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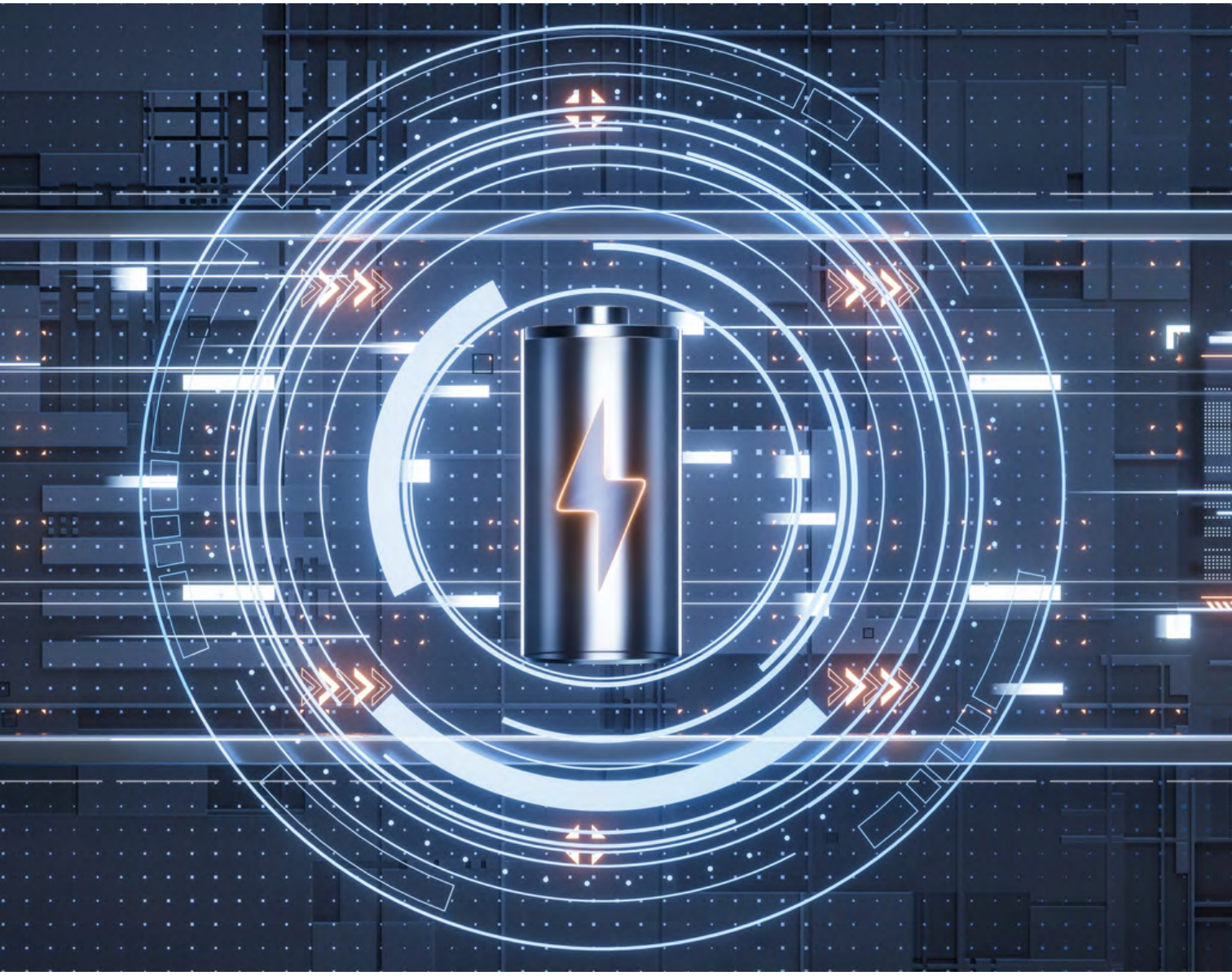
Battery Materials eBook



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Battery Materials Processors Are Supercharging the Market

The secret is strategic feedstock manipulation through advanced processing systems

By Sheila Kennedy, CMRP, Contributing Editor

Increasing pressure from legislative and environmental efforts is pushing drivers to change from internal combustion engine vehicles (ICEVs) to electric vehicles (EVs). The high standards of these customers have the manufacturers of batteries struggling to keep up. Advanced battery materials such as finely ground, ultra-pure lithium compounds and spheronized, dedusted anode compounds are at the root of efforts to meet constantly increasing battery requirements.

