

DEVELOPMENT OF DRY BATTERY ELECTRODES FOR AUTOMOTIVE APPLICATIONS.

DRY COATING FORUM – 03.11. & 04.11.2025, FRAUNHOFER IWS, DRESDEN
DR. A. GYULAI & S. DAMNALI, BMW GROUP

THE GEN6 PROMISES A LEAP IN TECHNOLOGY FOR OUR WHOLE PORTFOLIO AND THE BMW iX3 50 xDRIVE BENEFITS FIRST IN LINE:

+20% energy density on cell-level & 800 Volt technology

Peak charging rate: 400 kW



Up to 372 km (WLTP) in 10 minutes

High voltage battery: 108,7 kWh energy capacity (UBE EU)

Up to 805 km range (WLTP)

Bidirectional charging – to load, to home, to grid



Significant cost advantage



Highest quality- & safety-niveau



Significant CO₂e reduction

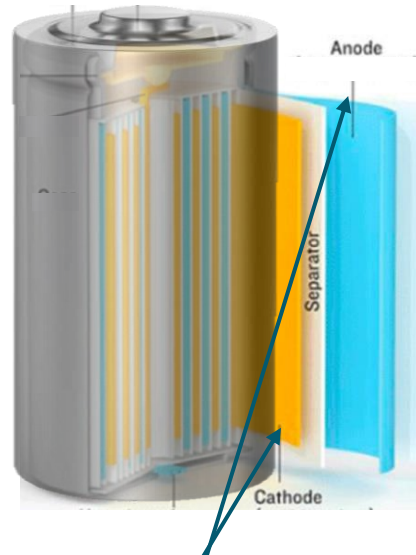
DRY COATING: FUTURE TECHNOLOGY.

BMW „Neue Klasse“ - Battery Cells



wet coated electrodes

BMW Dry Coating Project



dry coated electrodes



Reduce battery production cost, energy & space demand



No toxic solvents & reduced CO₂-emissions



Increase battery performance

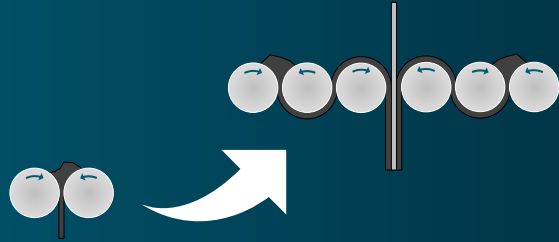
PRODUCT INNOVATIONS

PROCESS INNOVATIONS

CHALLENGES OF DRY COATING.

PROCESSING

- Scaling and line speeds



- Yields and production waste



- Dust + technical cleanliness



- Wear of equipment



MATERIAL COMPATIBILITY

- Material-property-process relationships



- Conductive additives



- PTFE reduction at low potentials



- PFAS restrictions



BMW PUBLICATIONS.



Journal of Energy Storage

Volume 124, 15 July 2025, 116850



Research Papers

Dry battery electrode production enabled by a scalable, continuous powder mixing

Korbinian Huber ^{a, b}, Stefan Stojcevic ^a, Yi-Chen Hsieh ^c, Ezgi Basak Müftügil ^c, Junpei Terada ^d, Charlotte Schriever ^a, Arno Kwade ^{b, e}

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Highlights

- Binder fibrillation in extruder enables dry battery electrode production.
- Examining the structural response of PTFE-binder to stress during extrusion
- Controlling powder properties by tuning relevant process parameters
- Dry coated cathodes exhibit lower tortuosities than wet coated electrodes.
- Dry coated electrodes perform well in electrochemical cell tests.



Journal of Power Sources

Volume 646, 1 August 2025, 237243



Effect of carbon black properties on dry electrode processing of cathodes for lithium-ion batteries

Serkan Z. Damnali ^{a, b, c}, Kimia Mazloumi ^a, Berkant Tekin ^a, Thomas Woehrle ^a, Alice Hoffmann ^b, Markus Hoelzle ^b

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- Solvent-free production of cathodes via calendaring.
- Characterization and correlation of carbon black properties with calendaring process.
- Carbon black properties affected the compressibility of the composite granules.
- Carbon blacks act as process aids during calendaring in dry coating process.
- Tailored material properties are required for dry coating process.



