Innovative Prozesstechnologien für Batterien der nächsten Generation

F. Hippauf, K. Schönherr, A. Dupuy, S. Poetke, M. Fiedler, B. Schumm, T. Abendroth, H. Althues, S. Kaskel

09. Innovationskongress Chemie | 31.05.2023

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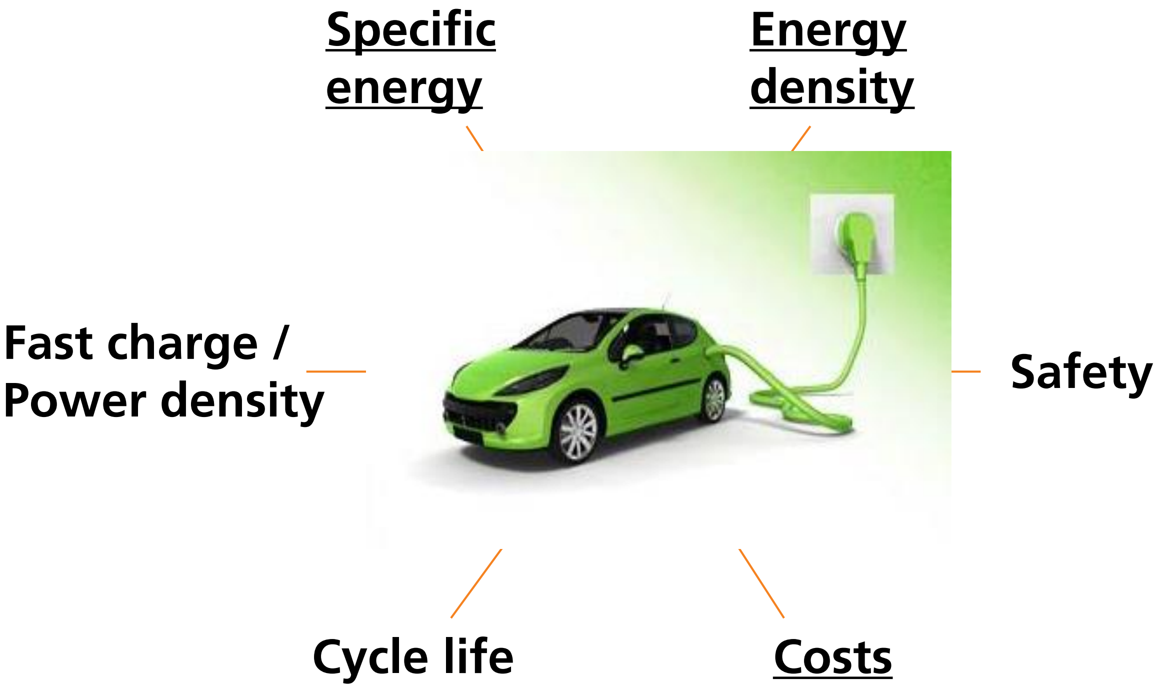
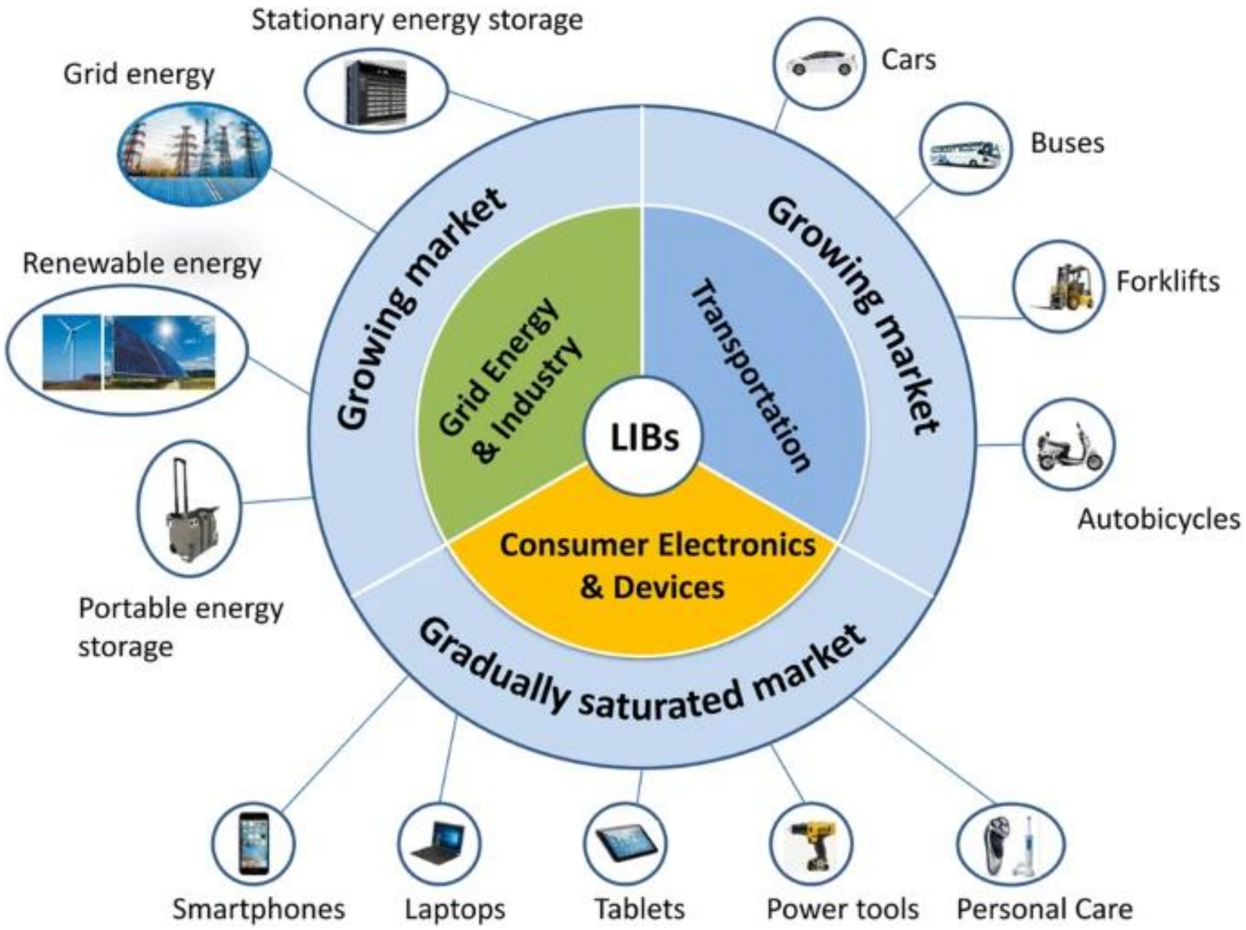
Next gen battery technology

