Continuous twin-screw extrusion and rheological analysis of electrode slurries for optimizing lithium-ion battery manufacturing

INTRODUCTION
Lithium-ion batteries (LIBs) are widely used in portable electronics, electric vehicles, and grid storage due to their high energy density and long cycle life. LIBs consist of a graphite-coated copper foil, which acts as the anode, an aluminum foil coated with active materials as the cathode, and a polymer film that separates both electrodes and only allows lithium ions to pass. A liquid electrolyte in which lithium salt is dissolved completes the setup.

The lithium-ion battery manufacturing involves many steps, including preparing and coating anode and cathode slurries. Proper mixing of the individual components and a homogenous coating process are essential for achieving batteries with a high capacity and many available charging cycles.

SLURRY MANUFACTURING
Continuous twin-screw compounding for manufacturing electrode slurries is a compact energy-saving alternative to the use instead of planetary batch mixers and offers the following advantages:

- Twin-screw extruders provide better distributive and dispersive mixing than dissolvers
- Reduced amount of solvents
- Solvents drying and recycling is highly energy consumptive
- Strong shear forces acting onto the material allow to reduce the solvent content of electrode pastes

Scalability
- Volume to surface ratio varies less than in batch mixers
- Good scalability from lab to production

Materials
Cathode slurries were prepared from the following raw ingredients:
- Solvent: water
- Active ingredient: LiFePO4 (LFP)
- Conductive agent: carbon black (CB)
- Binder: CMC/SBR

Extrusion
Slurries were prepared using a Thermo Scientific™ HAAKE™ Energy 11 Twin Screw Extruder (Fig.2) with a two-stage mixing screw at room temperature. Solids were dosed into the extruder with a gravimetric twin-screw feeder and water was dosed with a peristaltic liquid pump. The solid content was set to 50% with a total mass flow of 800 g/h. Samples were collected at 120 rpm or 1000 rpm screw speed. A sample with 43% solid content mixed at varying screw speed was also collected.

Scanning Electron Microscopy
Fig.3 Thermo Scientific™ Phenom™ G2 Desktop SEM
Fig.4 SEM images of cathode slurries

RHEOLOGICAL ANALYSIS OF BATTERY SLURRIES
Rotational and oscillatory rheometry enables the quantification of the viscoelastic properties needed to
- verify a proper mixing and a homogeneous distribution of active components within the electrode slurries.
- predict storage behavior and stability
- understand behavior during the coating process

CONCLUSIONS
- All slurries showed viscoelastic properties and yielding behavior.
- Viscosity, firmness and network (gel) character were increasing with increasing solids content.
- Higher shear forces during slurry compounding reduced final shear viscosity, firmness and gel character of the cathode slurry.