Next Materials

Volume 9, October 2025, 101181



Research article

Dry processed anodes with a fluorine-free binder for lithium-ion batteries

Vincent Gottsmann ^{a, b}, Florian Schmidt ^a, Thomas Wöhrle ^a, Stefan Stojcevic ^a, Astrid Trenkler ^a, Vanessa Fröhler ^a, Simon Lux ^{b, c}

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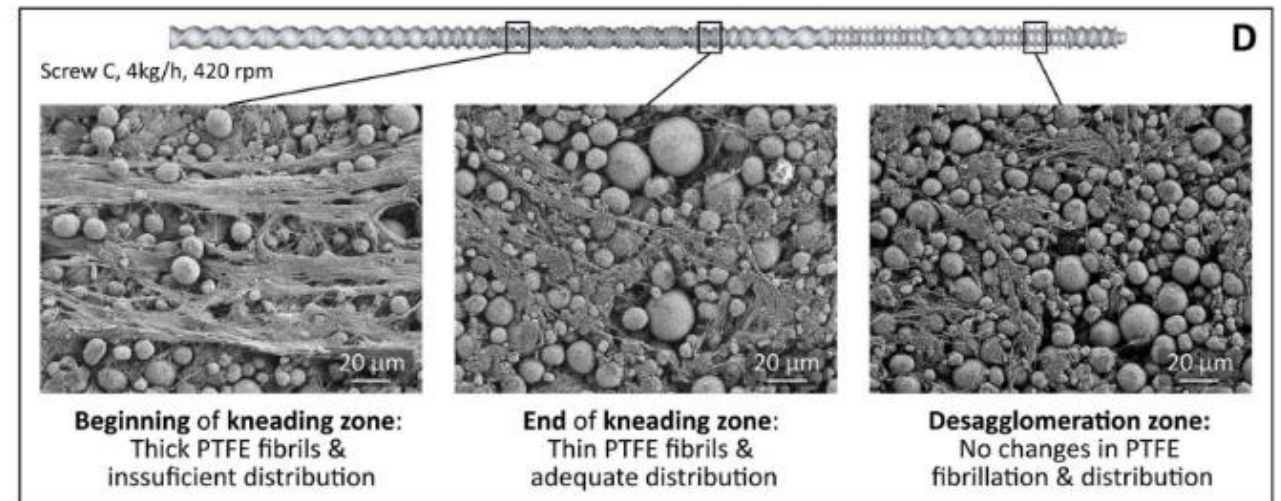
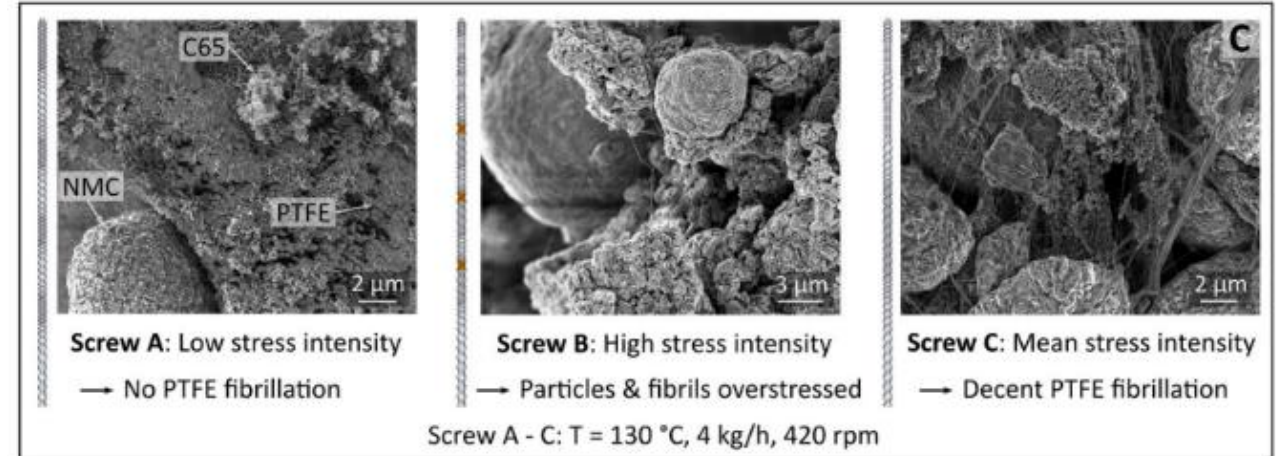
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Impact of screw configuration and screw elements during continuous mixing in an extruder