Primary areas where battery requirements are increasing are the need to be smaller, lighter, cheaper, and more resilient. Partnering with the right materials processing equipment supplier helps to solve these challenges.

CONFRONTING KEY CHALLENGES

The end use in electric vehicles is a challenging environment. The battery must fit in a small and mobile platform with exceptional performance to meet the demands of the drivers, who are used to this from combustion engine cars. Compared to what was historically available from EVs, new converts to EVs want higher-capacity and longer-life batteries. They want batteries that charge faster and hold more energy so they can drive farther. This puts pressure on the battery manufacturers, who need to make their products as small and compact as possible while increasing energy density.

As the requirements from end users and battery manufacturers are moving up the supply chain, they eventually reach the battery material producers. The material producers must manipulate their products to produce these gains. With specifications and requirements becoming even more challenging, they require purer products, tighter particle size distributions, and rounder particles with higher density. The equipment within the material factory influences the ability to meet these requirements.

ADVANTAGES OF PURPOSE-BUILT, CUSTOMIZABLE SYSTEMS

Specialized processing equipment is needed to produce the materials that go into batteries. The best systems are tailored to the producer's exact application. For example, the cathode and anode are utilized as coatings on films, and the powders have specifications that allow both the mechanical and electrical properties needed. Specifications such as narrow particle size distributions and high degrees of roundness are key. The tailored systems are designed around each customer's material and those specifications will enable

the material producer to obtain these properties.

Customization examples include dedusting systems for finely micronized particles, equipment materials of construction for proper wear protection, and implementing the equipment in a closed-loop, tightly controlled system.

Dedusting systems remove the ultra-fines generated during micronization. Removal of dust (ultra-fine particles) without removing too much of the properly sized material can increase the energy density by allowing for more powder to be packed in the battery, and the battery to be smaller and lighter. Performing this task while limiting contamination and keeping yield high are the selling points of a well-designed, purpose-built system.

Diverse and comprehensive wear protection options are another customization candidate. Using ceramic and/or polyurethane coatings or other wear-resistant coatings in the fabrication of equipment helps to reduce wear, increase component life, and improve system operation and uptime. Additionally, with this fabrication, the customer will have fewer parts per million (ppm) of metal pickup.

More complex solutions may also be required, such as implementing materials processing equipment in a closed-loop system. These systems recycle the gas, allowing processing with an inert gas rather than just air. A properly designed system will limit oxygen ingress and inert gas leakage, providing high product quality and limiting inert gas consumption. Such solutions require a great deal of equipment and process expertise. One provider's equipment may produce milled material that looks the same, but a customized, high-end solution would operate better based on experience gained by the implementer over many years.

WHY PARTNER WITH EQUIPMENT PROS?

Partnering with specialists in advanced materials processing systems allows battery materials manufacturers to better keep up with dynamically evolving demands. It also avoids the high costs and skilled labor requirements of developing complex systems internally.

An example is Hosokawa Micron Powder Systems (www.on-hosokawa.com), which offers a variety of technologies that are used in the production of lithium-ion batteries. Its expertise and global footprint were established through 100 years of experience developing equipment for processing powders, which perform with high efficiency and minimal downtime for many years. Distinctive services, equipment, and systems provide a complete solution.

