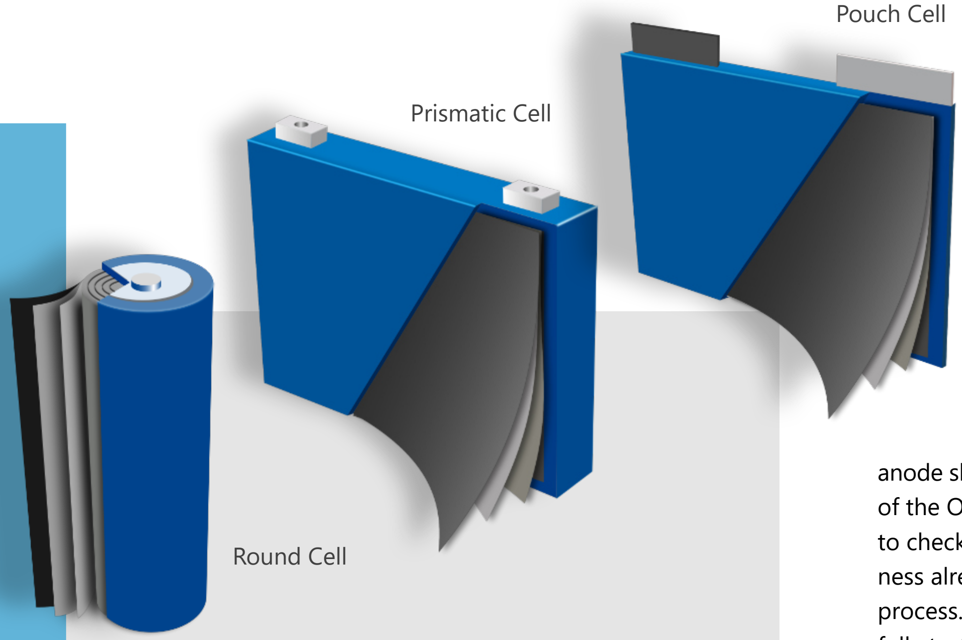


The battery and its cell formats

Round cell, prismatic cell and pouch cell

The lithium-ion battery modules consists of several battery cells. Each battery cell contains an anode, a cathode, a separator and the liquid, ion-conductive electrolyte. The lithium ions move from one pole to the other through liquid electrolytes. This happens in a vacuum under complete exclusion of air.

The battery cells perform the central task of the battery: storing and releasing energy. Depending on the application – e.g. in entertainment electronics or in the automotive industry – cell size and format differ. The majority of battery cells are available in three formats: cylindrical, prismatic and as a thin, flexible pouch variant.

The different cell formats are manufactured in a similar way, but there is a key difference in the manufacturing process: in the case of the cylindrical cell, the electrodes and separators are wound, in the case of the pouch cell, they are stacked. The layers of a produced cell can be wound flat or stacked. In contrast to the pouch cell, the enclosure of the prismatic cell consists of a rugged material, usually metal.

anode slurry on copper foil. With the help of the OptiSense aproach, it is possible to check the quality of the coating thickness already at this early stage of the process. The method has been successfully tested on electrodes in series tests in the laboratory.

