Segmented rechargeable micro battery for wearable applications based on printed separator and LTO/NMC electrodes

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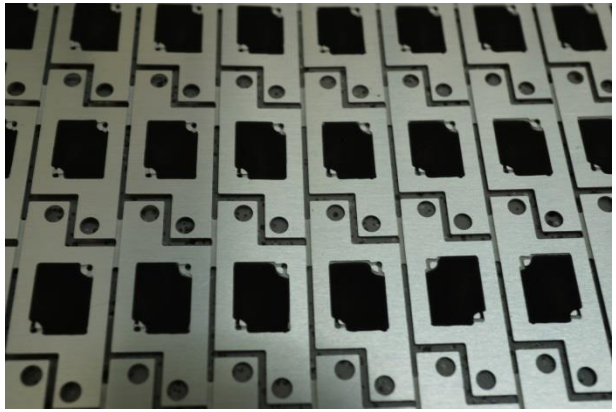
MAT FLEX END

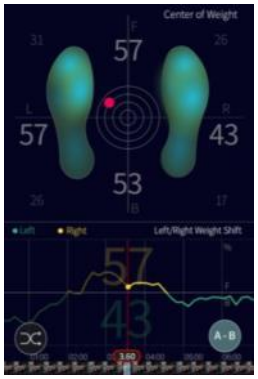
Outline

- Applications for thin rechargeable micro batteries
- IZM Packaging technology of micro batteries on substrate level
- The concept of segmented flexible battery
- Electrode development
- The lithium micro battery prototyping line and battery assembly
- Micro battery test results and parameters
- Conclusions