Standout services:

- *Full system process expertise:* Tailored, highly efficient systems are designed and engineered by experts in both the technologies and processes. Solutions are based on the customer's unique materials, goals, and specifications.
- *Test centers:* Hosokawa-built systems can be validated by running the customer's materials through the system at a test center. The customer-provided material will be processed to the customer's specifications. This service is a strongly recommended option, though, for customers wanting a process guarantee, it is required to ensure the equipment will meet expectations.
- *Analytical laboratory:* The analytical laboratory goes hand in hand with the test center. When a product is processed in

a test center, particle size and density analyses of the samples produced are conducted in the lab to ensure compliance to the specification. This ensures the machine will perform as expected for the customer.

- *Engineering services:* Extensive project, mechanical, electrical, and controls engineering experience has been accumulated by developing and deploying materials processing machines in different kinds of factories all over the world. New application design and engineering are thus met with efficiency and effectiveness.
- *Aftermarket services:* Customers can order their spare parts directly through Hosokawa and consult on what spare parts are needed. Service engineers are available to install, troubleshoot, and provide additional training on site.
- *Contract manufacturing:* Hosokawa can process material on a contract basis for customers, bridging the gap until equipment can be purchased or is ready. It is also useful for customers working to obtain large quantities of material for testing.

Available small-scale equipment:

- *Picoline:* This benchtop lab unit manufactured by Hosokawa is beneficial to customers who want to process small samples in their own laboratory. It can grind and classify (dedust) anywhere from a few grams to about 100 grams of sample at a time to support internal testing and analysis.
- *Multiprocessing unit:* This lab or very small pilot plant unit can process samples up to about 10-20 pounds at a time, providing customers with an analogous process to what will be produced on their full-size equipment. Running samples for internal testing or downstream process testing indicates how it will perform in large-scale environments.

Large production systems:

- *Micronization:* Sophisticated size reduction systems and powder processing solutions are available to serve even the most unique milling and micronization applications, ensuring the intended particle

Hosokawa Mikro ACM® Air Classifying Mill is a fine mechanical impact mill with an integrated classifier. It was designed to grind a wide range of materials down to D97 < 20 µm. In the production of lithium-ion batteries, it is used for grinding and micronizing both cathode and anode materials.

99.9 fine lithium

size and material performance.

- *Spheronization:* Rounding of particles with spheronization systems changes particle morphology, turning flakes into potato-shapes up to and including nearly spherical particles at narrow particle size distribution.
- *Dedusting:* Dedusting systems, often used in line with mills and spheronization equipment, remove ultra-fine particles. Sharp cut points and high yield give the best results.
- *Particle coating:* High and ultra-high shear powder blenders are used to coat powders and embed with additives and homogenize, thus decreasing additive loading and allowing for optimal downstream processing.

DIFFERENTIATED SOLUTIONS

Battery materials processing is a hot market facing ever-increasing requirements. Materials processors striving to meet the demands can turn to advanced equipment providers with the expertise to develop quality custom-designed systems, accompanied by value-added services. Partnering delivers the flexibility and agility to meet distinctive needs with differentiated solutions, backed by a continuing commitment to helping the customer succeed. Working together, lithium-ion battery performance, efficiency, and service life will continue improving to meet the needs of the day.

HOSOKAWA MICRON GROUP
Process technologies for tomorrow.

The new product line for processing systems to produce **ENERGY PERFORMANCE MATERIALS**

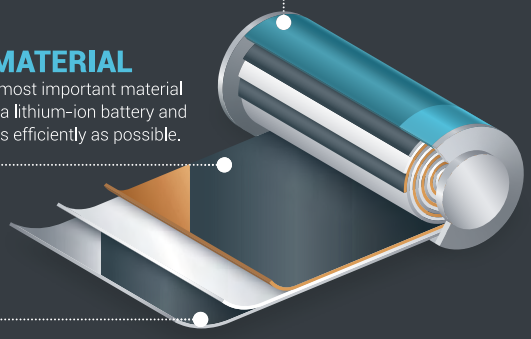
Advanced battery solutions for cathode and anode material

When charging and discharging a lithium-ion battery, the lithium ions move from the cathode to the anode and back again. The cathode and anode of a battery are made of different materials. A wide variety of lithium compounds (e. g. LCO, NMC, NCA or LFP) are used in the cathode. Graphite or lithium titanate form an essential component of the anode. On has developed special processes for lithium compounds as well as the rounding of graphite.