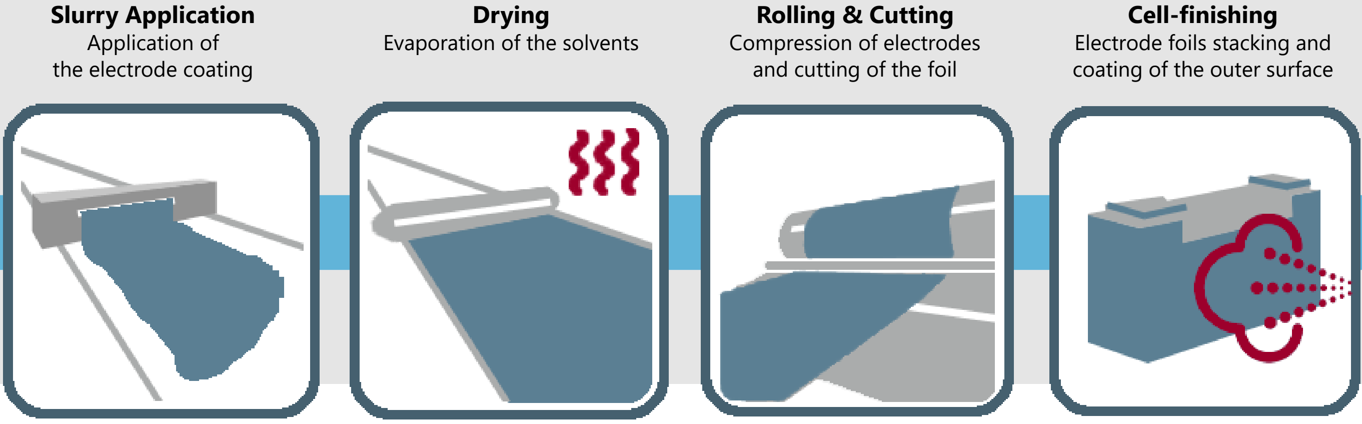
The particularities of about slurry application

The slurry is applied on both sides, so the foils cannot be laid down. It hovers through a drying machine on an air cushion. Significant costs can already be saved after this processing step by detecting faulty coatings and avoiding drying cracks. The powerful and modular test systems based on "Paint Checker industrial Tube" sensors are particularly suitable for this demanding task due to the seamless integration capability into the automation process of the production line.

Electrode testing using OptiSense technology

In the next step, the coated foil runs through a rolling mill, the technical term is calender. During this process, 200 tons of pressure are applied to the coating. The goal is a coating with uniform thickness; which varies only a few micrometers around the target value. The OptiSense technology can check the coating thickness of the rolled foil, i.e. the anode material (graphite) on copper foil and

Different process stages of battery manufacturing



the cathode material (lithium compound) on aluminum foil. The short measuring time of the OptiSense technology is ideally suited for the contactless inline characterization of the calendering process in lithium-ion battery production. For this purpose, the sensors are mounted at various positions on the rolling mill. By combining many individual sensors into a sensor array, the measurement reliability increases. at the same time, the system is less prone to false measurements.

Coil test

The foil tape is still too wide for a battery cell, so it is cut into narrow strips. This long, narrow electrode tape is cut to the proper length by a machine. The white separator film mounted between the two electrodes is also cut to length. In addition to the drying and calendering process, the OptiSense photothermal inspection system can detect uneven coatings without contacting the surface, thus avoiding costly rejects.

Cell finishing

After the coated electrode foils have been dried, rolled and cut to size, they are assembled into battery cells. Special machinery stacks the different foils on top of each other thus forming a battery cell. Special machinery stacks the different foils on top of each other thus forming a battery cell.

Excessive foil is cut off, thus bringing the electrodes to a uniform size. The protrusions form the connection to the energy supply, i.e. the plus and minus pole of the cell. They are the connection to the outside world; and are welded by a laser. In a pouch cell, the finished stack is wrapped in aluminum foil. It will later be sealed in such a way that a waterproof bag is created. The pouch cell is flexible and, can easily dissipate heat via it's large surface. In a prismatic cell the stack is enclosed in a sealed metallic housing. The enclosure gets a paint coating isolating the cells from each other in the final battery assembly. The thickness of this insulating layer is already tested inline in several production lines using OptiSense photothermal sensors:

