



Advances in Continuous Extrusion-Mixing of Dry Electrode Mass – How to tackle the Challenges with LFP-based Formulations

Dry Coating Forum 2025

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Agenda

- Dry mixing via twin-screw extrusion
- Maturity of twin-screw extrusion for DBE
- LFP processing
 - Challenges in LFP processing
 - Results microscale LFP
 - Results nanoscale LFP
- Gaps in the powder to electrode process
- Conclusions

Dry Mixing via Twin-Screw Extrusion

One tool for continuous mixing



Raw materials:
AM, CB, PTFE,...



Premixing

Fibrillation / dispersing

Shaping / size reduction

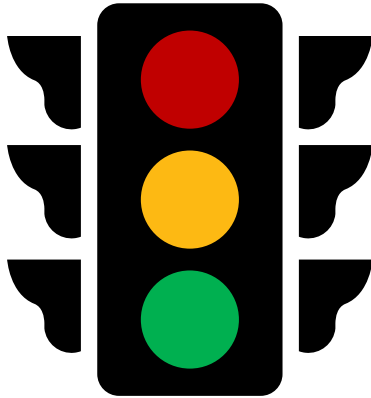
Fine control of the process via tuning of:

- Screw configuration
- Screw speed
- Throughput
- Temperature profile



Maturity of Twin-Screw Extrusion for DBE

Strongly governed by the cell chemistry



LFP cathode

NMC cathode

Graphite anode



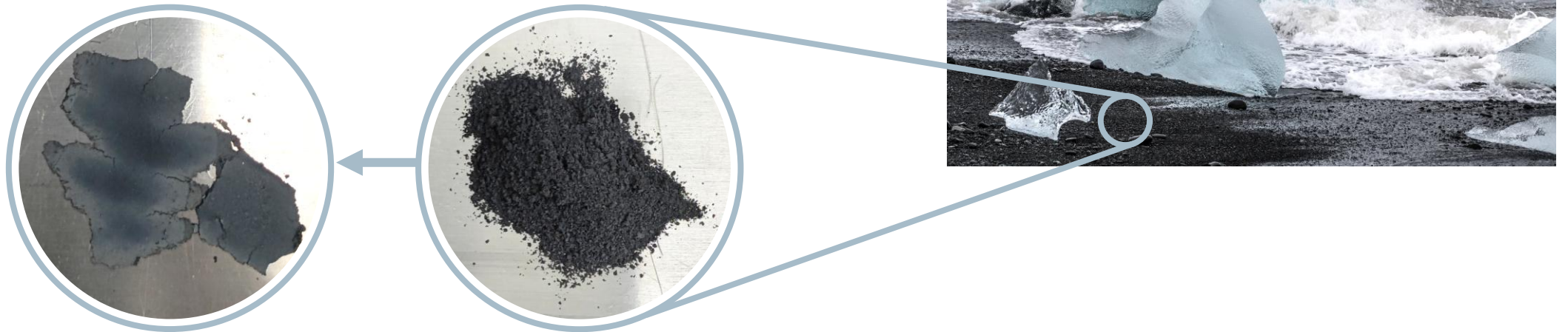
Anode compound processing

- Extruder screw diameter: 62 mm
- Screw speed: 500 rpm
- Throughput: 150 kg/h

Challenges of LFP dry processing

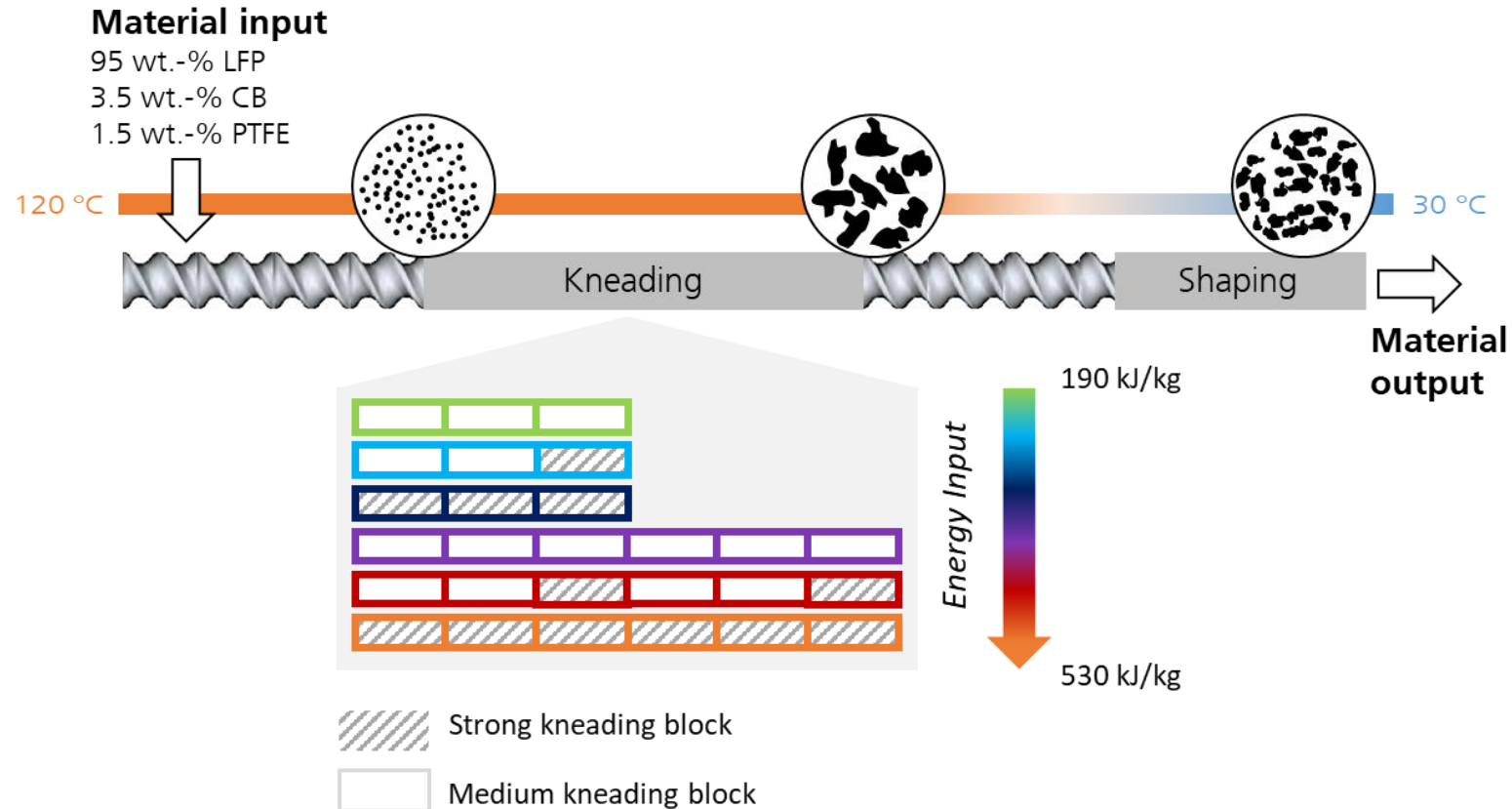
Or: What do Iceland's black sand beaches have in common with LFP processing?

- Underfibrillation vs. overfibrillation
- Hardness / brittleness of the extrudate
- Overtorque in calander, roll damage
- Fragile films
- Thin electrode films
- ...



Dry Extrusion Mixing of LFP based formulations (microscale LFP)