Huber et al., Journal of Energy Storage, **2025**, 124,116850

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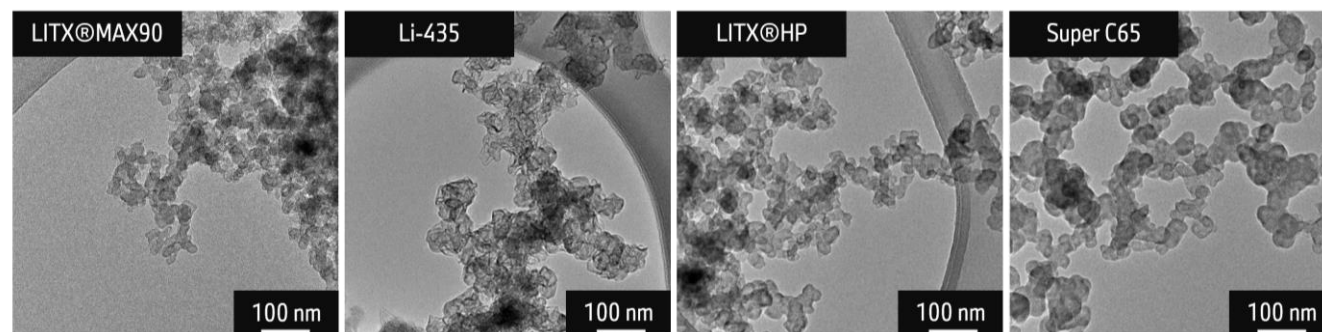
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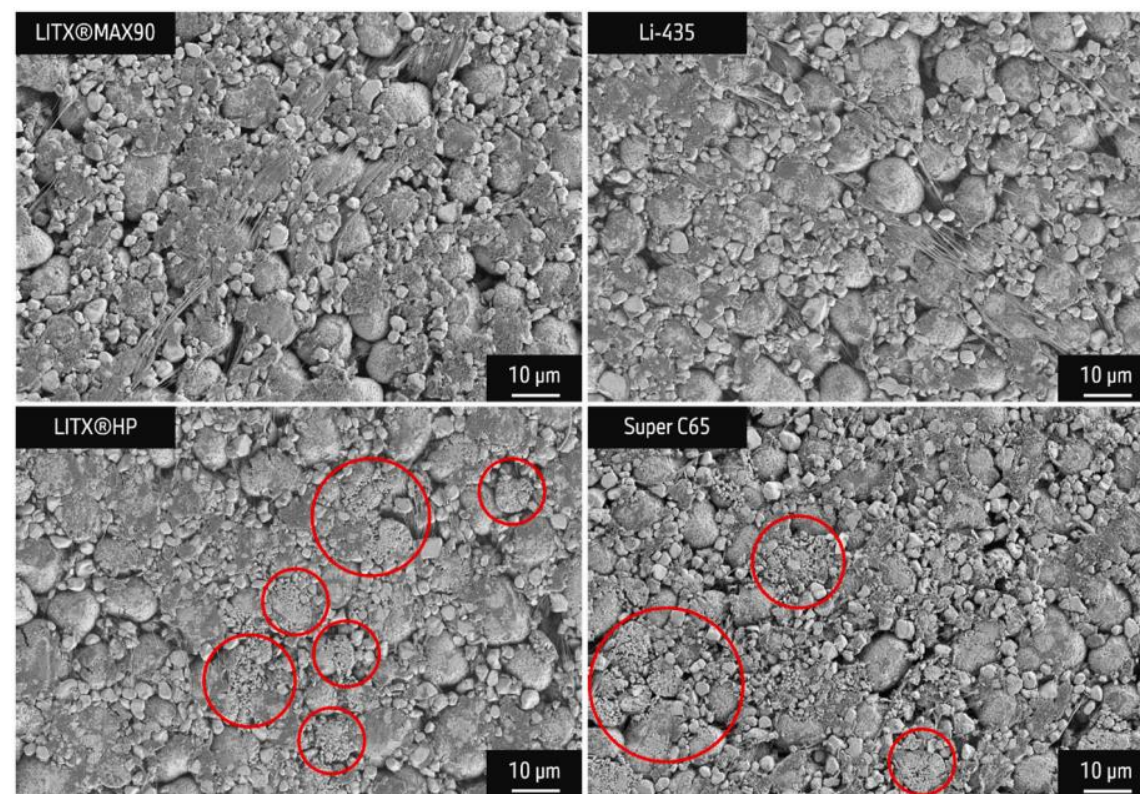
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TEM images of carbon black



SEM images of electrode surfaces, red circles highlight particle cracking of active material