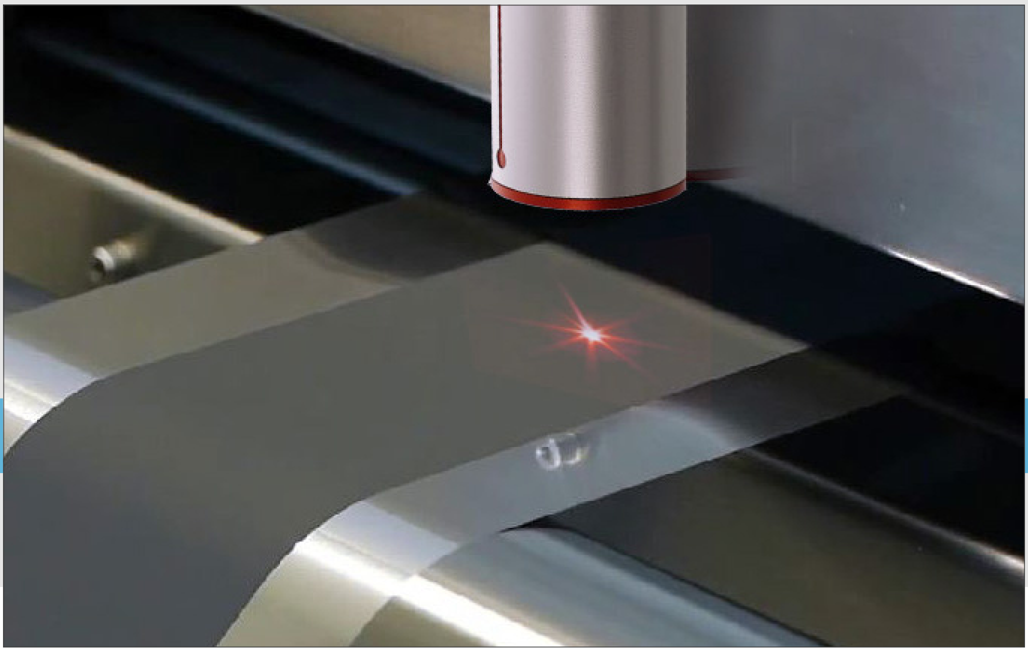
From battery cell to module

Many automobile manufacturers use flat pouch cells for their e-mobiles, as these can be manufactured and folded in any shape thanks to their flexible shell. To protect against damage and to dissipate heat, the cells have a rugged aluminum enclosure that is hermetically laser-welded. The enclosure is often coated with a light-curing paint, which is then cured directly in a UV chamber. Several of these cells are combined to form a battery module. Size and number of these modules finally the vehicle's performance and range. Up to 800 volts are present – significantly more than at the domestic mains socket. The cells must therefore be isolated from each other in order to reliably prevent a short circuit and possible burn-out of the entire battery.

For this purpose, the outside of the cell is equipped with a coating that must both protect the surface and take on the necessary insulation function. The coating thickness is a safety-relevant parameter that must be carefully monitored in production. The coating thickness can be checked precisely using OptiSense's photothermal technology.

The coating thickness on the outside of the cell is a safety-relevant property

Since the coating thickness is a function-critical property, all types of coating defects such as uneven paint application or paint flow as well as damage, scratches, cracks or trapped particles such as dust or lint must be reliably detected. Hence, a non-contact, 100 percent test is very advantageous: Immediately after coating, each cell moves on a conveyor belt to a measuring station. Here the thickness of the coating is checked at several positions by OptiSense systems without touching the cell. With the photothermal measuring method, a fast, quantitative determination of the coating thickness is available, which delivers precise, reproducible results. However, short cycle times and limited space regularly present very special challenges: In order to



OptiSense technology checks the coil, a long, narrow electrode strip

assess the quality of the coating as a whole, measurements are taken at several positions, as outlined above. But the measuring time cannot be shortened arbitrarily due to physical reasons. It would take too long to move a single sensor from one measuring point to the nextand the conventional sensors available on the market are simply too big for simultaneous multi-point measurement.

For this reason, a system was developed that can measure several points at the same time and whose sensors are small enough to accommodate them next to each other in the tightly limited space. After just four months of development, the PaintChecker industrial n-gauge, a photothermal measuring system for non-contact, non-destructive coating thickness measurement, was created that can control several sensor heads simultaneously. It is suitable for wet and dry organic coatings such as paints, varnishes and powders on metal, rubber and ceramics. The system consists of a central controller to which up to eight sensors can be connected. The PaintChecker industrial n-gauge has various interfaces to an upstream PLC for software integration into the production line.

Performance parameters for applications in electromobility

By folding the optical path of the optics by 90°, it was possible to shorten the sensor head so that it fits into extremely cramped installation environments.