State of the art and R&D trends

Applications and requirements





Y. Ding et al *Electrochemical Energy Reviews* volume 2, pages1–28(2019)

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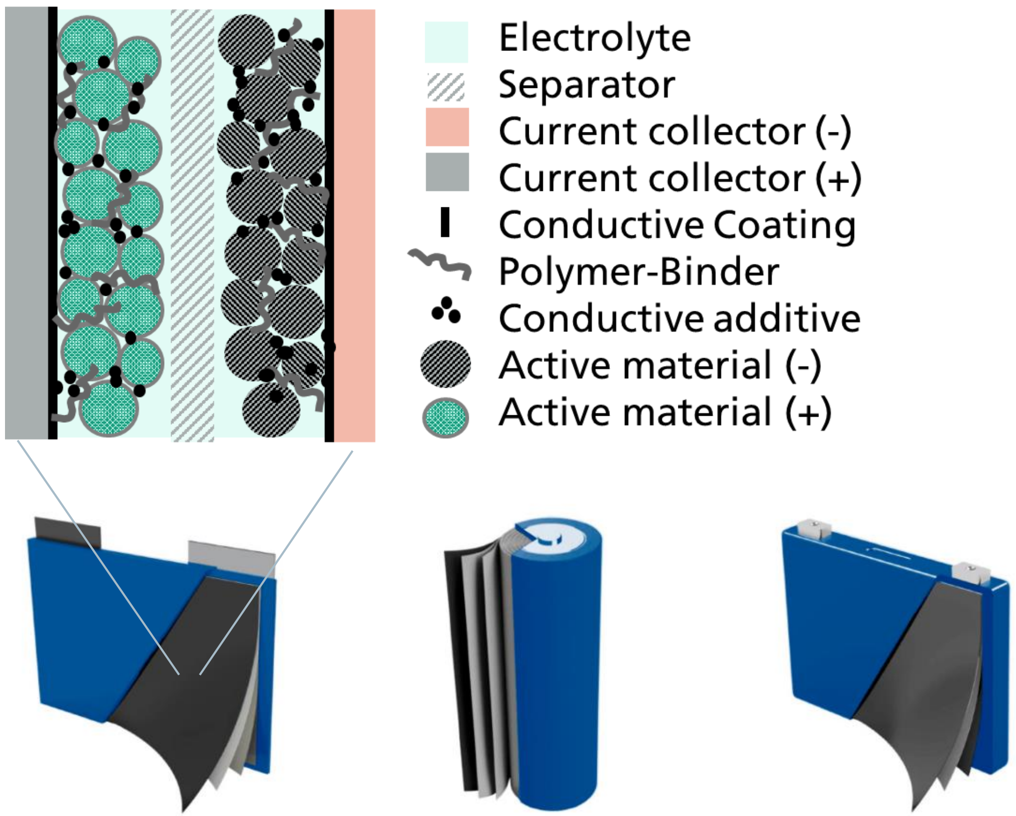
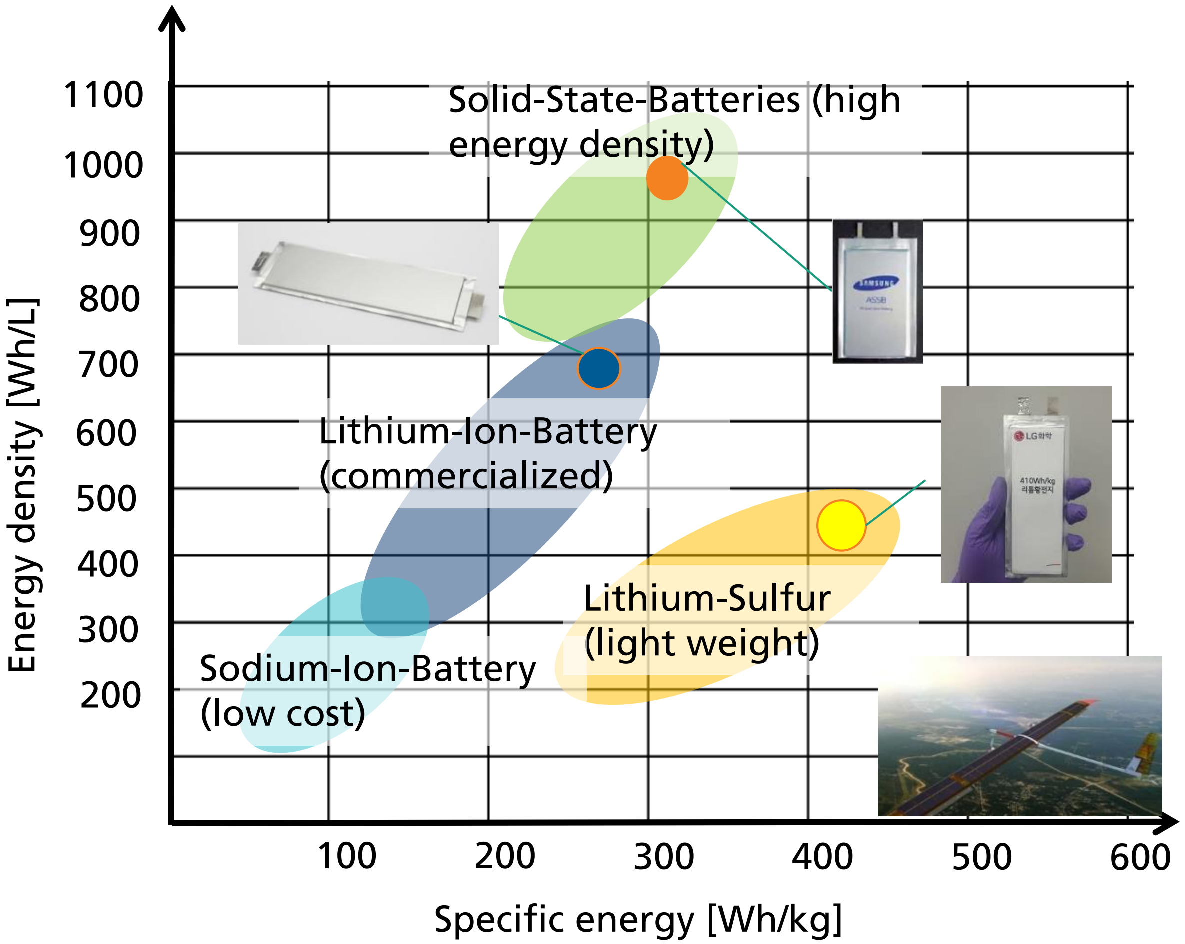
Next gen battery technology

State of the art and R&D trends

Battery cell composition (Scheme)





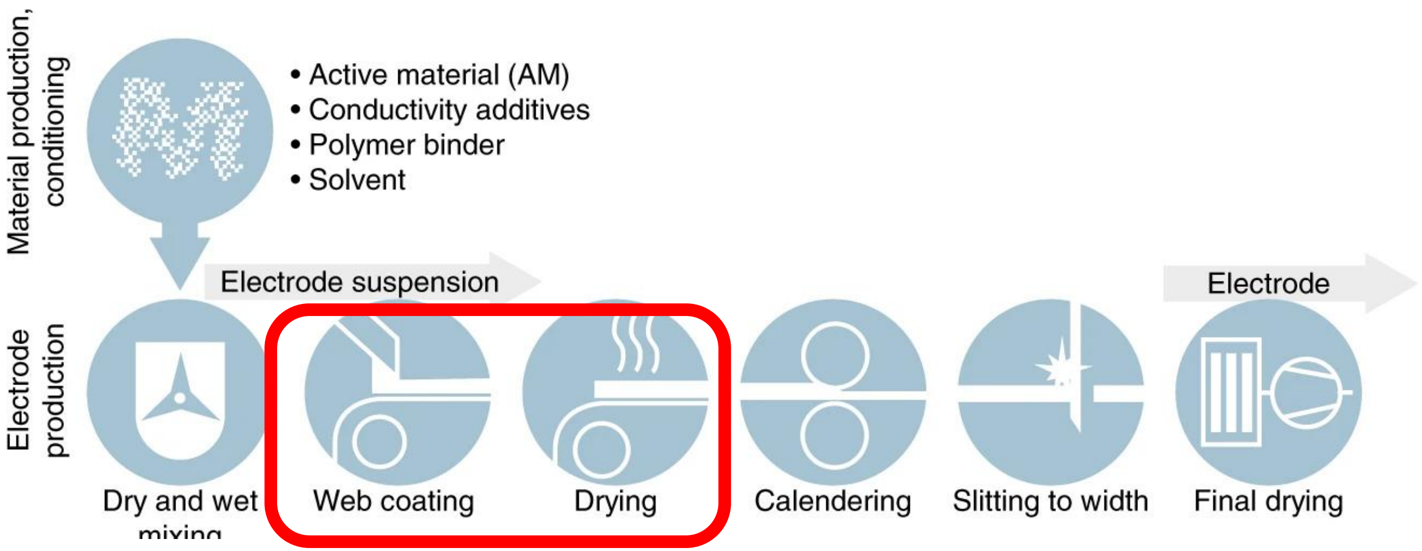
Löbberding et al. World Electr. Veh. J. 2020, 11 (4), 77; https://doi.org/10.3390/wevj11040077