Extruder screw variations

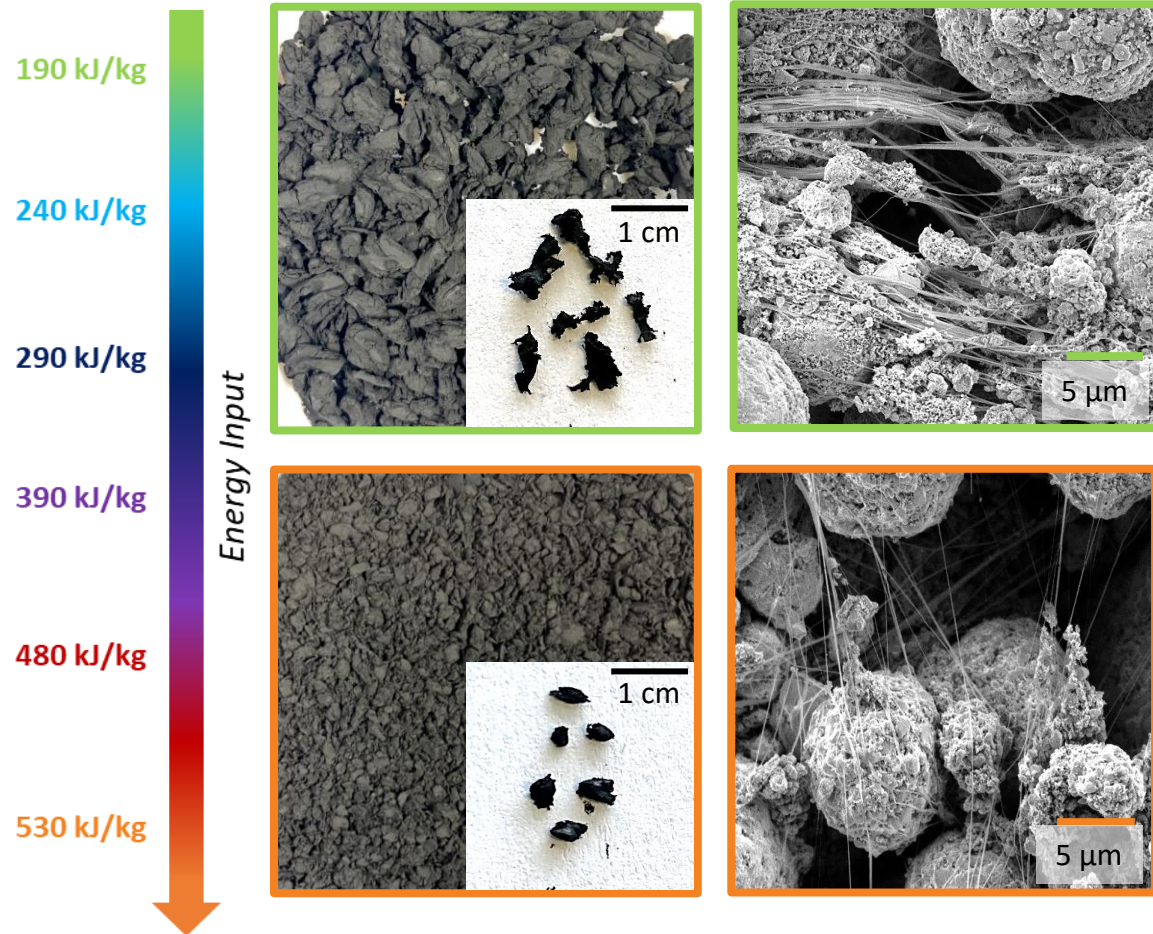


PTFE fibrillation

- Thermal energy input (T)
- Mechanical energy input (rotational speed, throughput, screw configuration)
- Residential time and stress on the material

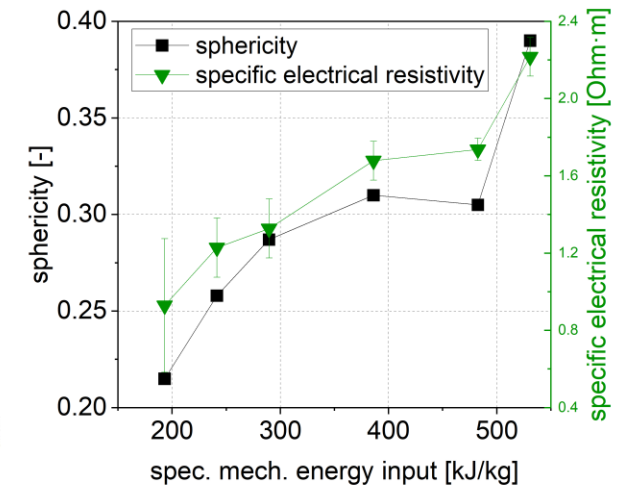
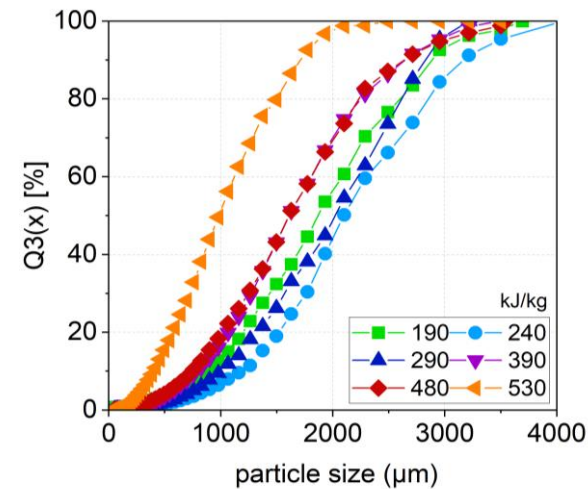
Analysis of LFP Granules