Damnali et al., Journal of Power Sources, 2025, 646, 237243

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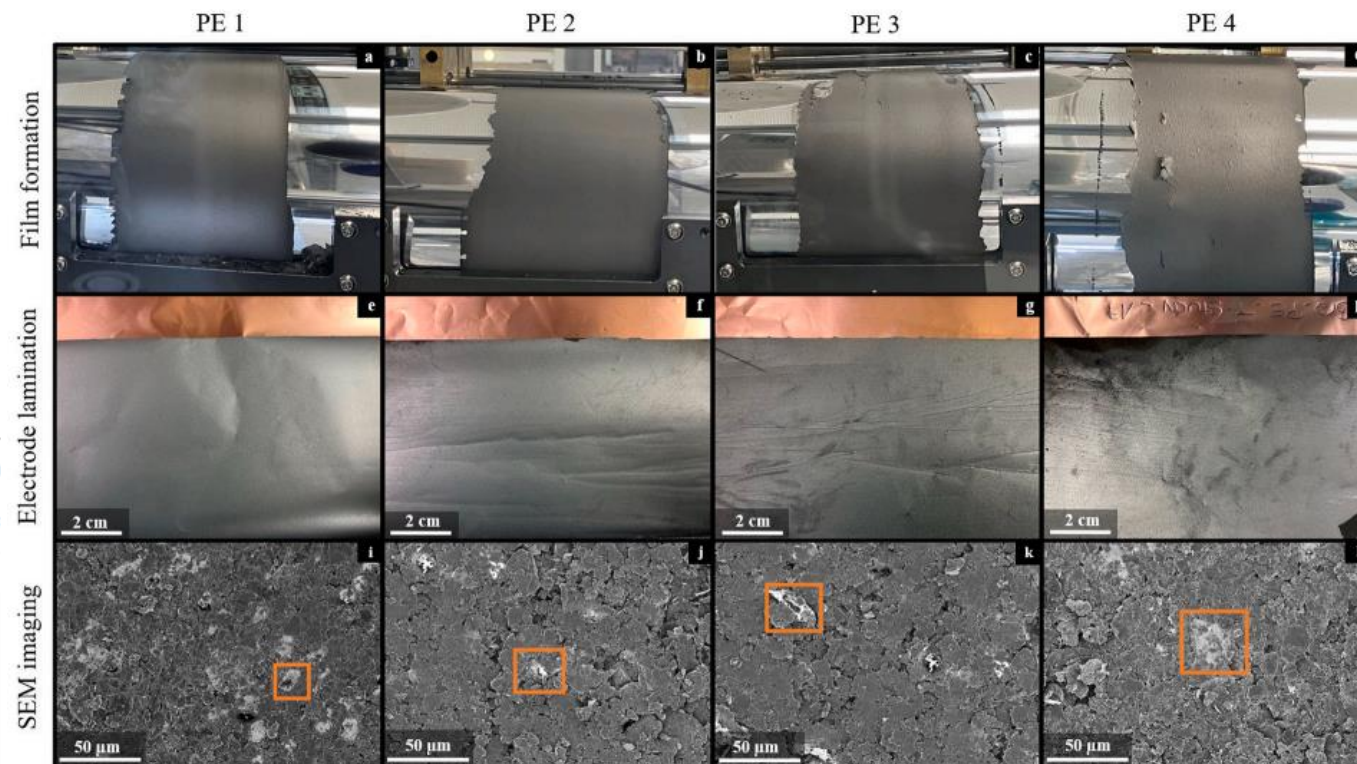
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Film formation (a-d), electrode lamination (e-h), morphological characterization via SEM of anodes with different PE binder grades

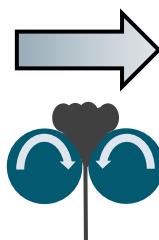
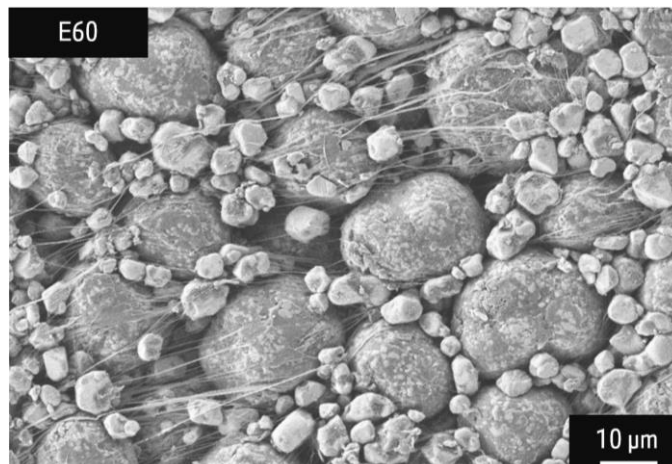
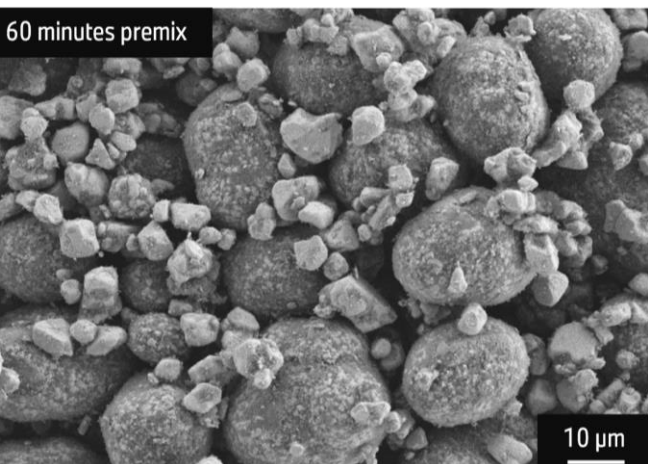
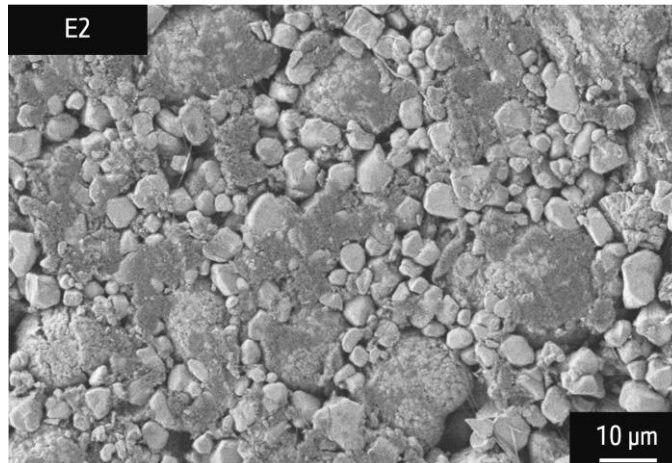
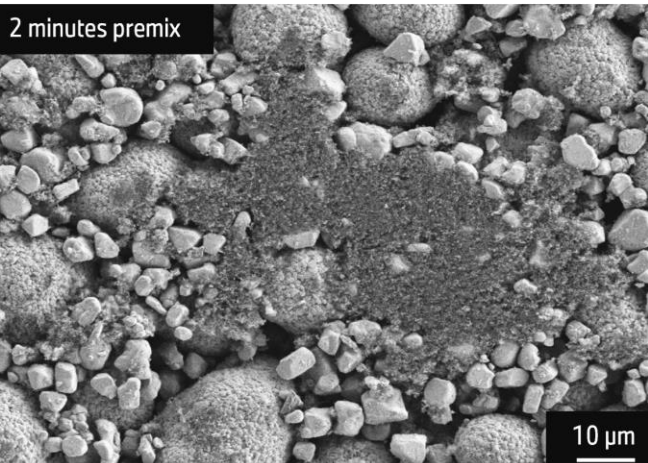
Gottsmann et al., Next Materials, 2025, 9, 101181