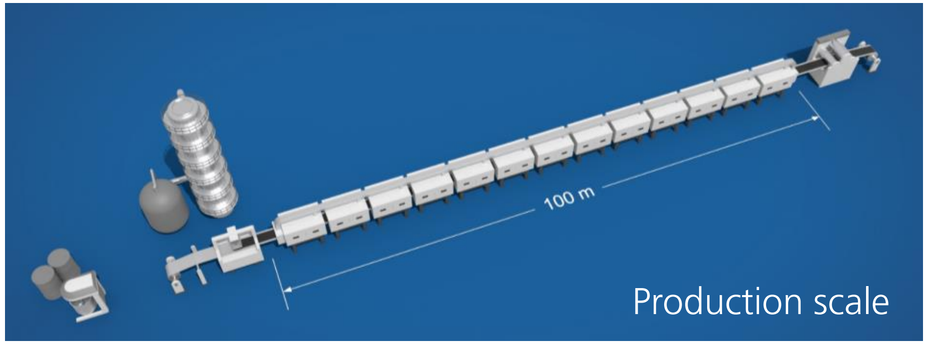
Next gen battery technology

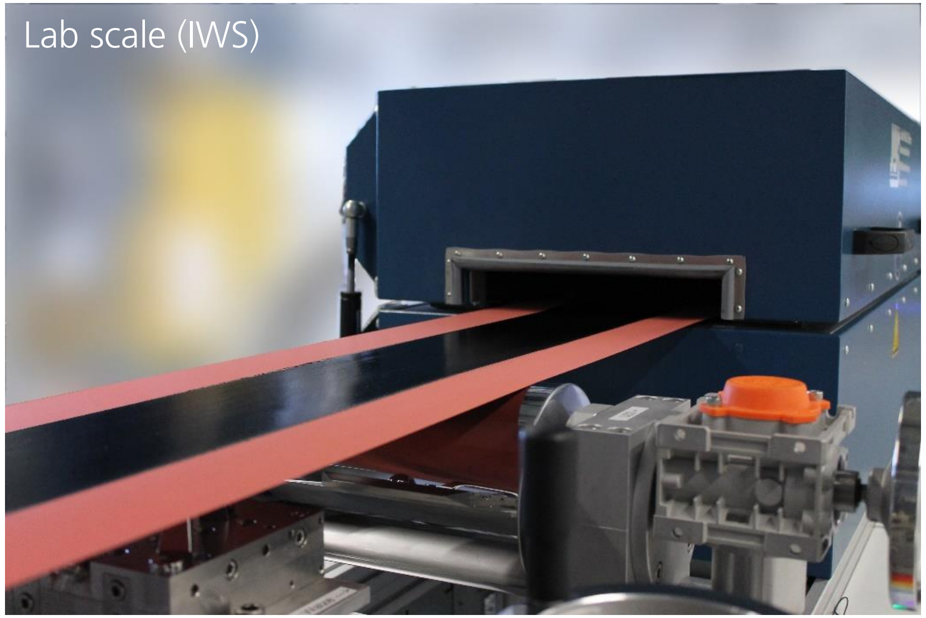
State of the art and R&D trends

State of the art production technologies (electrode)

- Coating process requires high energy consumption and the use of toxic organic solvents







Nature Energy **volume 3**, pages290–300 (2018)

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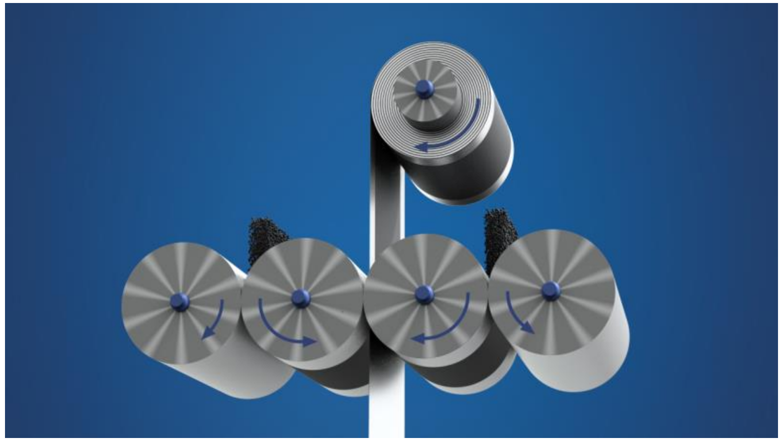
Video on Youtube

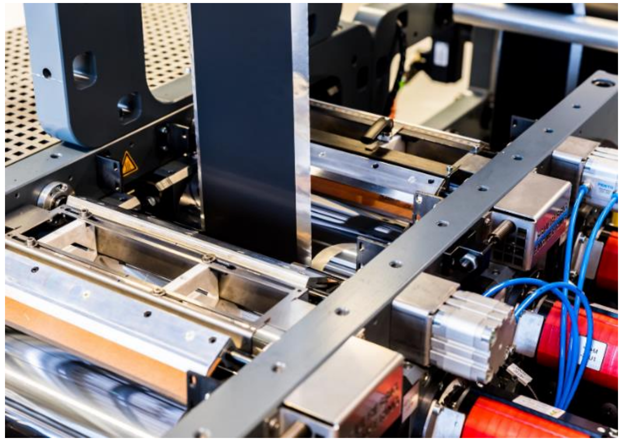
Process Innovations @ Fraunhofer IWS

Dry transfer electrode coating - DRYtraec

Solvent-free electrode processing via DRYtraec®

- No solvent / no drying → small footprint, low energy consumption
- Cost-efficient / scalable production possible
- Compatible with sensitive materials