Physical properties



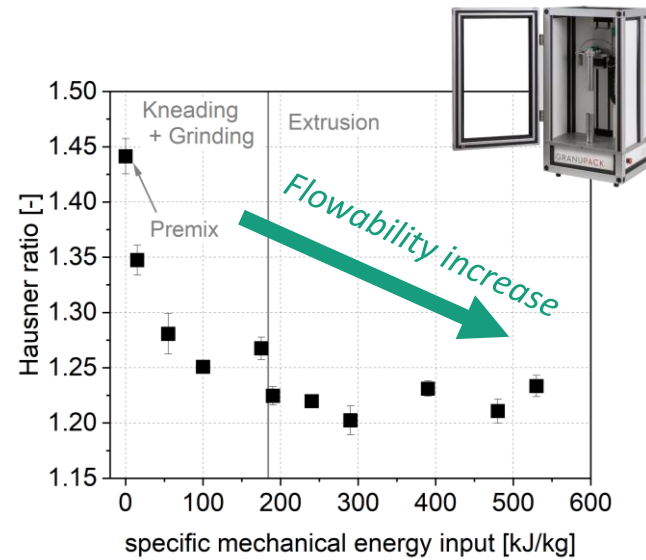
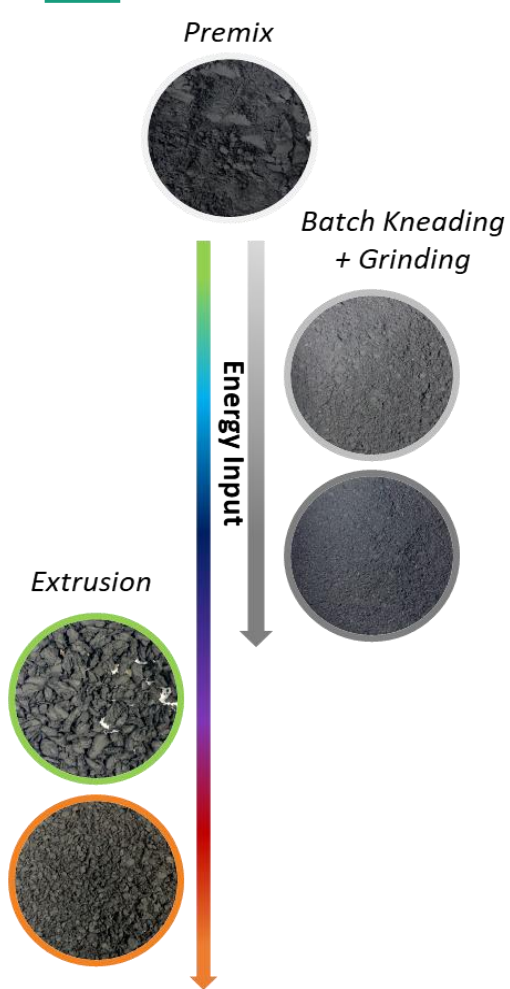
Changes in Macrostructure with increased mech. stress

- Particle size reduction
- Stronger PTFE fibrillation, homogeneous fibre structure
- More spherical shapes
- Increased specific electrical resistivity