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INTEGRATING ADAPTED CONDUCTIVE ADDITIVES.

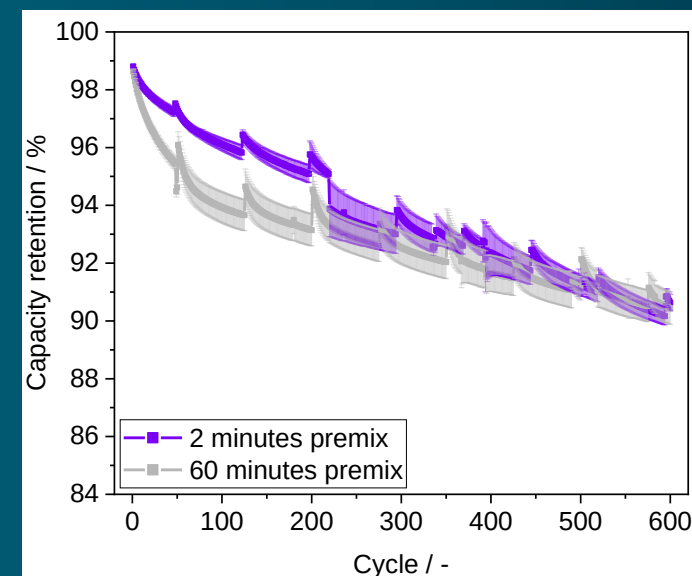
Premix of active material and carbon black

