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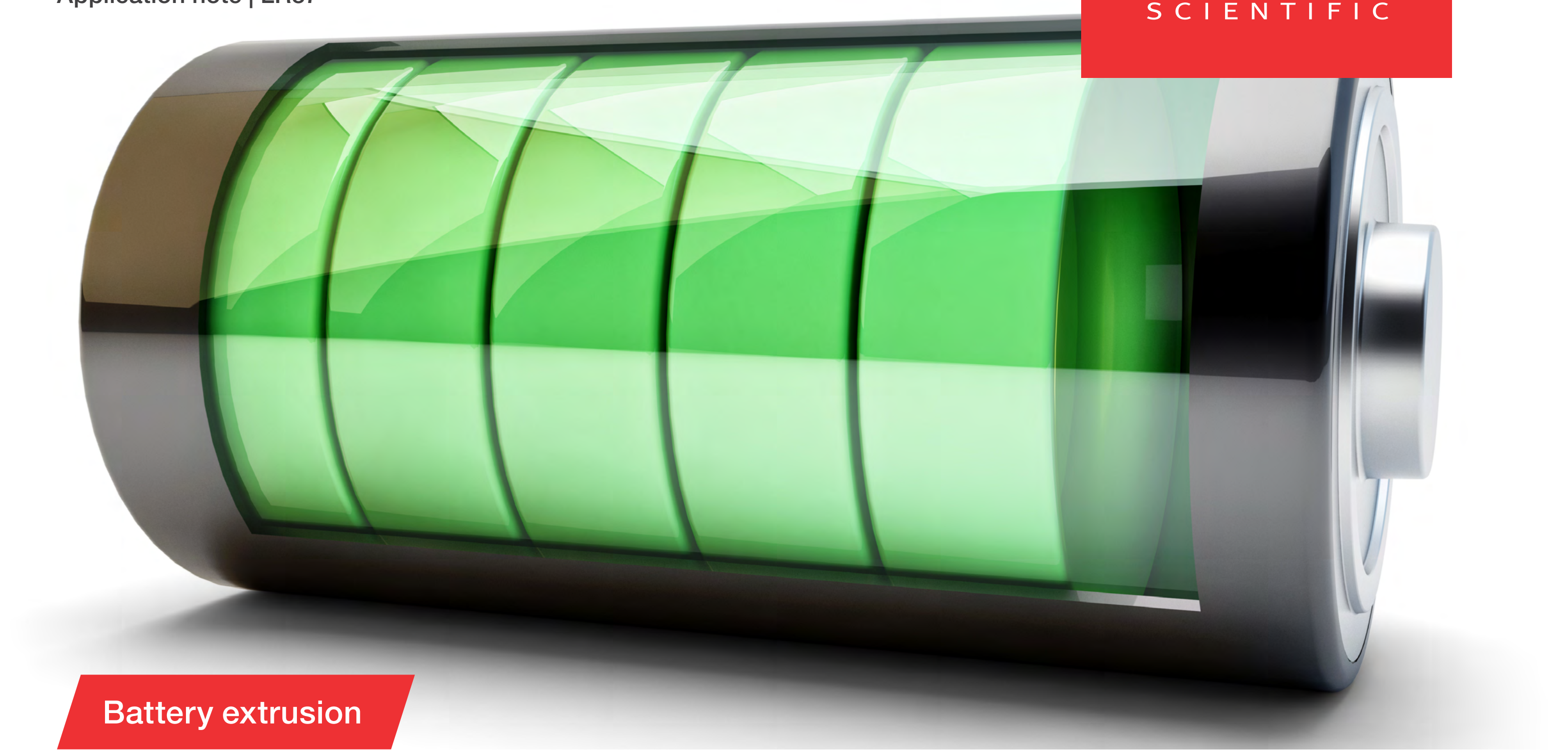

Battery extrusion

Continuous twin-screw compounding of battery slurries in a confined space

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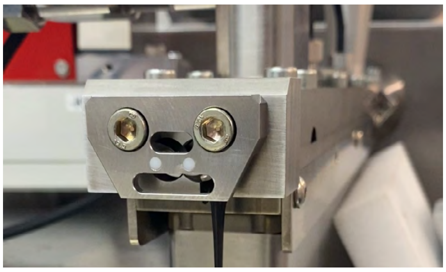

Figure 1: Cathode slurry compounded using Energy 11 Twin-Screw Compounder.