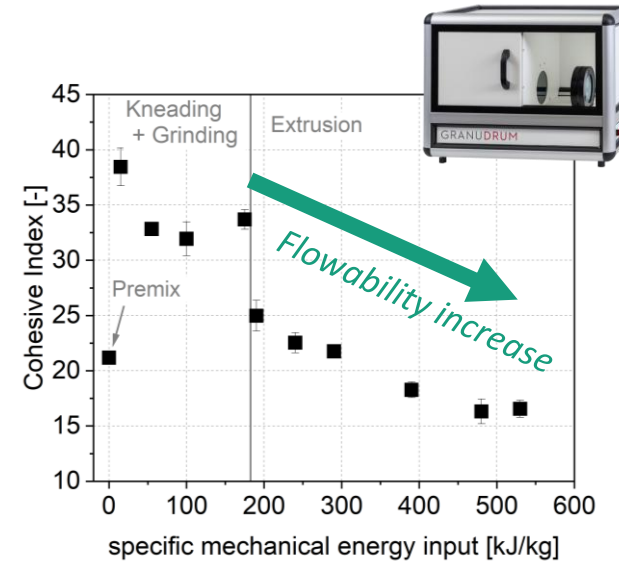
Analysis of LFP Granules

Rheological properties



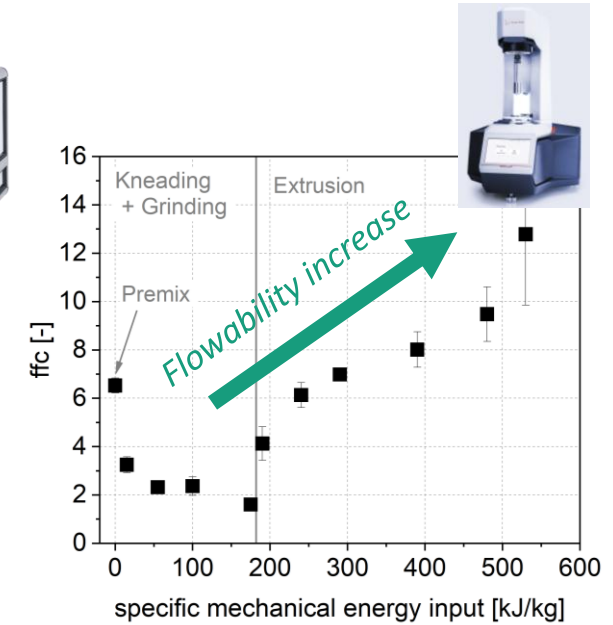
Hausner ratio

$$Hr = \frac{\rho_{tap}}{\rho_{bulk}}$$