Calendered electrode



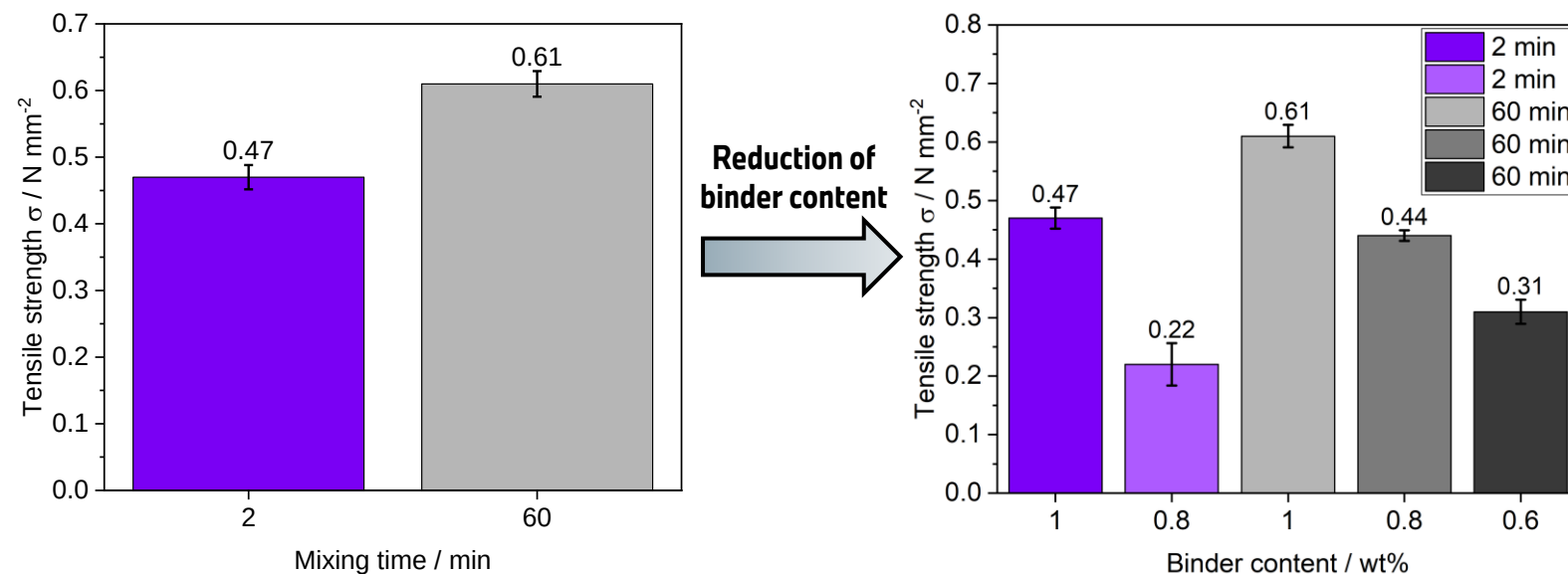
Cathode **dry**: 97.5 wt% NMC811, 1.5 wt% carbon black, 1 wt% PTFE
 Anode (wet): 95.8 wt% AG, 1.6 wt% CMC, 1.6 wt% SBR, 1 wt% carbon black
 Design: Porosity $25 \pm 1\%$ (dry), $30 \pm 1\%$ (wet), $n/p 1.1 \pm 0.005$
 Separator: Polyolefin (PP-PE-PP) separator
 Electrolyte: 270 μL 1 M LiPF_6 , 0.2 M LiFSI in EC/DMC/EMC 1:1:1

- Deagglomeration and coating of carbon black on active material surface by extended mixing time during premix
- Homogenous distribution of carbon black leads to stronger and more uniform fibrillation of PTFE
- Similar cell performance in cycling ageing test



INTEGRATING ADAPTED CONDUCTIVE ADDITIVES.

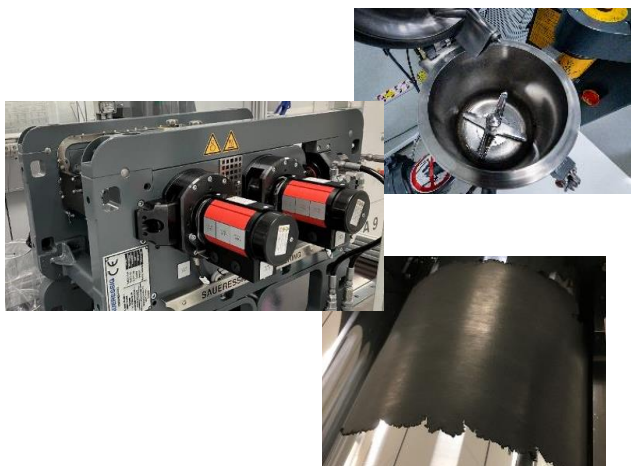
Tensile strength of free-standing films



- Increased tensile strength for free-standing films produced from mixture which was premixed for 60 minutes
- Reduction of binder content to 0.6 wt%
- No film formation possible from mixtures premixed for 2 minutes with 0.6 wt%
- Carbon black surface serves as attachment sites for PTFE fibrillation

DRY COATING AT BMW GROUP – CURRENT STATUS.

R&D + LAB



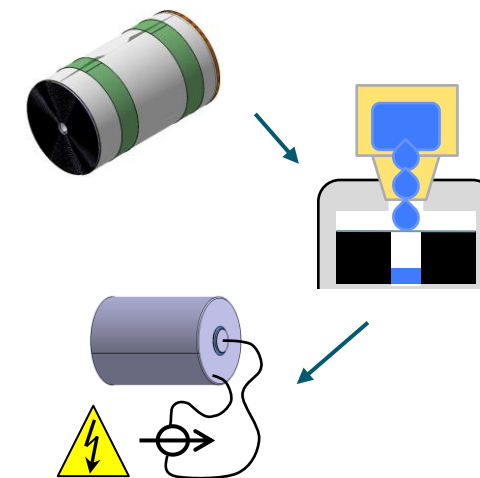
- ✓ Material compatibility for DBE
- ✓ Process-structure-property relationships

PROTOTYPE DRY ELECTRODE



- ✓ Separate Anode & Cathode lines
- ✓ Roll-to-Roll continuous coating:
up to 320 mm width & 50 m/min line speed

CELL MANUFACTURING



- ✓ Integration into existing downstream processes

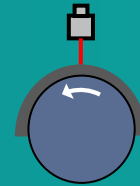
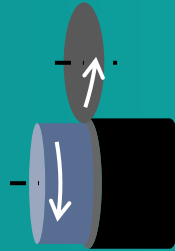
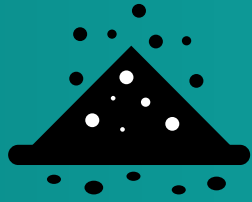
PRODUCT INNOVATIONS

PROCESS INNOVATIONS

MARKET IMPLEMENTATION

UPSCALING – EQUIPMENT CHALLENGES.