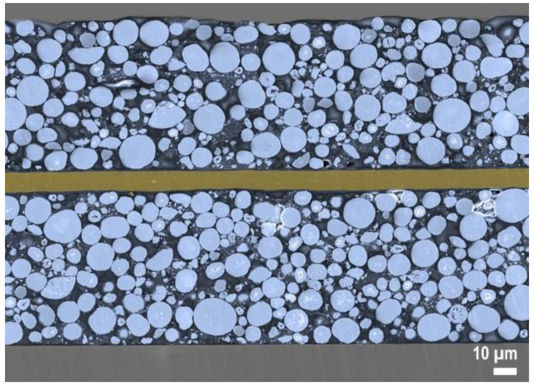


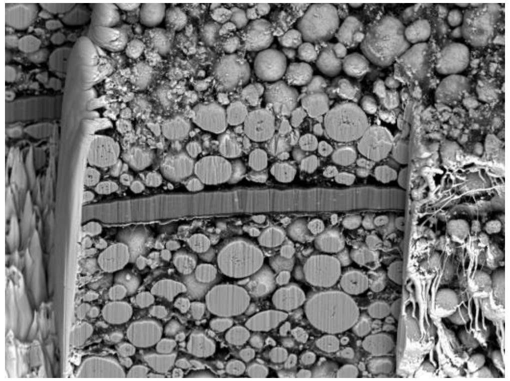
Process Innovations @ Fraunhofer IWS

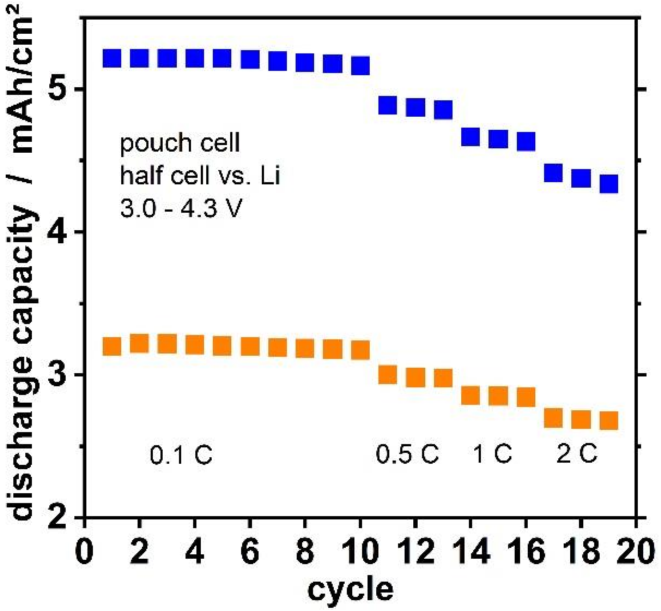
Dry transfer electrode coating - DRYtraec

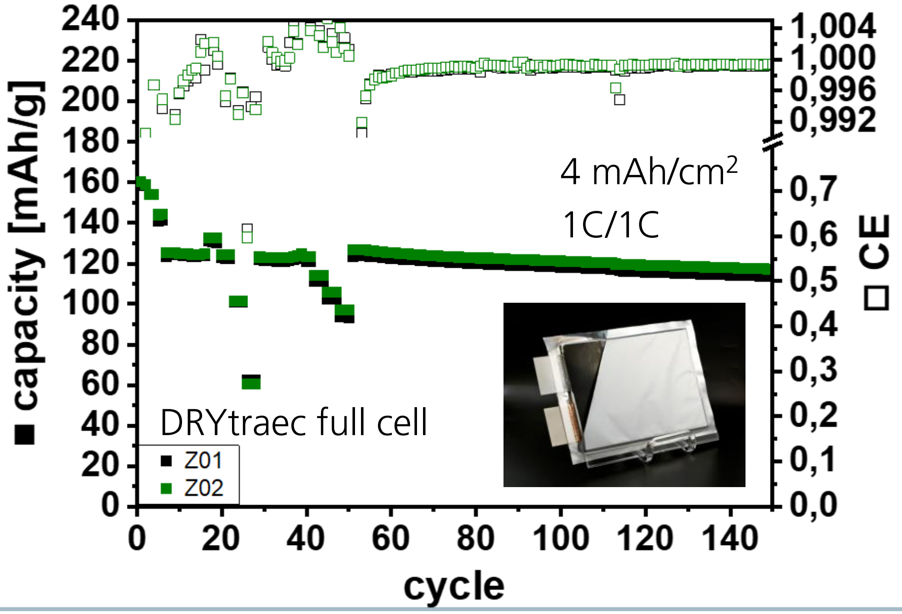
Electrode properties (Lithium-Ion battery electrodes)

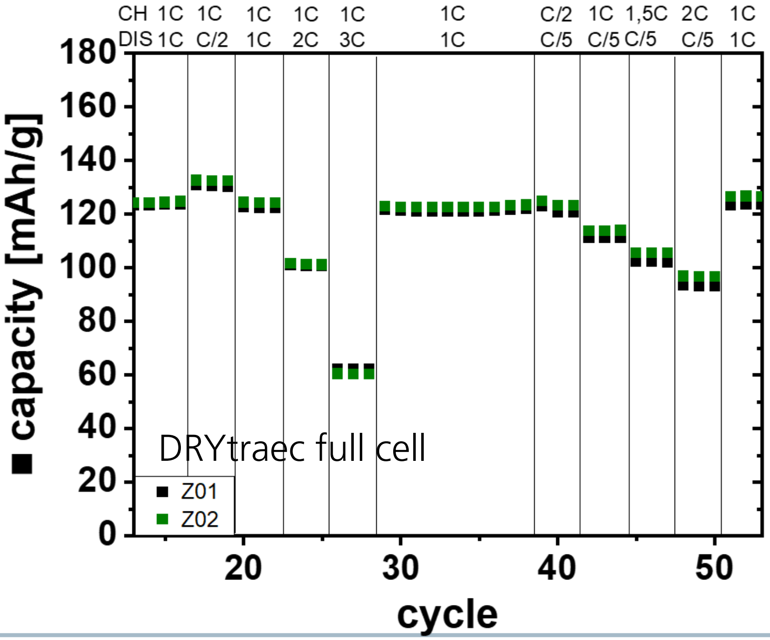
- Lithium-Ion cathode: 94.5% NMC, 4 % CB, 1.5 % PTFE
- Full cell testing with graphite anode: 98% Graphite, 2% PTFE









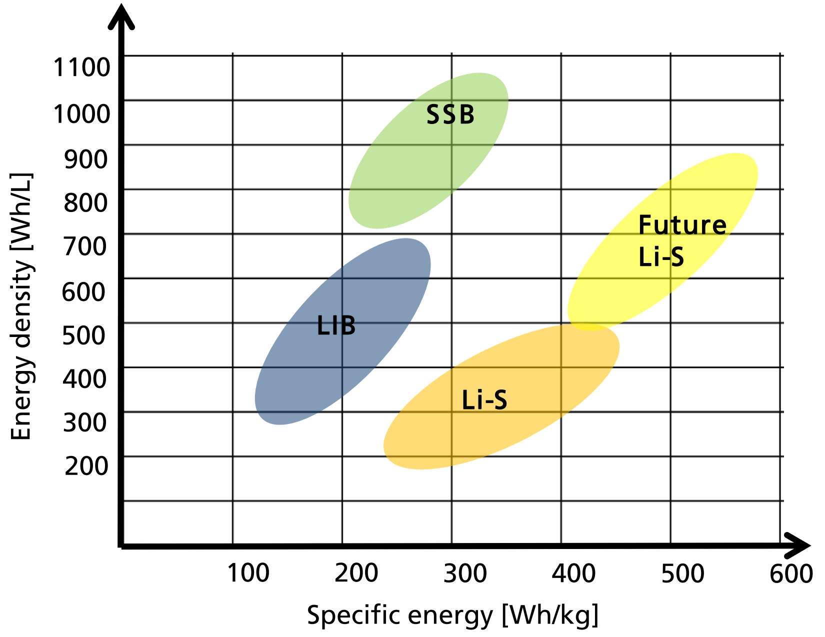


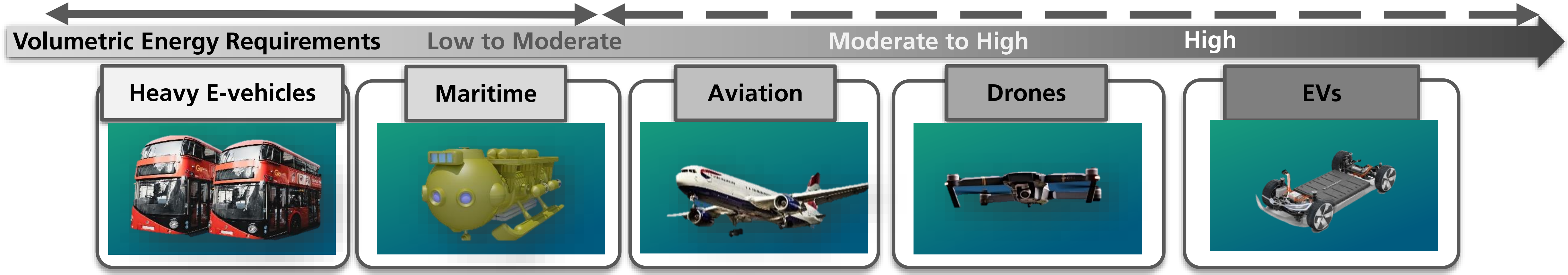
Lithium Sulfur (Li-S) Batteries

Light weight energy storage

Advantages of Lithium-Sulfur batteries

- Cost-efficient and abundant active material
- High gravimetric energy density / low volumetric energy density