Flexible batteries for wearable electronics

www.cyberglovesystems.com/



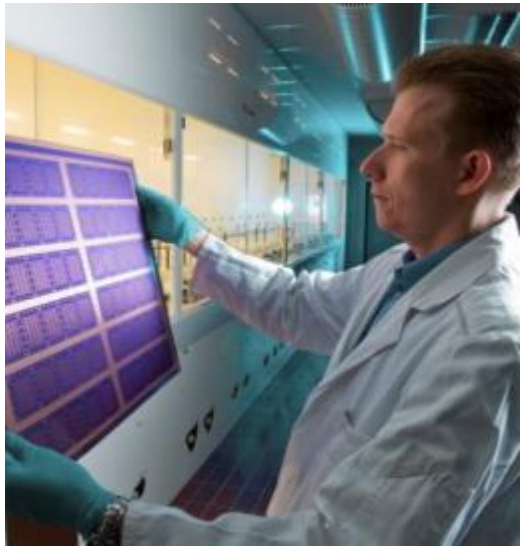
Salted Venture

Smart bracelet,
and other electronic wrist bands

SenseGo,

Packaging of micro batteries on substrate level

High density printed circuit board, metal laminates



System Integration and Interconnection Technologies

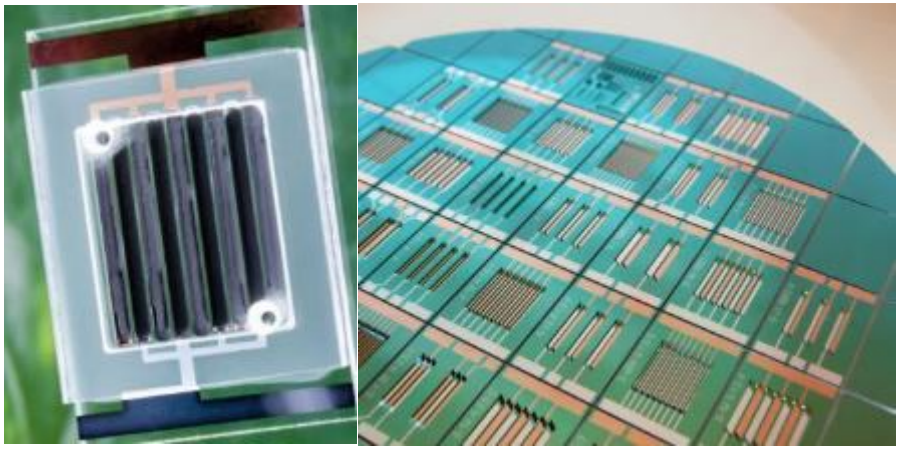
Silicon wafer technology

Wafer Level System Integration

Substrate options

Metal, laminate

Silicon/Glass



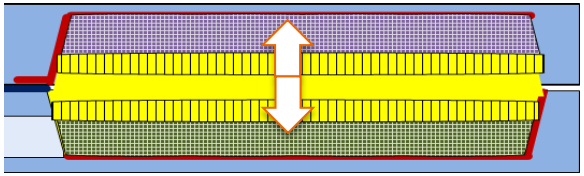
5 cm² 1 cm² 0.2 cm² 4 mm² 0.8 mm²

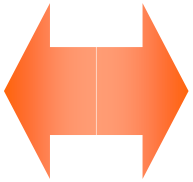
metal

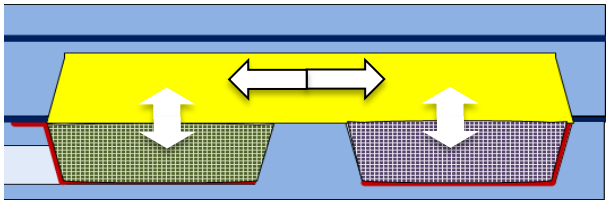
Silicon/glass

