RESEARCH NEWS

Fraunhofer at the Hannover Messe 2023

Laser technology for energy-efficient production of battery cells coupled with improved performance

High-performance battery cells are a crucial prerequisite for electrifying the mobility sector. In light of this, researchers at the Fraunhofer Institute for Laser Technology ILT in Aachen have developed innovative laser-based technologies for producing lithium-ion batteries that, compared to those produced conventionally, can be charged more quickly and have a longer lifetime. Furthermore, laser-based drying is a significantly more efficient means of coating water-based electrodes. Using a demonstrator, Fraunhofer ILT will present its forward-looking laser technologies for battery cell production at the Fraunhofer booth (Hall 16, Booth A12) at the Hannover Messe 2023.

Whether they are used in stationary energy storage systems or in electric cars, buses, bikes and scooters, batteries will play a central role in the mobility of the future. This is why researchers around the world are working on improving battery performance. Scientists at the Fraunhofer Institute for Laser Technology ILT in Aachen have recently developed two laser-based manufacturing technologies that not only save energy in production, but also make it possible to create battery cells with higher power density and a longer service life.

One of the key steps in producing lithium-ion batteries is the manufacture of graphite-based electrodes. For these electrodes, a copper foil is coated with a graphite paste using roll-to-roll processes and then dried in a continuous furnace at 160 to 180 degrees Celsius. As well as consuming a great deal of energy, the gas-powered continuous furnaces – which feeds the copper foil on a conveyor belt – take up a lot of space: They are between 60 and 100 meters long and dry up to 100 meters of foil per minute when operating on an industrial scale.

Efficient drying with diode lasers

The researchers at Fraunhofer ILT have developed a system in which a diode laser carries out the drying process. The laser beam has a wavelength of 1 micrometer and is amplified by special optics that illuminate the electrode over a large area. The optics were specially designed for the drying system by Fraunhofer's industry partner Laserline. Samuel Fink, group leader for Thin Film Processing at Fraunhofer ILT, explains the principle behind the process: "In contrast to the hot-air drying process, our diode

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laser projects a high-intensity beam onto the copper foil, which is coated with graphite paste. The jet-black graphite absorbs the energy. The resulting interaction causes the graphite particles to heat up and the liquid to evaporate." The Fraunhofer technology provides a number of benefits: Compared to power-guzzling continuous furnaces, the diode laser is very energy-efficient, and the system gives off little heat to the environment. Furthermore, the laser drying system takes up much less space than conventional furnaces. "Drying with the diode laser will reduce the energy required by up to 50 percent and the space needed for a drying system on an industrial scale by at least 60 percent," predicts Fink.

Modified 3D electrode structure for improved performance

In addition to these benefits, the team at Fraunhofer ILT has been able to improve the power density and lifetime of the lithium-ion batteries. Once again, thanks to laser technology: in this case, a high-power ultrashort pulse laser (USP) with 1 millijoule of pulse energy introduces a hole structure, referred to as channels, into the battery electrode. These channels serve as a highway for the ions – they significantly reduce the distance the ions have to travel and shorten the charging process. At the same time, this prevents defects from occurring, which in turn increases the number of charging cycles and ultimately extends the lifetime of the battery.

Both the laser-based process for producing the hole structures and the positive impact they have on the battery cell are well-known, in theory. What the Fraunhofer researchers have done is to transfer the principles into praxis: from the laboratory to a scalable, industry-ready process that uses ultrashort pulse laser radiation in the femtosecond range to modify the electrodes. "The short interaction time of the laser pulses is sufficient to ablate the material, but also prevents the holes from melting, which means that the battery does not lose power," explains Matthias Trenn, team leader for Surface Structuring at Fraunhofer ILT.

One of the challenges the ILT scientists faced was how to process larger areas to achieve the high throughput required for industrial production. The Fraunhofer team solved this problem by using a multi-beam arrangement with parallel process control. Four scanners, each with six beamlets, process the foil in parallel. They cover a width of 250 millimeters and process the graphite layer continuously. The multi-beam optics were developed and implemented in close collaboration with Pulsar Photonics GmbH, a Fraunhofer ILT spin-off founded in 2013.