Figure 2: Energy 11 Twin-Screw Compounder, one liquid and one solid feeding system in a glove-box. The Energy 11 setup requires only an approx. space of 770 mm height, 890mm length, and 730 mm width. The control panel is mounted outside the box for easy access.

Battery slurry production is commonly realized by batchwise compounding of active materials, carbon black, solvents, binders, and additives in stirred vessels. This bears the risk of batch-to-batch variations, is labor-intensive, and requires production downtimes. Also, the transfer from lab scale pre- paration of novel formulations to production scale is difficult.

Twin-screw compounding offers a continuous production process with precisely controlled material shear, heat transfer, material throughput, and residence time. It provides high reproducibility, less cleaning time, and high material efficiency. Two parallel, co-rotating and intermeshing screws, embedded in a cylindrical barrel with dosing ports, mix, knead, and shear materials and eventually convey the compound through an outlet at the barrel end. Attaching a die to the outlet extends the system to a twin-screw extruder. Scalability of twin-screw extruders' geometry enables easy transfer from lab processes to high-throughput production of slurries.

Lab scale compounder

The Thermo Scientific™ Energy 11 Parallel Twin-Screw Compounder represents all functionalities of a production extruder scaled down to lab size with throughputs ranging from 0.1 to 4.5 kg/hr. Its small footprint allows it to be placed entirely into glove boxes or other containment systems, together with liquid and solid feeders placed on its housing, as demonstrated in Figure 2. This is required for cathode materials that need to be handled in a dry environment and for protection of the operators from hazardous chemicals. Liquid barrel cooling and controlled degassing ensures safe operation. With a flexible screw design and five dosing positions along the barrel, the instrument enables quick changing of the composition of the slurries and the processing route.

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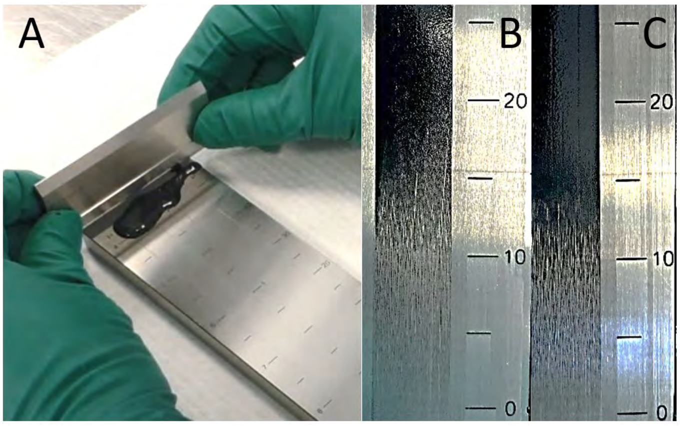

Figure 3. Examination of (A) cathode slurry on a grindometer. Average particle size of cathode slurry is bigger when produced at (B) high throughput than (C) low throughput.

Slurry characterization

A broad variety of slurry properties can be achieved within minutes, and producibility of novel formulations can be tested. Examination of the freshly compounded slurries on a grindometer shows differences in the grain size depending on the throughput, for instance, as shown in Figure 3. Rheological characterization of the slurries using the HAAKE™ MARS™ Rheometer reveals variations in the strain rate of dependent viscosity (see Figure 4). The characteristic flow curve determines the stability of the slurry suspension and its further processability in coating systems. For slurries stored in buffer tanks prior to coating, high viscosity at low shear rates (10^{-3} s^{-1}) is advantageous as it reduces sedimentation. During coating, however, high shear rates (10^{3} s^{-1}) occur and a high shear thinning behavior is advantageous. After coating, the slurries ideally quickly regain a high viscosity, which prevents the coating from spreading.