- Material handling & dosing
- Electrode cutting & technical cleanliness
- In-Line product analysis & quality control
- Equipment wear monitoring



Example: Edge cutting

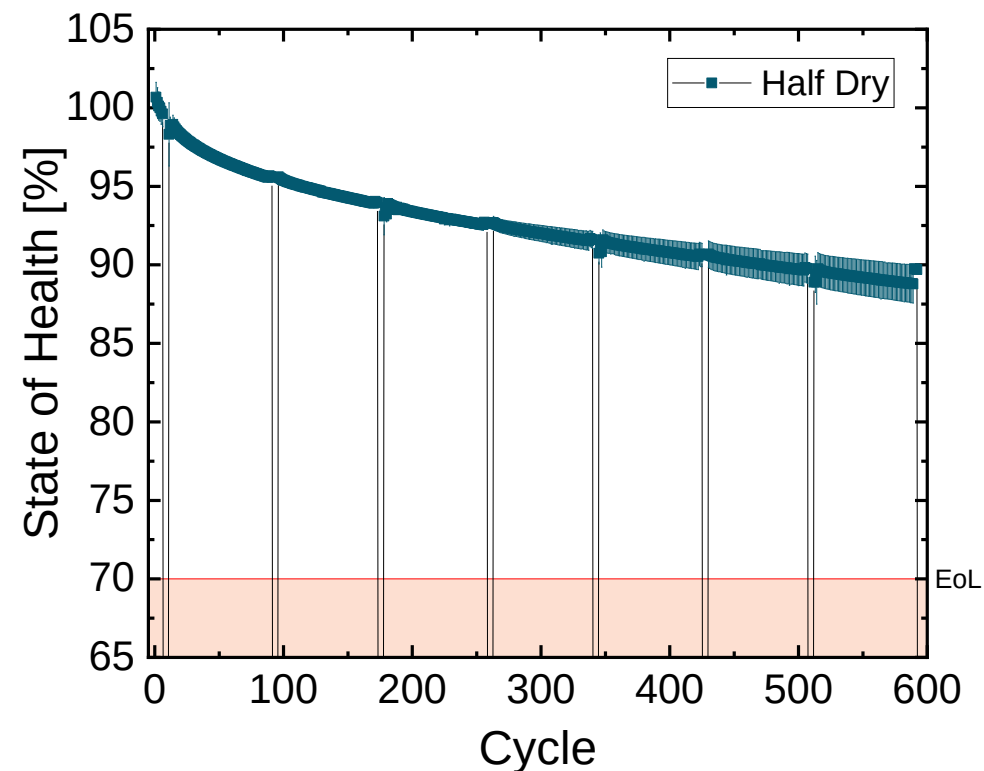
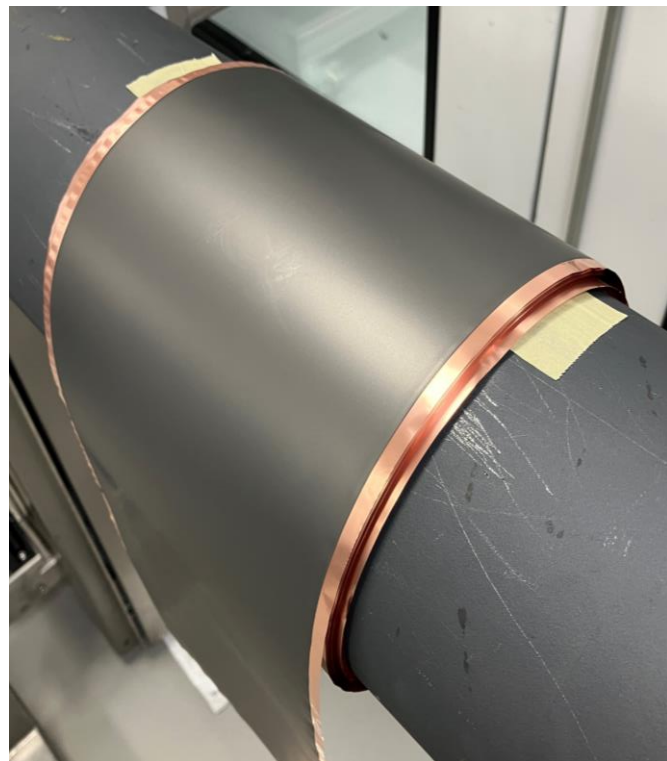
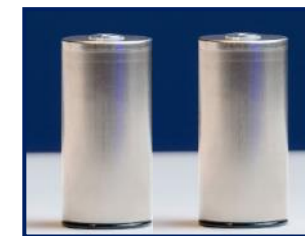


- Squeeze cut on roller surface
 - Strong wear on knife & roller
 - Knife cleaning necessary
 - Scrap suction necessary
- Clean cut not that easy

→ Further optimization of auxiliary equipment parts necessary

STATUS OF 4695 HALF-DRY CELLS.