With the angle sensor, which weighs just 150 g, coating thicknesses of up to 300 µm can be measured quickly, accurately and reproducibly within a mounting depth of just 40 mm. Several coating lines have meanwhile been equipped with the new OptiSense test system and immediately delivered excellent results.

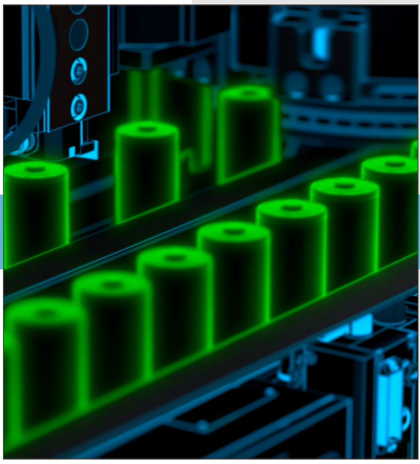
As a function-critical quality parameter, the coating thickness is subject to strict requirements regarding the accuracy and reproducibility of the measurement. As part of a measurement equipment capability analysis, the photothermal measurement process from Optisense was once again able to prove its superiority.

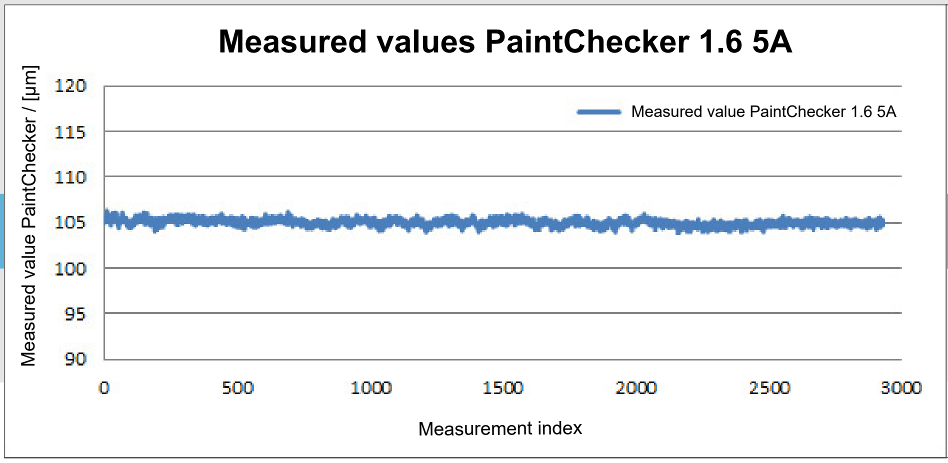
After 6 ½ hours of endurance testing with over 2,900 measuring cycles, the standard deviation of the measurement was below half a micrometer and was thus far more accurate than what can be achieved with conventional eddy current or magnetic induction measuring methods.

Digitization of battery production

With a focus on the digital transformation process, networked, digitally backed production and quality assurance of

The extremely low scatter of the measured values proves the high quality of the photothermal coating thickness measurement.





battery cell and module production is playing an increasingly important role. The digitization of industrial manufacturing is a key to optimizing the entire production chain and thus increasing the competitiveness of companies.

OptiSense is testing innovative data-driven approaches for process monitoring, control and quality assurance on industry-related pilot lines. In this way, battery production processes can be designed in a modular and requirements-based manner in order to significantly improve product quality and increase profitability of battery production.

Conclusion

This whitepaper presents solutions for the large-scale production of all three lithium-ion battery formats (round, prism, pouch cells) in several stages of manufacture: in slurry application, in the production of the electrode foils, in cell finishing and in the coating of the enclosure. With the photothermal measurement technology developed by OptiSense, manufacturers of lithium-ion batteries have an "early warning system" at their fingertips that can test battery electrodes before curing and further on over several production steps, thus significantly minimizing rejects. Closely monitoring the coating thickness is a key factor in many aspects of battery production and can greatly improve cost reduction, resource conservation and product safety. The successful applications and unique selling points of OptiSense test solutions are a solid basis for competitive cell manufacturing and thus a sustainable and long-term positioning in the field of battery production.

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