Cohesive Index

$$CI = \frac{1}{D} \sum_x \sigma(x)$$

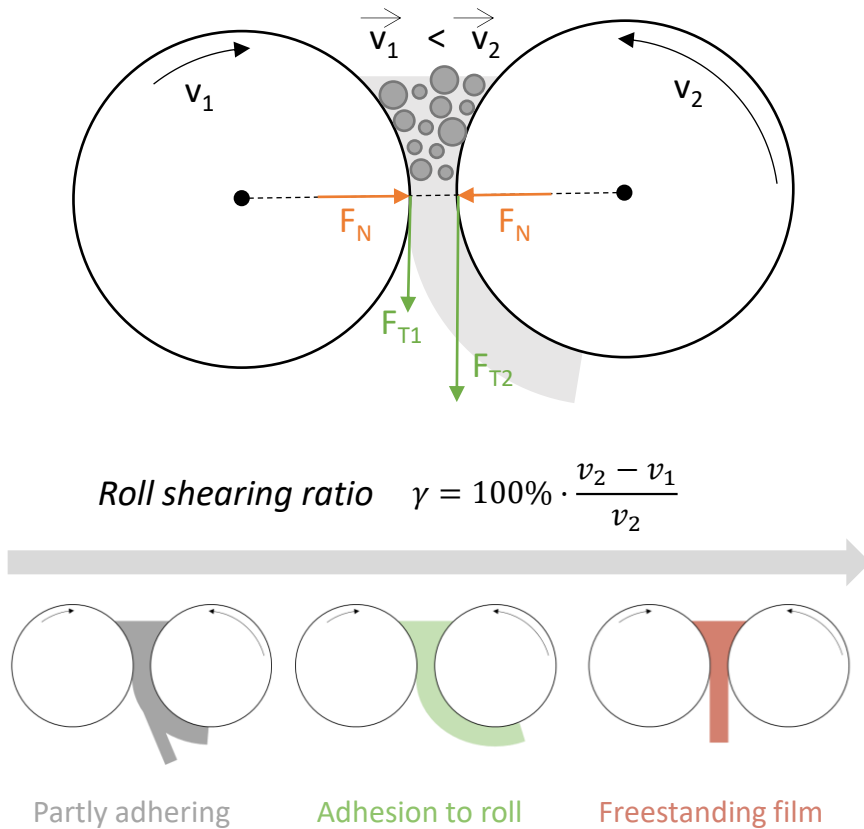


ffc-value

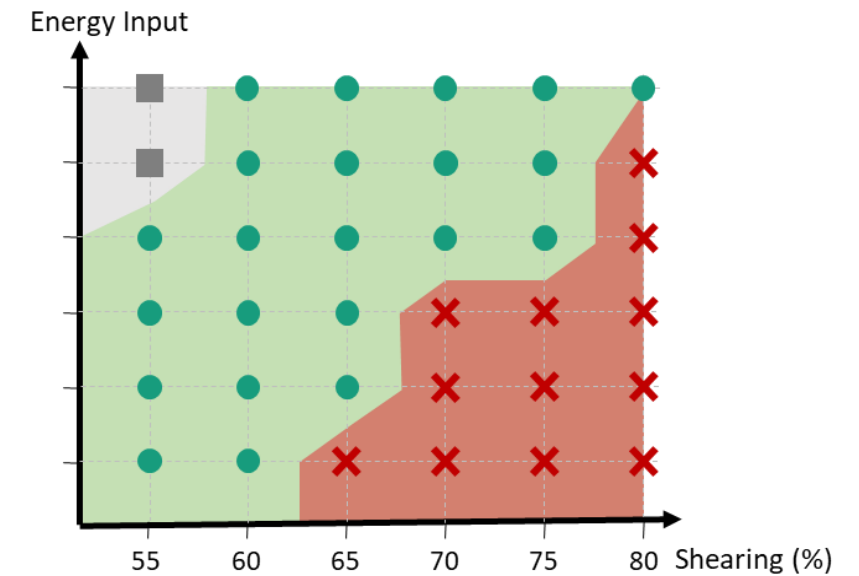
$$ffc = \frac{\sigma_1}{\sigma_c}$$