Conclusion

Downsides of batchwise battery slurry production are conquered by continuous twin-screw compounding. Thermo Fisher Scientific provides lab scale twin-screw extruders for battery slurry development that fit into spaces as small as glove boxes. The twin-screw compounding process is scalable, easing the transfer of process parameters established in the lab to application of production scale extruders. Precise characterization of the slurries' rheology using HAAKE MARS Rheometers allows one to predict the storage stability, coatability, and spreading behavior of the slurries.

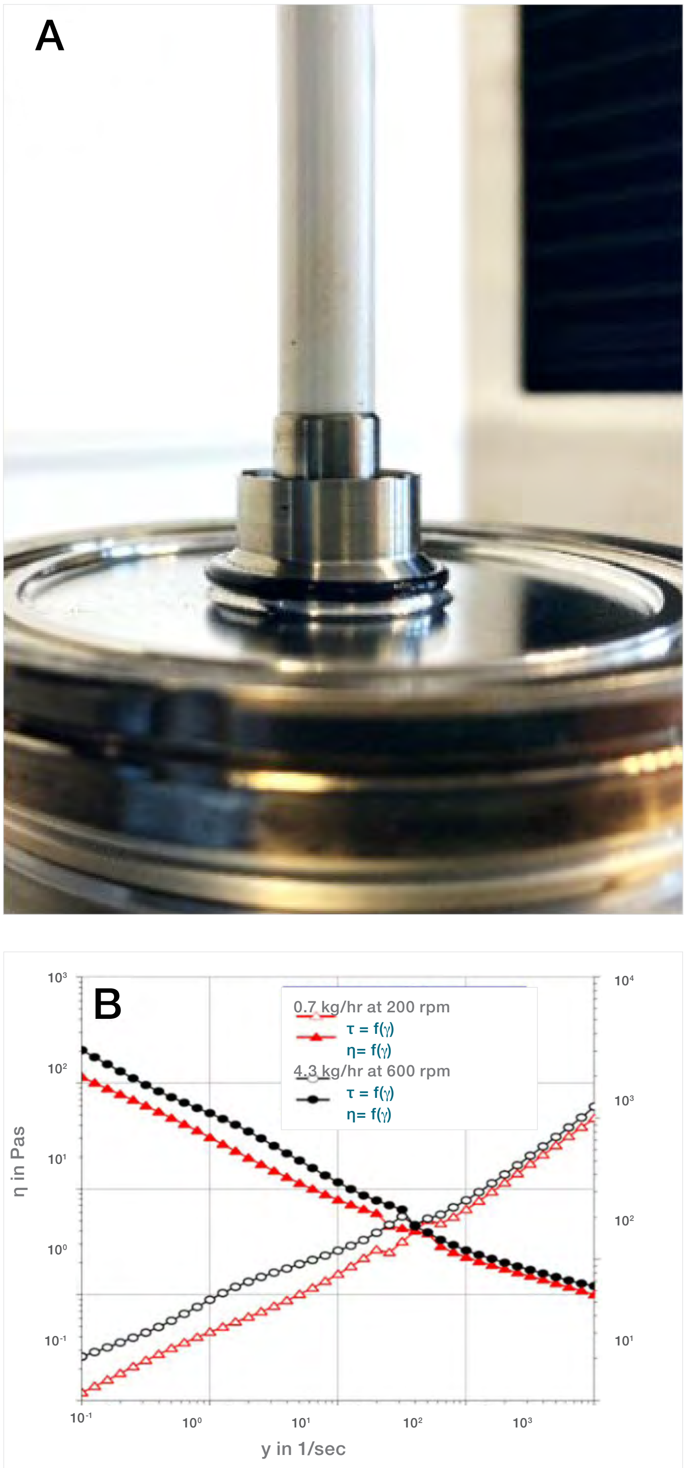

Figure 4. (A) Rheological characterization of cathode slurry in the HAAKE MARS Rheometer with plate–plate geometry. (B) Strain rate dependent viscosity function of cathode slurries produced at low and high throughput and screw speed, respectively.

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