- Complete solutions for advanced battery manufacturing
- Technologies for advanced battery materials (cathode and anode)
- Contamination-free grinding with classifier mills and/or fluidised bed opposed jet mills
- Spheroidization of natural graphite and synthetic graphite
- Mixing, drying and coating of battery material

RECYCLING
Production scrap can be recycled directly during battery production.

ANODE MATERIAL
Graphite is the most important material in the anode of a lithium-ion battery and must be used as efficiently as possible.



CATHODE MATERIAL
Lithium is the most important active material in the cathode and determines the performance of your batteries.

www.on-hosokawa.com

Chemical Industry Takes the EV Driver's Seat

Processing companies are poised to play a key role in developing battery technology.

By Barry Perlmutter

The aim toward decarbonization and a sustainable future has caused exponential growth in the electric vehicle (EV) sector in the last few years, causing an increase in demand for lithium-ion batteries. Lithium, which is needed to produce virtually all batteries currently used in EVs, has experienced a simultaneous increase in demand. It is expected that lithium demand will rise from approximately 500,000 metric tons of lithium carbonate equivalent (LCE) in 2021 to 3 million to 4 million metric tons in 2030.

PROCESSING LITHIUM BRINE

While operating companies may view themselves as mining companies, most lithium brine is commercially produced from either the mining of lithium-containing rock, such as spodumene, or from clay sources. To manufacture battery-grade materials, these companies act as chemical companies to get the lithium ready for the next steps to produce battery materials.

Right now, battery costs are about 30% to 40% of the EV cost. Reducing costs and improving reliability is the end goal. Best practices in chemical processing will be the key to achieving those goals. Indeed, battery materials include anode and cathode powders and

their pre-cursors: catalysts, solid-electrolyte materials and sodium-ion materials. Each materials process has reaction chemistry, solid-liquid separation, washing/purification steps, process drying, solids handling/conveying and packaging, to name a few.

MATERIALS RECOVERY AND SUSTAINABILITY

The final step in the process is recovering the materials from the battery-production scrap and from end-of-life (EOL) lithium-ion batteries. Materials that can be recovered include lithium, cobalt, manganese and nickel, as well as aluminum, copper, graphite and electrolytes. The recovery process is very complex, and solutions are also in their infancy stage. The production scrap and EOL batteries are initially crushed and shredded to produce a black mass.

Characteristics of the black mass will vary depending on the source, so it is much different from producing a chemical. The black mass is then dried, mechanically sorted and refined to recover the battery-grade materials. Each of these steps requires mechanical technologies as well as process technologies.

LITHIUM INITIATIVES IN THE U.S.

As we know, there is a great amount of interest and money surrounding the lithium market. The Federal Consortium for Advanced Batteries (FCAB) is led by the U.S. Energy, Defense, Commerce and State departments and includes many organizations across the government. FCAB brings together federal agencies to provide a coordinated approach to ensure a domestic supply of lithium batteries and accelerate the development of a robust and secure domestic industrial base. Its goals include:

1. Secure access to raw and refined materials and discover alternatives for critical minerals for commercial and defense applications
2. Support the growth of a U.S. materials-processing base able to meet domestic battery manufacturing demand
3. Stimulate the U.S. electrode, cell and pack manufacturing sectors
4. Enable U.S. end-of-life reuse and critical materials recycling at scale and a full competitive value chain in the U.S.
5. Maintain and advance U.S. battery technology leadership by strongly supporting scientific R&D, STEM education and workforce development

The opportunities for the chemical-processing industry are there. In this regular web-exclusive column we will explore current processes, technologies used, challenges and possible solutions. In the meantime, I'm happy to learn your thoughts on the industry, suggestions for future topics and the issues you are facing.

Bringing Process Safety to Lithium-Ion Materials

New technologies and evolving operating safety practices reduce risks for battery production.