S. Doerfler *et al.*, *Energy Technology* **2020**, *1*, 2000694
S. Doerfler *et al.*, *Joule* **2020**,*3*, 539
Y. Liu et al., *Adv. Mat*, **2021**, *8*, 2003955
M. Hage et al., *Adv. Energy Mat.*, **2015**, *5*, 1401968
B. McCloskey et al., *J. Phys. Chem. Lett.* **2015**, *6*, 4581
https://www.volkswagen-newsroom.com/en/electric-vehicles-3646

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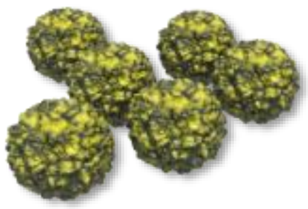
Li-S battery: Solvent-free S/C cathode coating

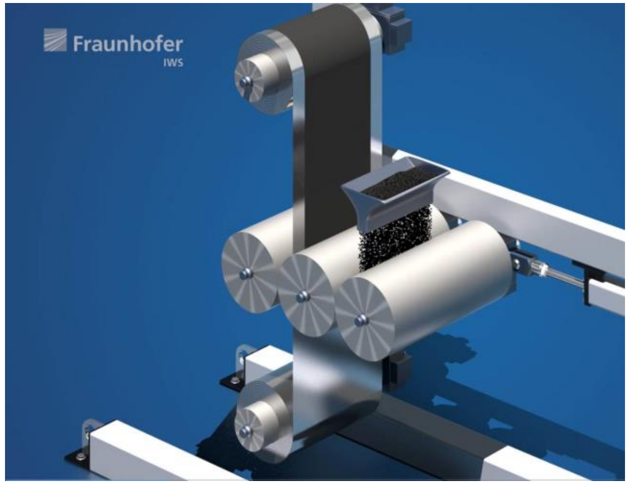
DRYtraec® process

Sulfur-Carbon DRYtraec cathodes

- Use of elemental Sulfur as active material
- Industrially available carbons as host material
  - Ketjenblack EC600JD, Nanocyl CNT
- Cathode composition: S/C/MWCNT/PTFE: 60/30/7/3



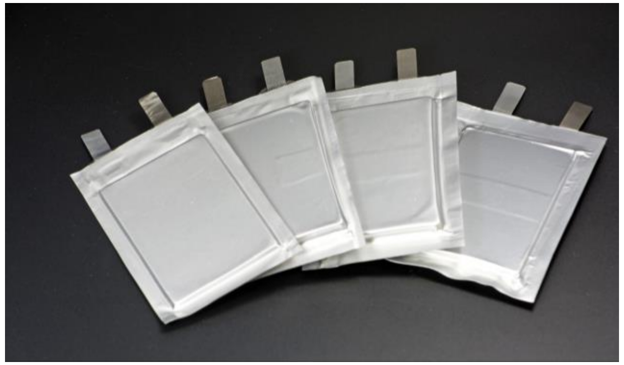
Carbon + Sulfur



Process advantages

- Avoides sublimation during drying
- Avoides sulfur oxidation (in slurry, and drying)
- Avoides solvent incompatibility with sulfides
- Low binder content (3 wt-% and less)

Specific energy:
> 400 Wh/kg on cell level



DE102017208220A1
WO2018210723A1
PCT/EP2018/062334

KR20200020702A
JP2020522090A
CN110869179A

ABTC Advanced Battery Technology Center

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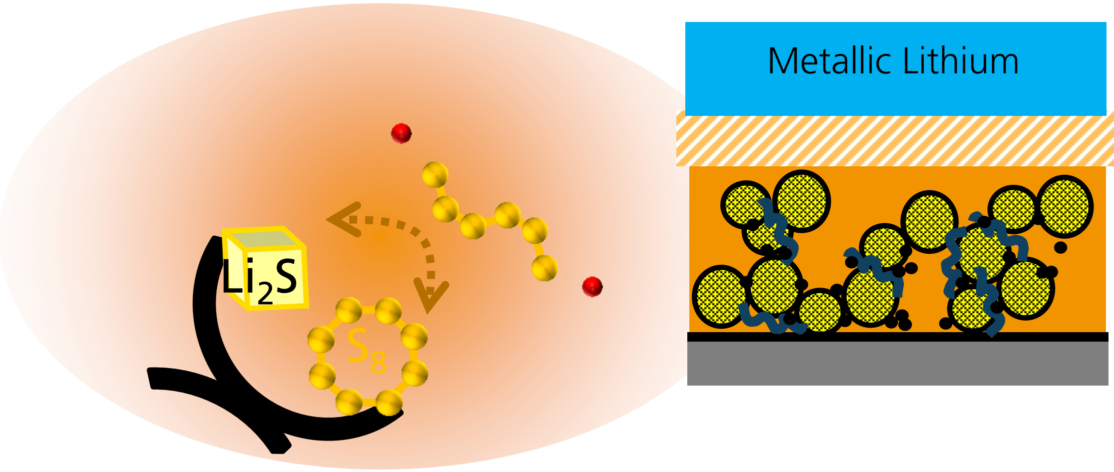
Li-S battery: conversion mechanism

From liquid to solid state chemistry

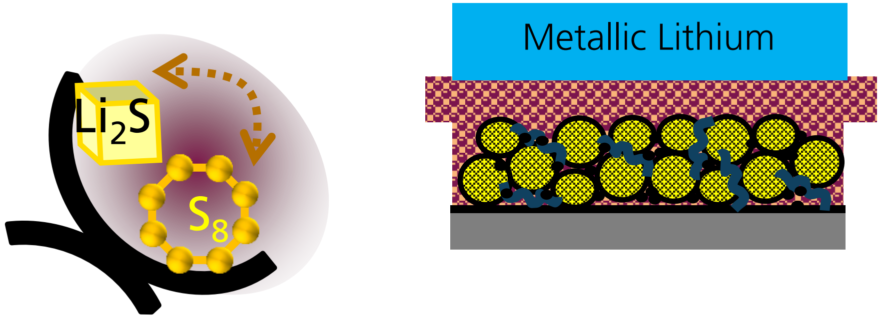
Liquid (ether) based conversion chemistry



Dissolution-precipitation mechanism

- High electrolyte content required (> 3 µl/mg-S)
- Limited specific capacity (~70 % S-utilization)

Solid (thiophosphate) based conversion chemistry



Solid state conversion mechanism

- Low electrolyte content required (< 2 mg/mg-S)
- Full specific capacity (~100 % S-utilization)

C. Barchasz et al, *Analytical chemistry* **2012**, *84*, 3973–3980.
C. Weller et al, *Energy Tech* **2019**, *7*, 1900625