Electrode Production - DRYtraec®

Film Formation



LFP processability window

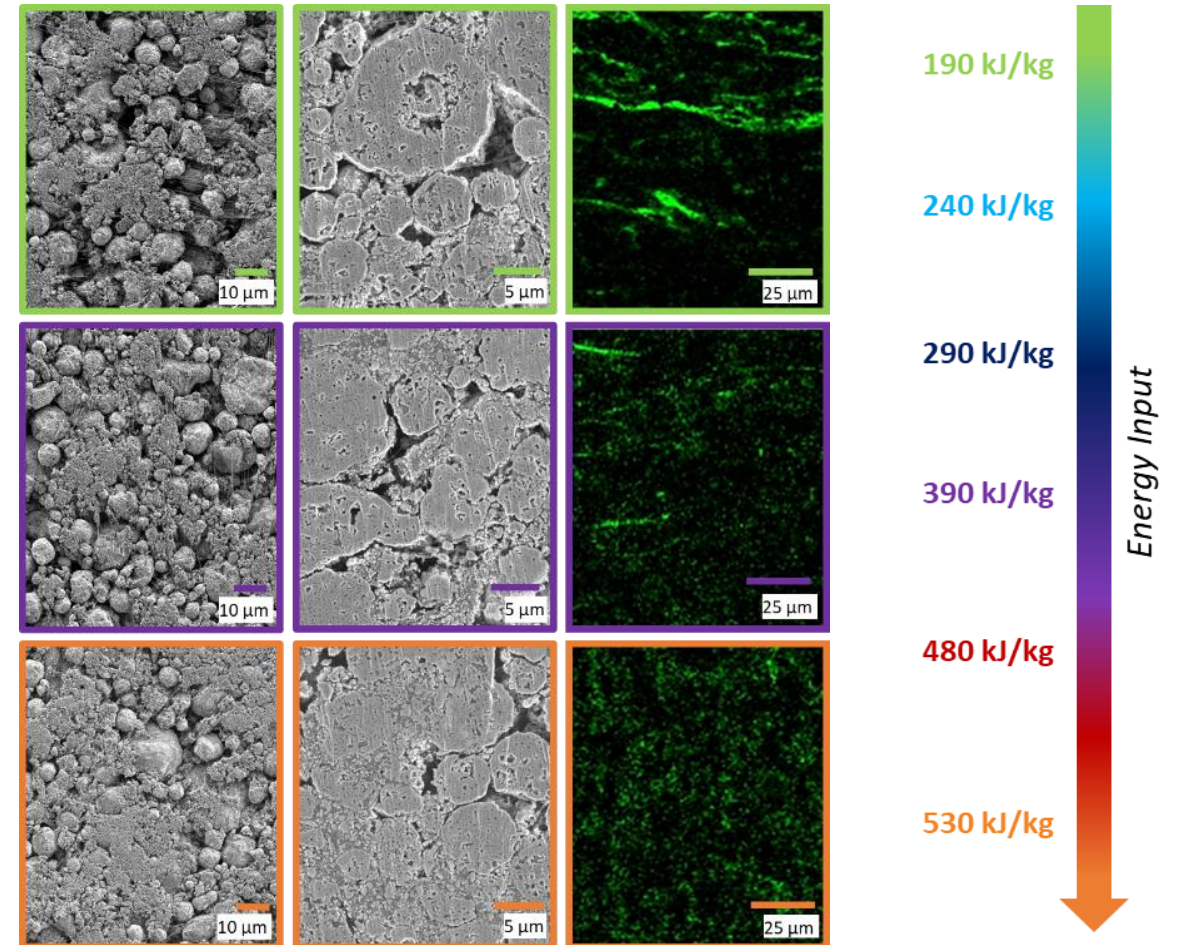
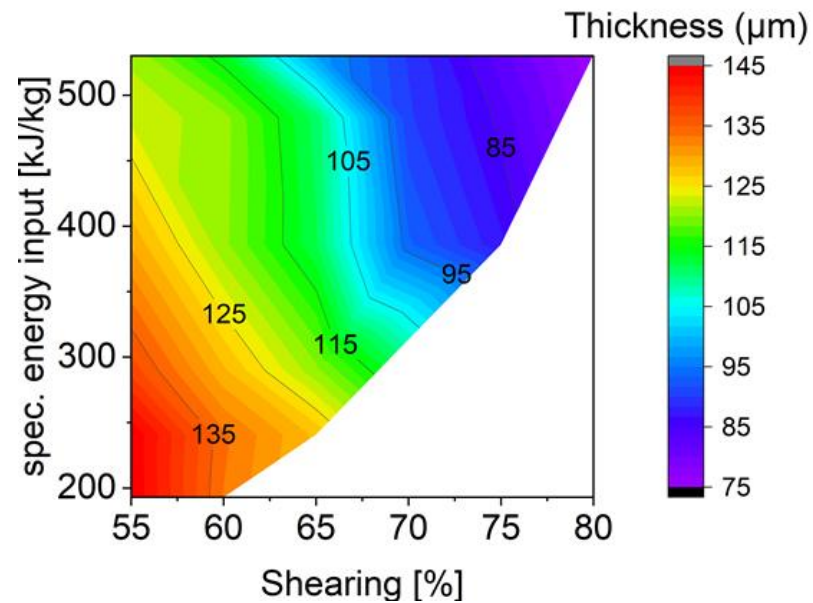