The research conducted at Fraunhofer ILT demonstrates that laser technology can be used as a digital production process to improve the quality of battery cells and significantly increase sustainability during manufacturing. "The next step is to scale up the technology from the prototype to an industrial production line," says Matthias Trenn.

People visiting the Fraunhofer booth (Hall 16, Booth A12) at the Hannover Messe 2023 (April 17–21) will be able to see a demonstration illustrating how the system is designed.

Battery technology: the key to the energy transition

The battery cell is the most valuable part of an electric car. According to information from the German Federal Ministry for Economic Affairs and Climate Action (BMWK), the battery cell is responsible for up to 40 percent of the value creation in electric cars. In the future, electric buses and scooters will also rely on high-performance batteries, as will stationary electricity storage systems used with photovoltaics or wind energy. With its "Batteriezellfertigung Deutschland" (Battery cell production in Germany) initiative, the BMWK is promoting battery cell research and associated projects. The Fraunhofer Research Institution for Battery Cell Production FFB in Münster is one of them: Fraunhofer ILT and a number of other Fraunhofer institutes are working to develop innovative electricity storage systems at Fraunhofer FFB. This center in Münster will not only test new technologies in the laboratory, however. Its integrated manufacturing capacities will also help industrial partners test their manufacturing processes for new cell formats on a near-industrial scale. The first construction phase for the Fraunhofer FFB was completed in February 2023.

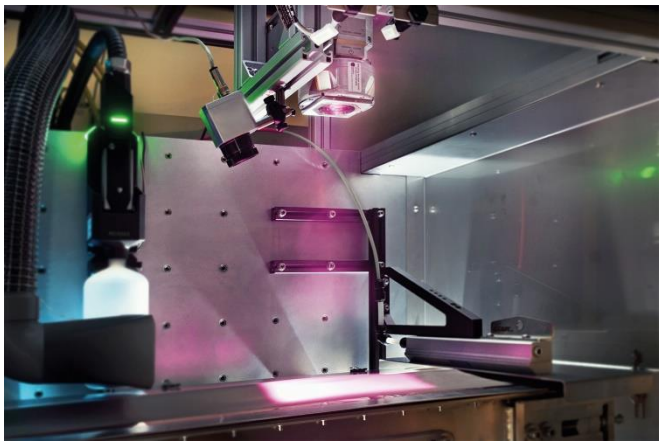

Image 1:
Drying with diode lasers: Thanks to the special optics, the laser radiates a larger area on the copper foil coated with graphite paste. The interaction between the graphite particles and the light energy generates heat and the liquid evaporates. © Fraunhofer ILT, Aachen, Germany.

Image 2:
High throughput: When creating the hole structures, the ultrashort pulse laser works with four scanner modules, each equipped with six beamlets.
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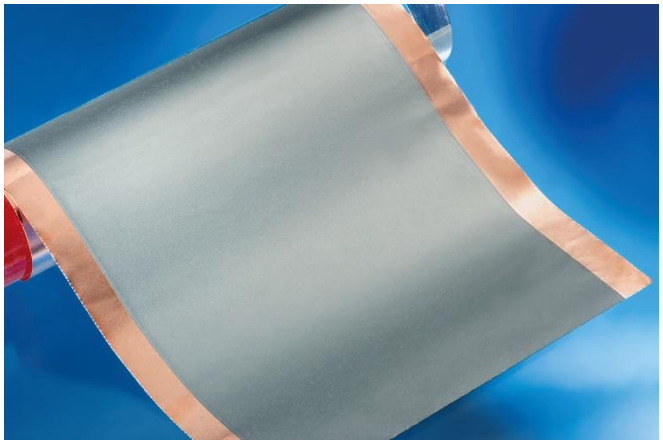

Image 3:
Electrode layer applied to copper foil and dried with laser technology: Researchers at Fraunhofer ILT have halved the energy required for drying in the production of lithium-ion batteries.
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