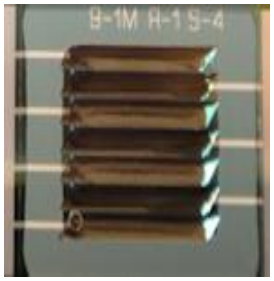
20 mAh 1 mAh 100 µAh 20 µAh

Stacked and interdigitated electrodes

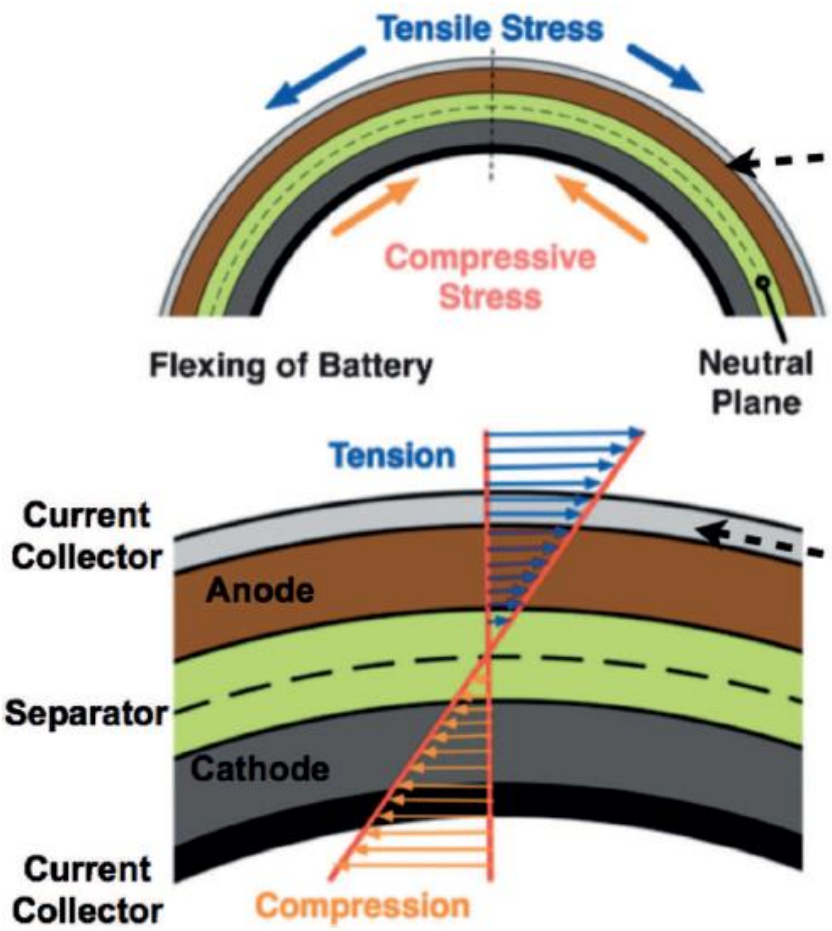


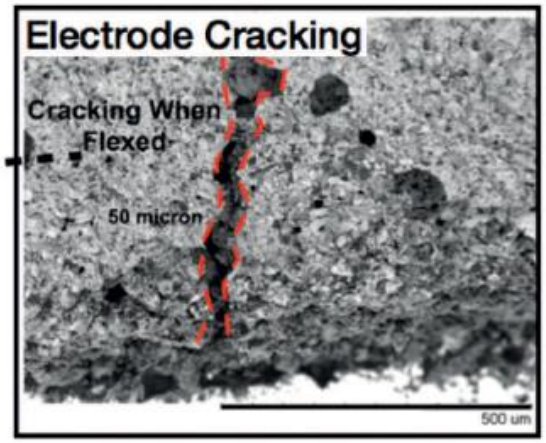


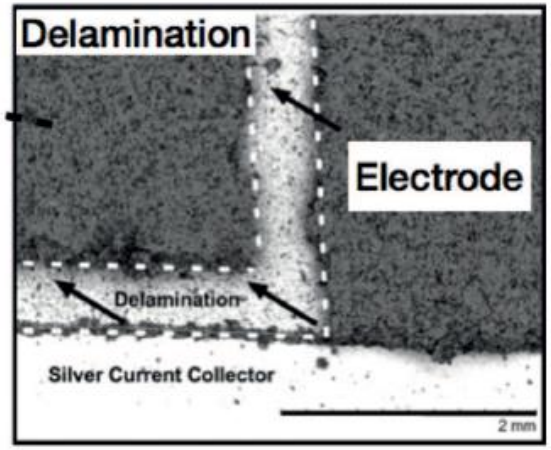




Flexible batteries ?







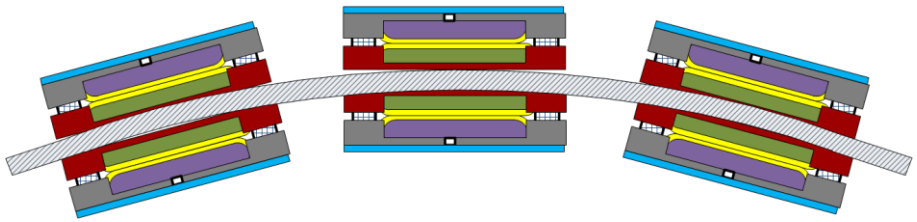
Recent Progress on Printed Flexible Batteries: Mechanical Challenges, Printing Technologies, and Future Prospects

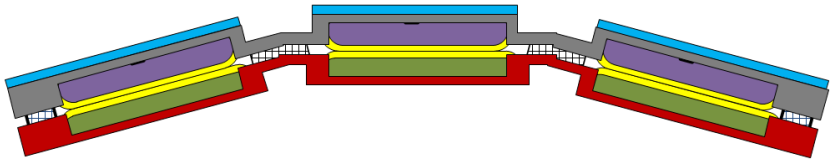
Abhinav M. Gaikwad,*[a] Ana Claudia Arias,[a] and Daniel A. Steingart[b]

The concept of segmented flexible battery

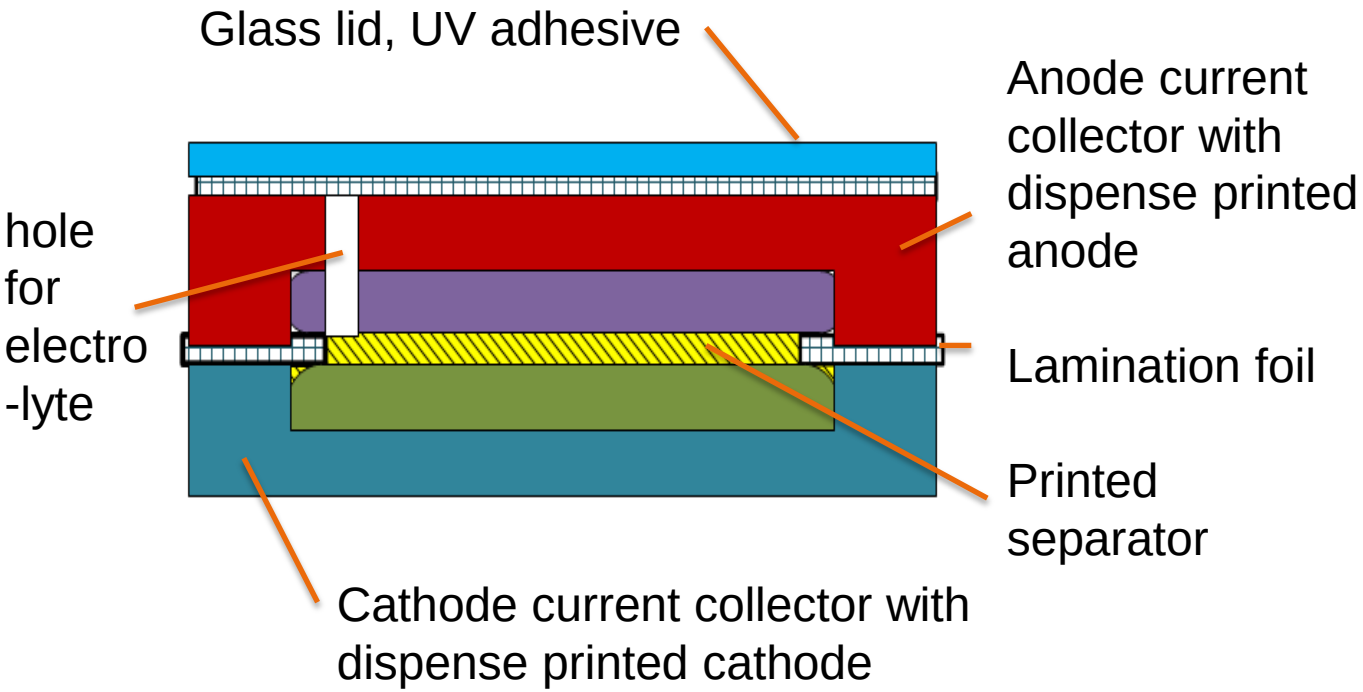
Interconnect individual batteries on a flexible substrate