Electrode Production - DRYtraec®

Electrode properties

Coatability

- High kneading intensity:
 - Thinner layers at constant calendering parameters

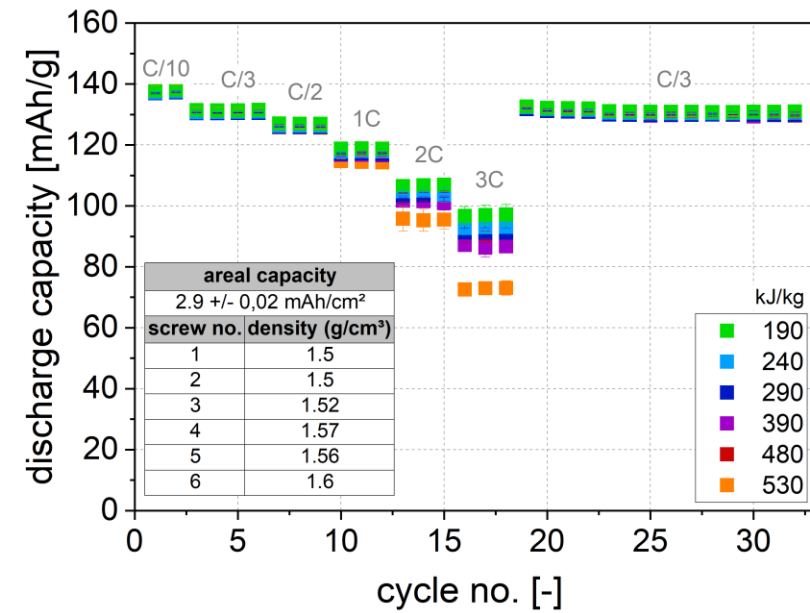
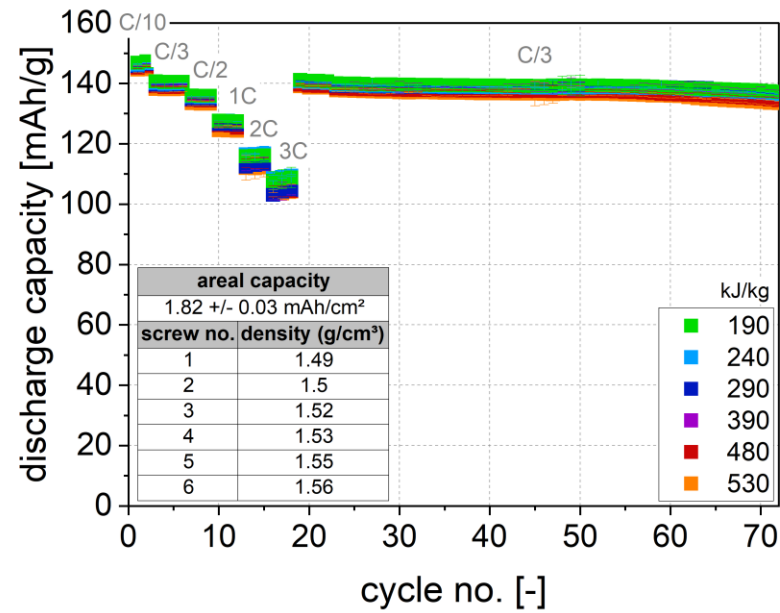