Li-S battery: Solvent-free electrode coating

Solid state cathodes

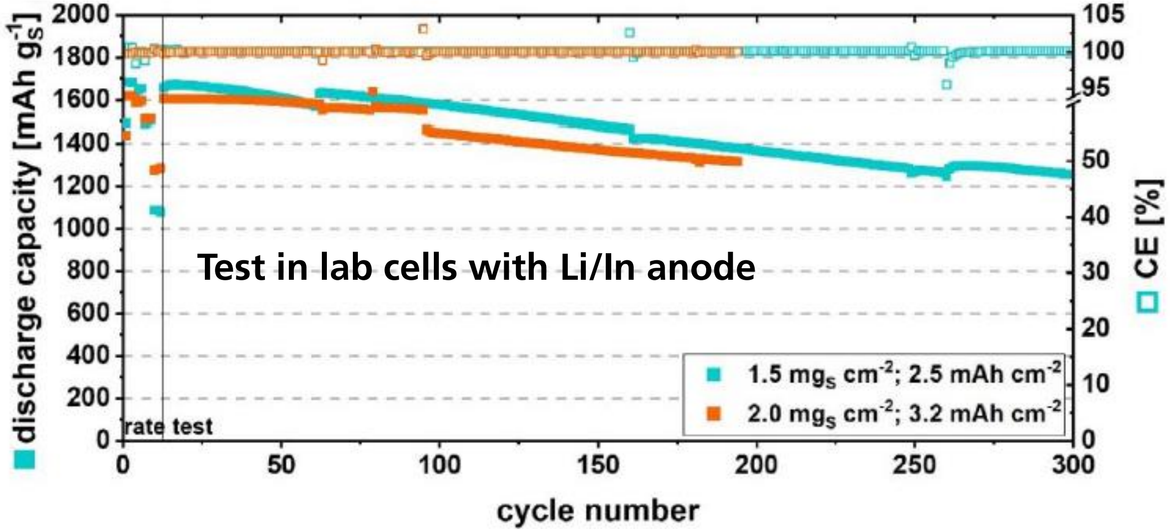
Composition of solid state sulfur cathodes

- Sulfur/carbon composites
- Solid electrolyte: Argyrodite (Li_6PS_5Cl)
- Cathode composition: S/C/SE/PTFE: 30/20/49/1

Performance data

- Full utilization / high specific capacity (> 1.500 mAh/g)
- High reversibility (> 200 cycles)
- Compact design / low electrolyte content

Dry film solid state cathode (0.1 wt% binder content)



M. Fiedler et al. Adv. Sustainable Syst. 7 (2023) 2200439

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Li-S battery: Solvent-free electrode coating

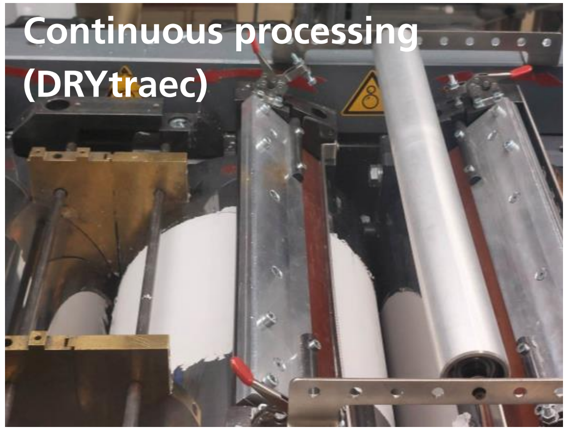
Solid Electrolyte Separator

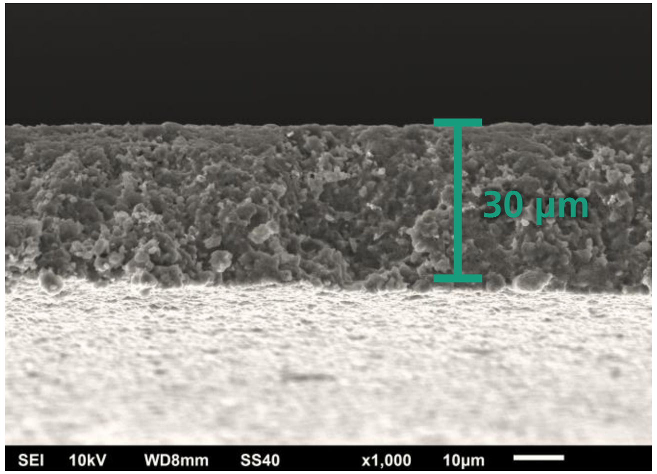
Composition of solid state separator

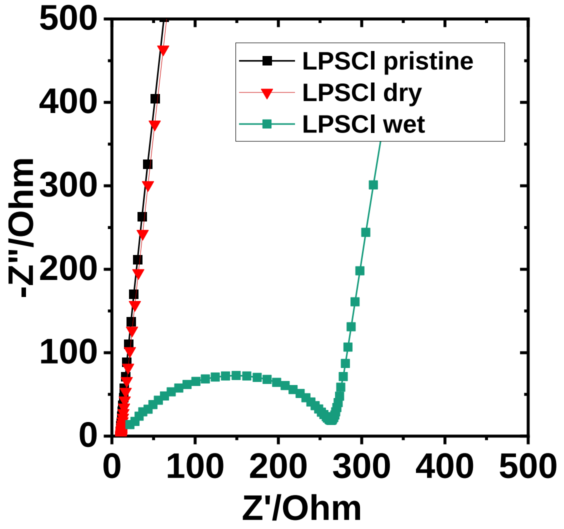
- Separators based on > 99 % solid electrolyte
- Solid electrolyte: Argyrodite (Li_6PS_5Cl)
- Binder content as low as 0.5 wt-% PTFE

Performance data

- DRY processing yields in sheets from 50-300 µm (before compression)
- Minimal influence on conductivity
- Down to 30 µm after compression (500 Mpa)







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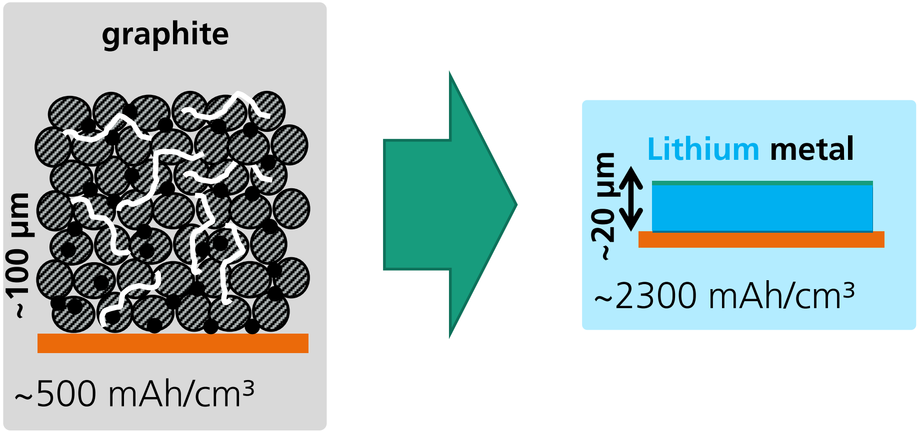
Process Innovations @ Fraunhofer IWS

