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Batteries, especially lithium-ion batteries are the leading technology of energy storage systems. In recent years, the market for lithium-ion battery storage has experienced unprecedented growth in line with the global energy transition and further electrification of the transport sector. Continuous advancements ensure that lithium-ion batteries are further optimized to increase longevity, efficiency and power density but also safety and recyclability.

Many factors influence the performance of a battery. Analytical technologies support the identification of optimization potentials at the most detailed level. In this interview, we want to highlight two relevant aspects: particle size and shape.

Malvern Panalytical are experts in this field. Formed by the merger of Malvern Instruments Limited and PANalytical B.V. on 1st January 2017, the company has headquarters in both Netherlands and UK. In the field of battery and renewable energy storage, Malvern PANalytical offer a wide range of physical, chemical and structural solutions for battery-based energy storage and its analysis.

We are talking to Umesh Tiwari, Segment Manager, New Energy

IBESA: As a provider for analytical technologies, how have you experienced the development of the renewable industry? What were the main advancements you have seen in the technology?

Malvern Panalytical: Renewable energy has developed significantly in the past few years, but it only becomes feasible when many interconnected technologies mature and supplement each other. Consider solar energy. First, it requires the development of high-efficiency solar panels. Solar energy has to be stored (for regular energy supply), so the energy storage technologies must be developed in tandem. Some new energy storage media that are gaining interest are Li-ion batteries and hydrogen. These, in turn, require supplementing technologies for mass-scale production and thermal management. Many breakthroughs in these interconnecting technologies have brought the new energy to a point at which it is not only a green alternative but also price-competitive compared to conventional energy.

IBESA: For renewable energy storage systems as well as e-mobility, capacity and performance are crucial and key differentiators for decision makers. Particle sizes and shapes influence the performance of a battery. Can you let us know how the size of electrode particles affects the performance?

Malvern Panalytical: Li-ion batteries have indeed revolutionized the transportation sector with efficient energy storage and accelerating e-mobility. The driving range of your car with one full charge, however, depends on the energy density of the installed battery bank. Likewise, the vehicle acceleration depends on its power density. Energy and power density of a battery depends largely on the quality of its electrodes, which are manufactured from the synthesized cathode and anode powder materials.

Individual particles in this powder may range in size from a few tens of nanometers to several micrometers. In general, small particles can be charged quickly and deliver higher power, whereas larger particles charge slower but deliver higher energy density. In a car, we need high energy capacity and high power so optimizing the particle size is a critical control parameter to achieve the desired battery performance for a given application. The world's leading battery companies use *Mastersizer 3000* in their processes to control particle size.

IBESA: Particle size also influences production efficiency. How do you support production with your analytical technology? At what point in development and production is it necessary to include analytical technology?

Malvern Panalytical Well, the cathode material is usually produced via a lengthy process with several steps. Consider the example of NCM cathode material, which is the most common in use in batteries today. In the first step, an NCM hydroxide powder, called precursor, is produced using co-precipitation from the sulfate solution mix. This NCM hydroxide is then mixed with LiOH (Lithiumhydroxide) and sintered at a high temperature to get the desired cathode material. Precursor production may take anywhere between 18 and 36 hours. Monitoring particle size evolution online can reduce the manufacturing time and enhance production efficiency. For online particle size monitoring, we provide the *Insitec* range, which can measure particle size in real time and feed the data to the SCADA system for process control.

IBESA: It is not all about size, the shape of particles is often underestimated. How does an even particle morphology improve production efficiency?

Malvern Panalytical: To manufacture electrodes, the powder materials are mixed in a solvent to make a paint-like slurry that is coated onto the current collectors. The quality of this coating largely depends on the size and shape of the particles. Spherical particles are generally desired for a uniform coating of high packing density. Particle shape thus affects the coating quality and battery performance. *Morphologi 4* is a powerful instrument that can reveal various particle morphology parameters, such as circularity, aspect ratio, roughness, and agglomeration that have a profound influence on coating quality. And it is not only the final cathode materials but also the precursor materials that can be investigated with this automated imaging technique. At the precursor stage, the particle shape likewise affects production efficiency, with spherical particles generally increasing efficiency.

IBESA: After analyzing the particle shape and identifying that there are too many different measurements, how do you further use the results? How can manufacturers achieve an ideal particle morphology?

Malvern Panalytical: *Morphologi 4* provides quantitative results that can be directly related to the coating quality and ultimately the battery cell performance. In particular, the circularity index can be

an important parameter to optimize the coating process with the final cathode material and the production efficiency of the precursor materials.

IBESA: Returning to the macro perspective; Where do batteries have the highest need for further improvements to ensure safety, full recyclability and reliable performance?

Malvern Panalytical: Battery technology is still evolving quickly, despite large-scale commercialization. Technological developments are driven by consumer demand more mileage per charge, longer battery lifetime, fast charge below 10 minutes, and exceeding the highest assurance of safety. There are many new chemistries and technologies such as solid-state batteries, lithium sulfur batteries, and graphene batteries that are on the cusp of scalable manufacturing and commercialization, as are significant improvements in the design of existing technologies. These new advances will soon propel electric vehicles to achieve more than 1,000 miles per charge, a charging time below 10 minutes, a million-mile lifetime, and the highest safety standards.

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