Electrode Production - DRYtraec®

Electrode properties

Cell performance

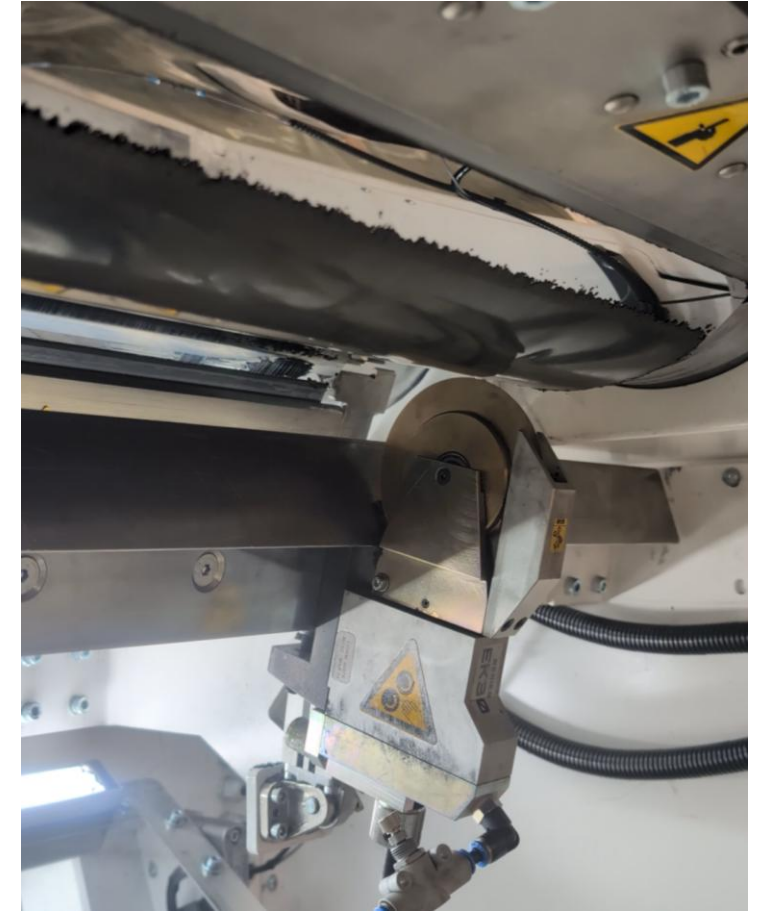
- Good cell performance in thin electrode layers
- Lower C-rate performance for thicker electrodes



Nanoscale LFP Processing

Status and outlook

- First promising mixing results
 - Novel approach of operating the extruder (no information can be disclosed)
 - Small process window
- First promising coating results at Fraunhofer FFB
- Next steps:
 - Improve reproducibility
 - Improve throughputs



Powder to Electrode Process

The mixing / calendering interface at a glance – which gaps must be closed?



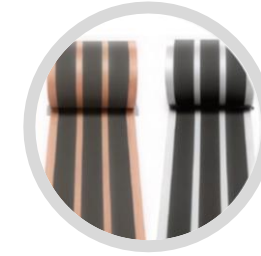
Mixing (for all mixer types)

- Increase efficiency (throughput rates)
- Reduce metal contamination:
 - Process optimization
 - Screw / Liner materials
 - Additives



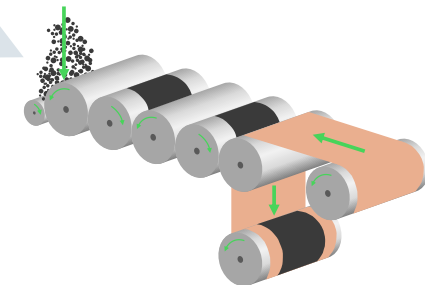
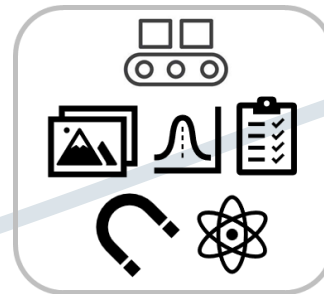
Interface

- Quality control: quantitative methods to characterize product quality
- Detection / separation of contaminants
- Storage / conveyance (easier with a granular product)



Calendering

- Reduce the scrap rate (in wet coating: < 0.5%)
- Increase efficiency (speed and width)
- Feed into calendar
- Dust reduction (less severe with granular product)



Conclusions

- **Extrusion mixing: one tool for (1) premixing, (2) fibrillation/dispersing, (3) shaping/size reduction**
 - Efficient cooling/heating of process zone (-15 °C → 200 °C)
 - High degree and precise control of fibrillation
 - Broad spectrum of parameters allows to tailor the process for each specific formulation
 - Easy handling, storage and dosing of fibrillated compounds
- **DRYtraec® process: wide coating window & able to produce thin films**
- **Collaboration is required to solve remaining issues**



Want to test
continuous
DBE mixing?
Please get in
touch.



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