Lithium coating

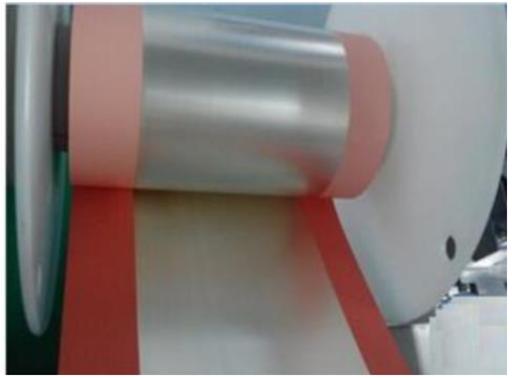
Lithium metal anodes - motivation

- Lithium metal anodes are key for high energy battery cells
- High specific capacity → high volumetric and gravimetric energy density



State of the art Lithium film processing

- Extrusion + Rolling → challenging / expensive for low thickness (< 20 µm)
- Vacuum deposition → challenging / expensive for µm thickness (> 2 µm)



100 µm Li on Cu foil via rolling process (mtixtl.com)

Li on Cu foil via vacuum deposition process (sidrabe.com)

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Process Innovations @ Fraunhofer IWS

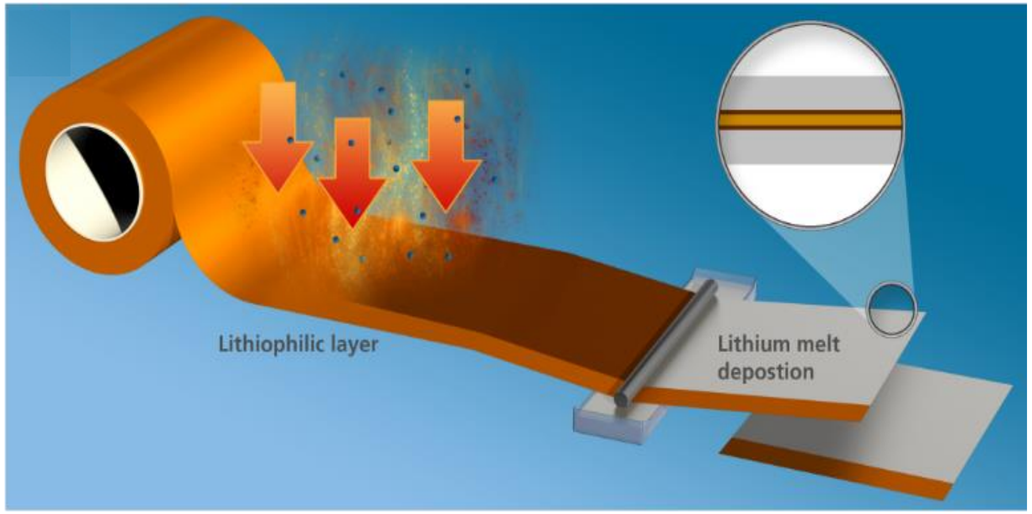
Lithium melt deposition

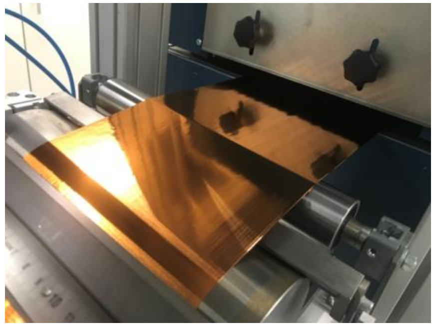
Melt deposition – process concept

- Step 1: Lithiophilic surface treatment on current collector foils to enable wetting of Li melt
- Step 2: Deposition of molten Lithium on modified foil

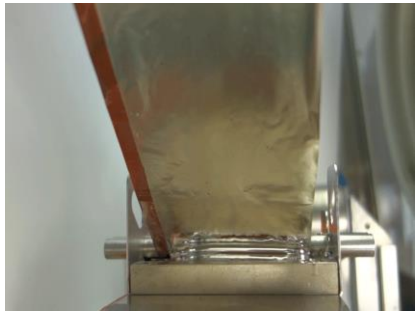
Process advantages

- Suited for a thickness range of 2 – 30 µm
- Scalable process – demonstrated in double-sided / roll-to-roll (R2R) deposition (lab scale)





R2R promotion layer coating



R2R lithium coating

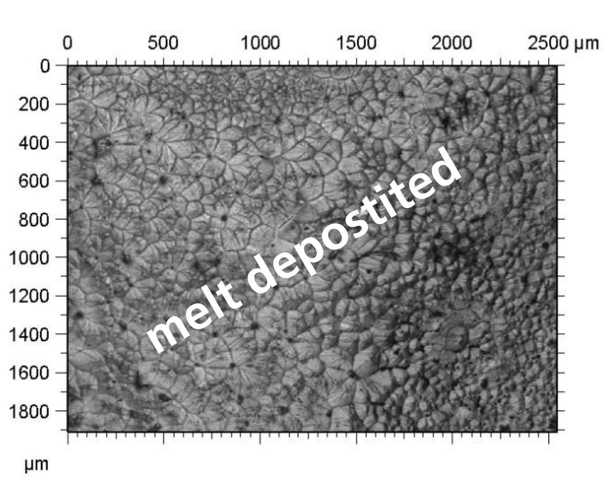
K. Schönherr et al. Chem. Eng. J. Advances 9 (2022) 100218