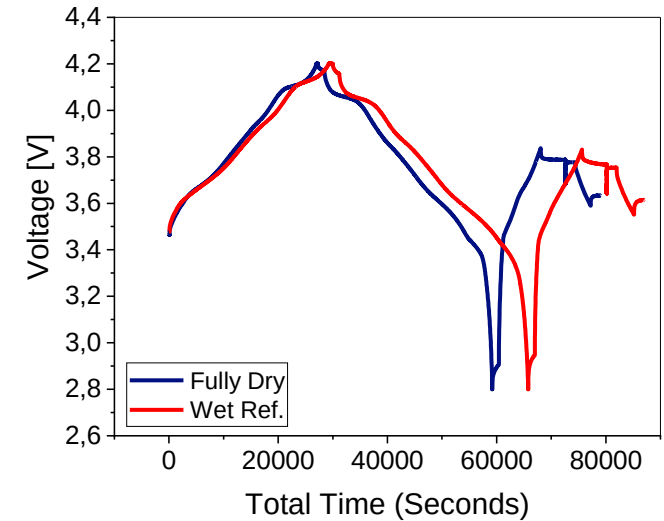
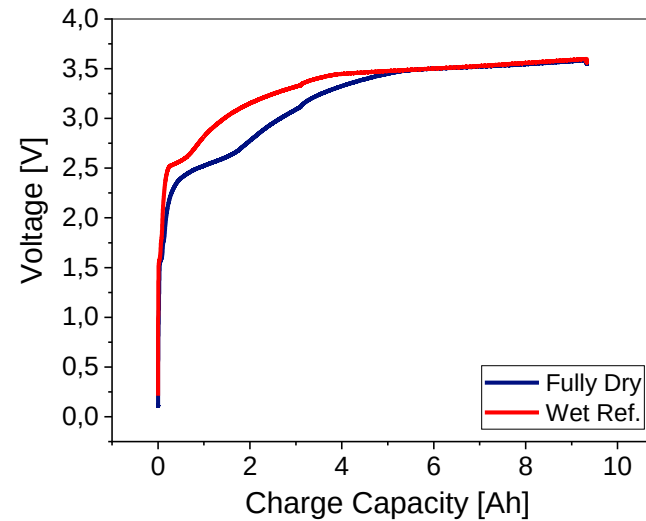
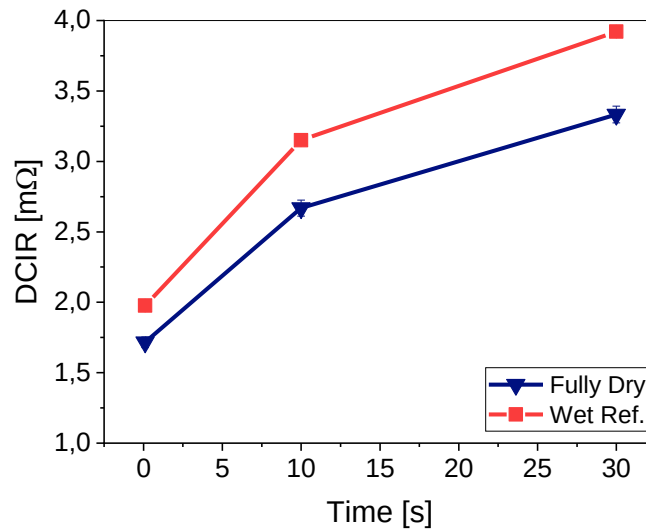
First 108Wh Half-dry (dry anode) 4695 cells for downstream & performance analysis



Well integrateable into downstream processes. Cells show good lifetime performance.

STATUS OF 4695 FULLY DRY CELLS.

First 112Wh fully Dry 4695 cells vs. 114Wh Wet reference



- Different mechanical behavior of electrodes in winding & cell manufacturing
- Lower resistivity but increased side reactions for fully dry electrode



No unexpected showstoppers discovered → Detailed analysis of fully dry cells ongoing.

SUMMARY.

- **Building up a strong competence in dry coating**
 - Analysis of materials
 - Development of electrode compositions
 - Process development for upscaling
- **Support suppliers to commercialize the technology**
- **Collaboration with industry partners across the process chain**

Outlook 2026

- R2R LFP dry coating
- Cylindrical cells with PE based anode