By Barry Perlmutter

The list of chemicals to make a lithium-ion battery is long and complex. There are solids and solvents involved for reactions or precipitation, purification and drying. There are different equipment technologies for each step as well as for solids handling. Operators and process engineers must be experts in all these areas to safely produce these battery materials and chemicals.

In my 40 years in the chemical industry, I have seen firsthand the improvement in process safety from the equipment side and operations side. Starting with reaction/precipitation, agitators are more robust. The double-purged mechanical rotating seals eliminate solvent emissions, and computation fluid dynamic (CFD) modeling for flow simulation optimizes the crystallization.

Many types of equipment technology today are designed to eliminate operator exposure. For example:

- For pressure filtration, there are agitated Nutsche filter-dryers as well as fully enclosed filter presses.
- Vacuum belt filters are designed with low-pressure housings to allow for inert-gas purging under vacuum as well as contained solids discharge.
- Centrifuges are designed for containment and isolation from the operating environment.
- For processing of low solids or liquids, plate filters and candle/tubular filters offer an alternative to disposable manual bag and cartridge filters.
- Dryers and vacuum systems are designed for full recovery of vapor dusts, solvent-ladened gas streams, and final product dusting.

For solids handling, there are many systems available for charging of solids into vessels (powder pumping), solids discharge (isolation and rotary valves, liners) and solids conveying (pneumatic and pressurized screw conveyors). These techniques eliminate the particulate emissions during solids transport.

An important topic is the

instrumentation that surrounds all the equipment. Instrumentation vendors have sophisticated techniques for monitoring and preventing exposures, and engineers must investigate the "smart" approaches to equipment.

While the above focus on safety is on machine design, operator safety training, personal protective equipment (PPE), and safety cultures at the plants are also improving. There are many different approaches including the use of hazard and operability studies to ensure that plants are operating safely.

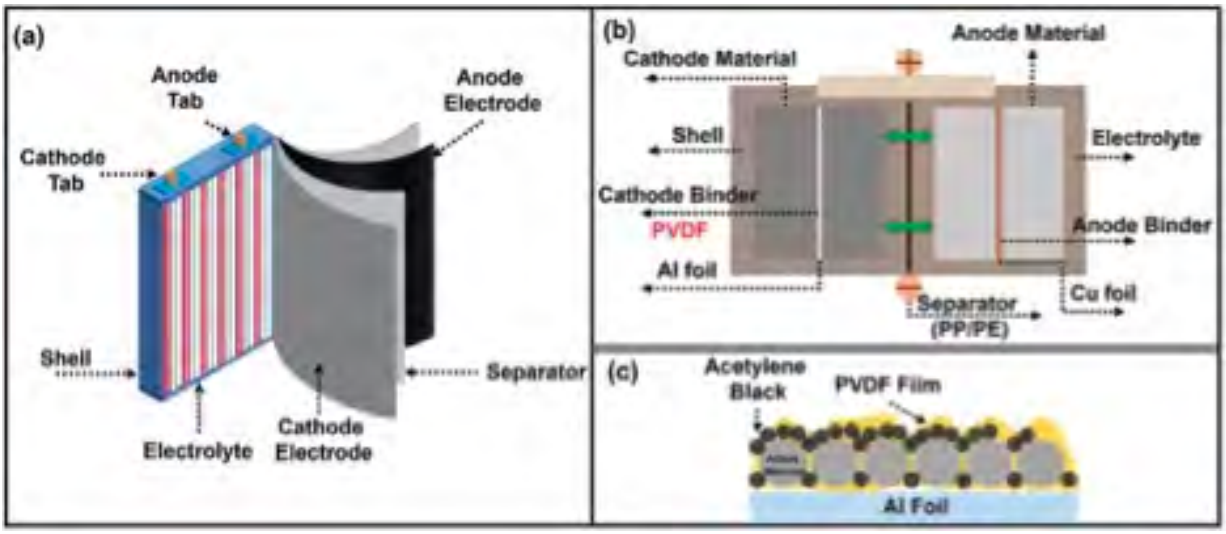


Figure 1: A lithium-ion battery is a small chemical plant. The detailed structure is as follows: a) main components, b) internal structure and c) structure of cathode materials and Al foil (Yellow coating represents PVDF film).