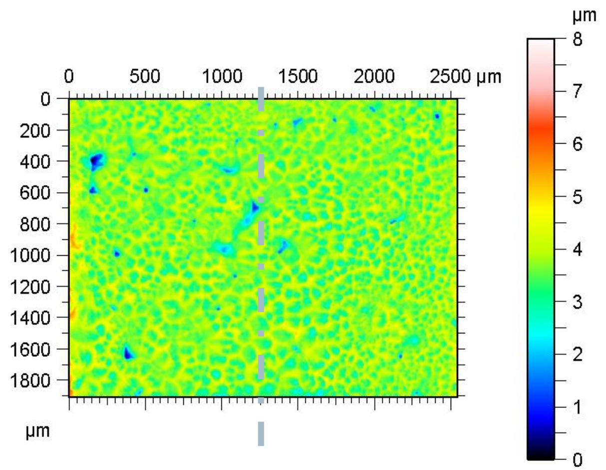
Process Innovations @ Fraunhofer IWS

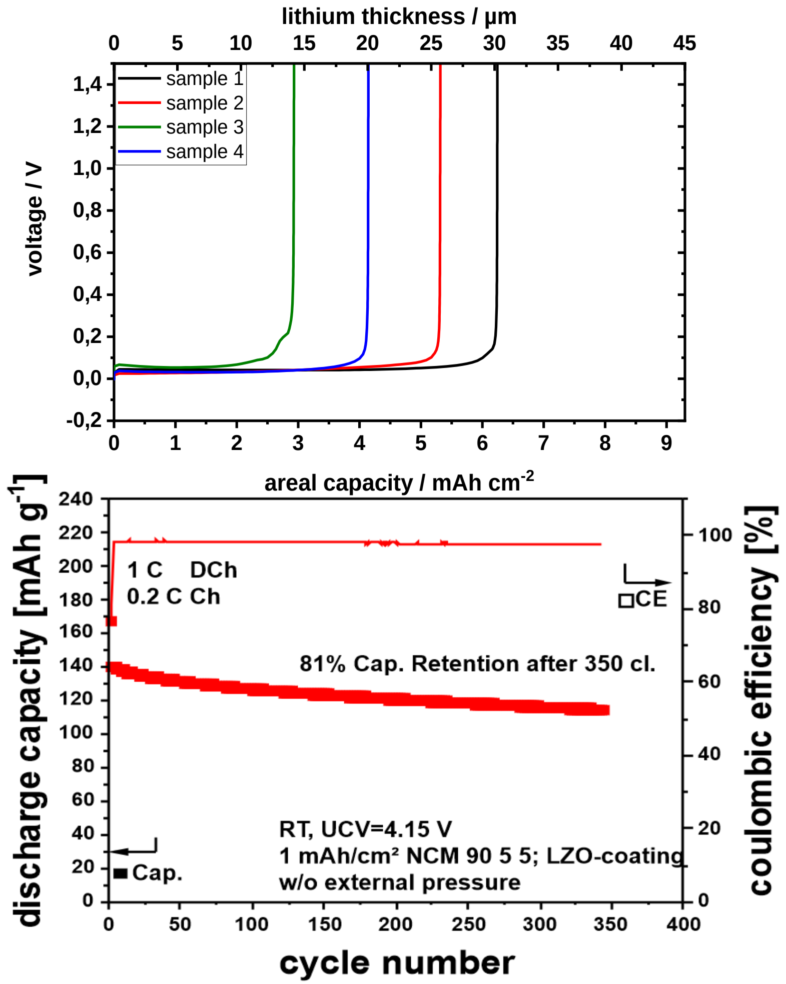
Lithium melt deposition

Lithium film properties

- Tunable thickness range
- Demonstrated in solid state battery (metal oxide cathode)
- Surface roughness: sa: 0.4 µm, sz: ~ 7 µm (comparable to rolled Lithium)







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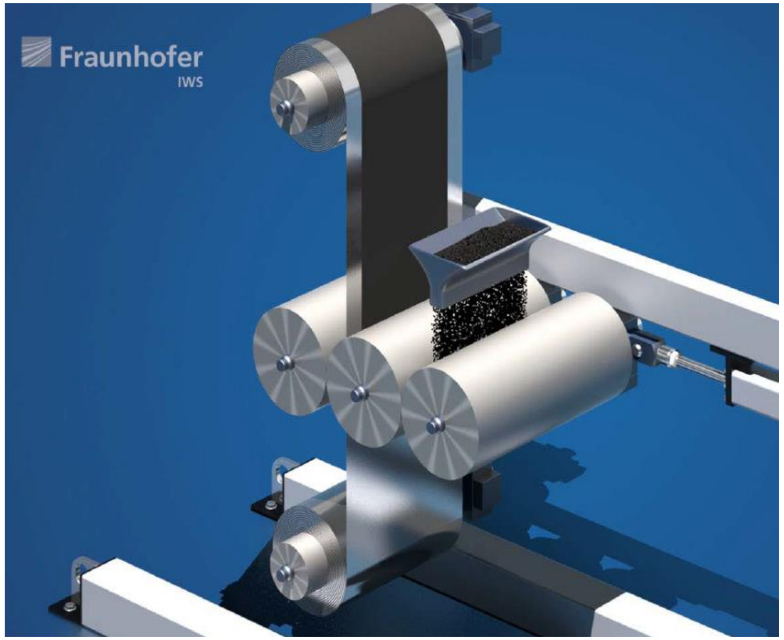
Summary

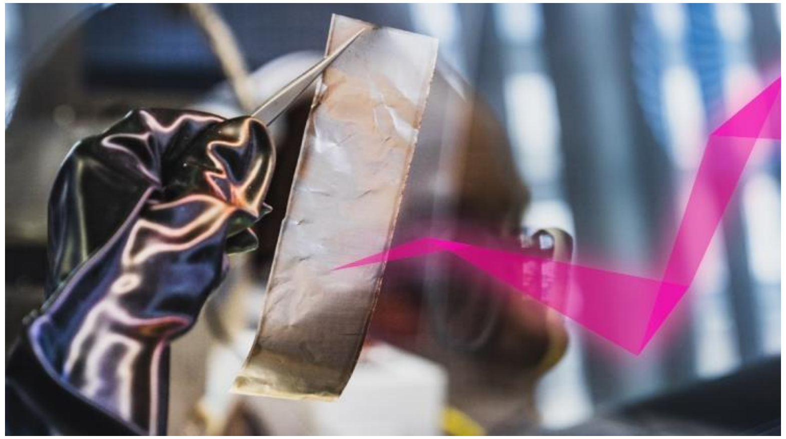
DRYtraec®

- Green, solvent-free electrode coating with reduced TCO & footprint
- Applicable to LIB and next generation batteries
- Advantageous processing for Li-S and solid state battery components
- Solid state electrolytes enable a new generation of Li-S cells

Lithium melt deposition

- Scalable technology for Lithium coatings from 2 – 20 µm thickness
- Demonstrated on thin Ni and Cu current collectors





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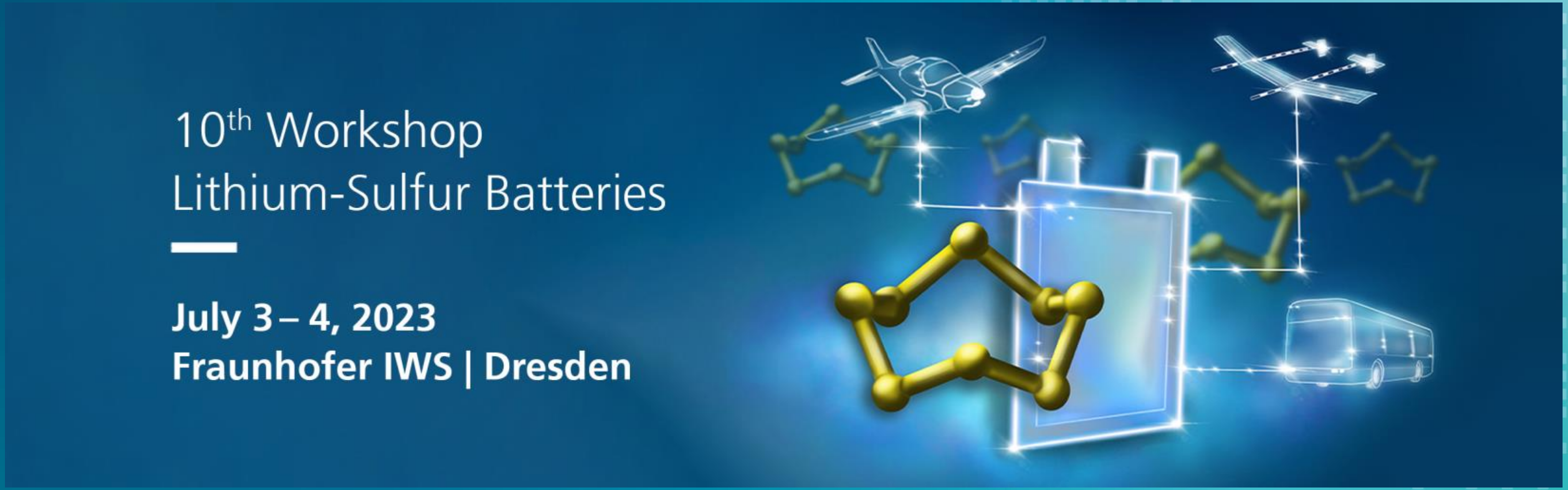
Events


10th Workshop
Lithium-Sulfur Batteries
July 3 – 4, 2023
Fraunhofer IWS | Dresden


Dry Coating Forum
Shaping the future of dry battery electrode processing
September 12 – 13, 2023 | Fraunhofer IWS | Dresden

Contact

Dr. Holger Althues
Advanced Battery Technology Center
+49 351 83391 3476
holger.althues@iws.fraunhofer.de

Fraunhofer-Institut für Werkstoff- und Strahltechnik IWS
Winterbergstraße 28
01277 Dresden
www.iws.fraunhofer.de

www.drytraec.de

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Thank you!

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