BATTERY CHEMICALS VS. TSCA

Recently, there have been discussions concerning new rules by the U.S. Environmental Protection Agency (USEPA) for regulating toxic chemicals. In a *New York Times* article, "Public Health vs. Economic Growth: Toxic Chemical Rules Pose Test for Biden," there is a debate over the limits being considered for 10 chemical substances for initial risk evaluations under the Toxic Substances Control Act. One of the chemicals debated is important in battery materials: N-Methylpyrrolidone (NMP) is used to remove the polyvinylidene fluoride (PVDF) binder from the cathode material (as shown in *Figure 1*). The cathode active material and conductive agent acetylene black are chemically bonded with current collector Al foil by PVDF, and batter makers use NMP to dissolve the PVDF during recycling operations.

The debate around regulation of NMP and the other nine listed chemicals is beyond the scope of this column. However, as discussed above, the equipment and approaches exist to minimize and eliminate exposure to these chemicals. In addition, there is ongoing research into developing fluorine-free alternative materials and solid-state electrolytes for lithium-ion batteries. Advances in this direction will also change the discussion.

In science and engineering, there is often no clear answer to a "social-good" question, but with collaborative and holistic approaches, the pathway will be found.

Decipher Solids Drying Decisions

Lab and pilot testing are critical when considering dryer options for battery materials.

By Barry Perlmutter

When it comes to battery materials, there are many types of solid-liquid separation and centrifugation technologies available. Here, the challenges begin with the slurry formulation. The slurry suspension includes multiple components such as cathode and anode materials, binders and additives. Plus, slurry stability and flowability impact the downstream processes. There are many characteristics to analyze to determine the best slurry mix. Considerations include particle size distribution and particle interactions, such as zeta potential, tendencies to agglomerate, viscosity, density, pH and temperature. I will examine these factors in a future column, along with testing and data collection.

But for now, solids drying is the next step. To that end, we will focus on several dryer alternatives available.

SELECTING THE RIGHT DRYER

Depending on the process step, there are several alternatives for the dryer. Let's begin with the cathode and anode materials. There is a large variation among manufacturers about the characteristics of the powders being produced.

For a continuous process, many

operations use spray dryers. A design with a high-speed rotary atomization can produce a powder with nice spherical particles with low residual moisture content, a narrow particle size distribution with no oversize material and a typical mean particle size of 5-20 μm. The design can also handle abrasive particles.

Horizontal paddle dryers are suitable for batch operations. These units can operate at temperatures up to 650° C with very close wall tolerances of the paddles to avoid crust formation on the dryer vessel walls. Paddle dryers can also operate at low temperatures under vacuum drying conditions. The paddle designs convey the solids forward and backward creating a 3D turbulent zone for optimum mixing/drying. Paddles can also be heated for added heat transfer to the powders.

Batch dryer designs also are available as vertical conical dryers. In this type of design, helical arms move the solids upward and downward for 3D mixing/drying with very close wall tolerances. The helical arms are also heated for additional heat transfer to the product.

FLUID BED DRYERS

For lithium carbonate and lithium hydroxides, fluid bed dryers are another option. The designs are normally stationary bed with high air flow rates for efficient heat transfer and drying. Multi-zone operation with drying and cooling enhances the operation with a smaller footprint.

All of these dryer types are fitted with integrated dust filters to eliminate emissions and recover additional product. Electrolyte solvent recovery systems are also installed for condensing and reuse of the solvents back into the system for a closed-loop design.

As for installation and degree of complexities, spray dryers and fluid bed dryers require large footprints with additional heaters, fans and external cyclones or bag/dust filters, but they offer the benefit of continuous operation. Batch dryers are easier to install yet require either upstream buffer tanks or a second dryer for continuous operation.

Lab and pilot testing will help guide battery material operators through the different options available. It's important to have robust data collection, drying curves and heat balances during the process to determine the optimum design for battery materials manufacturing.