Thinned regions between segments allow bending

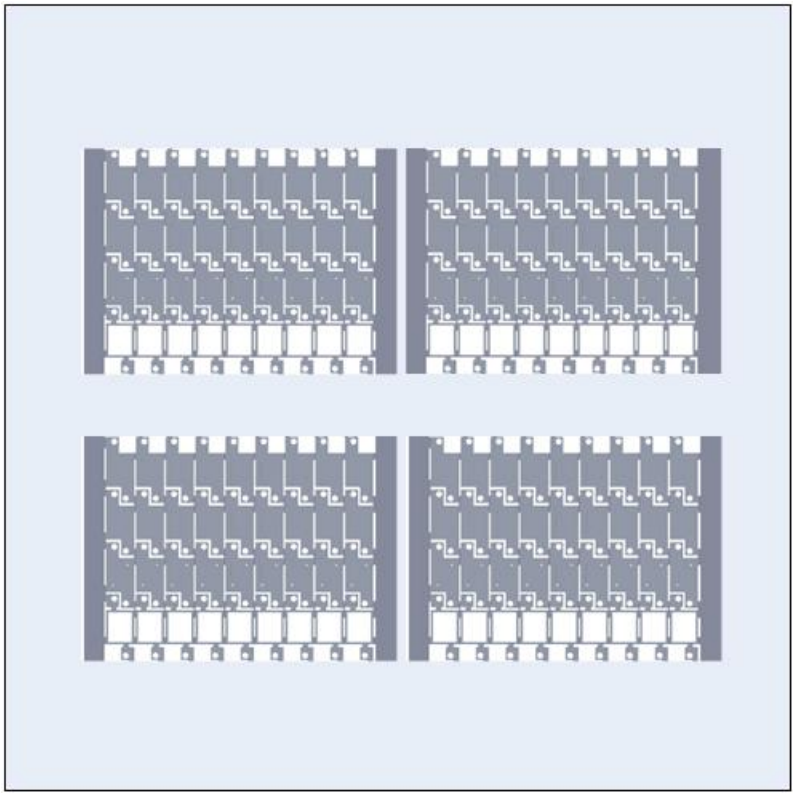




IZM laminated battery cross section



Substrate panel design



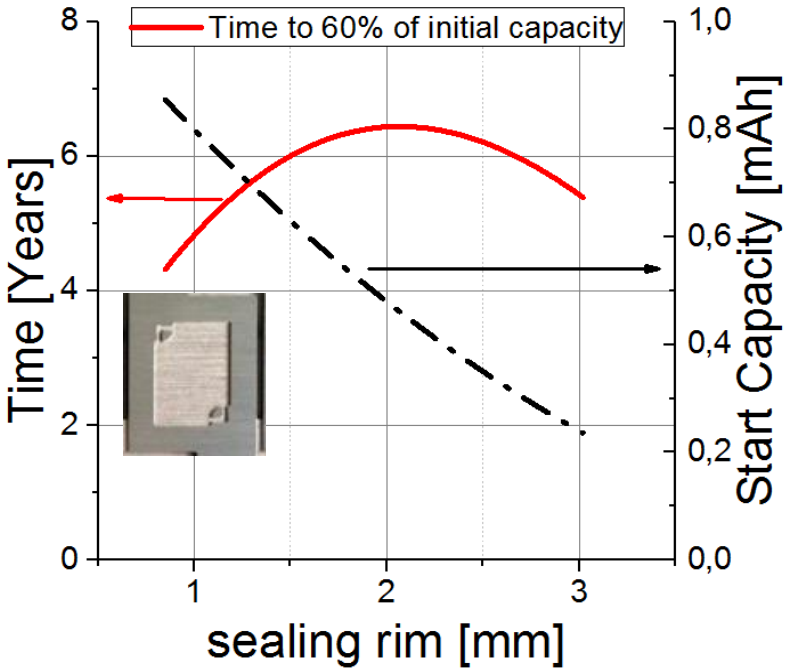
The life time issue of polymer laminated micro batteries

Water permeation through the polymer sealing will consume lithium:

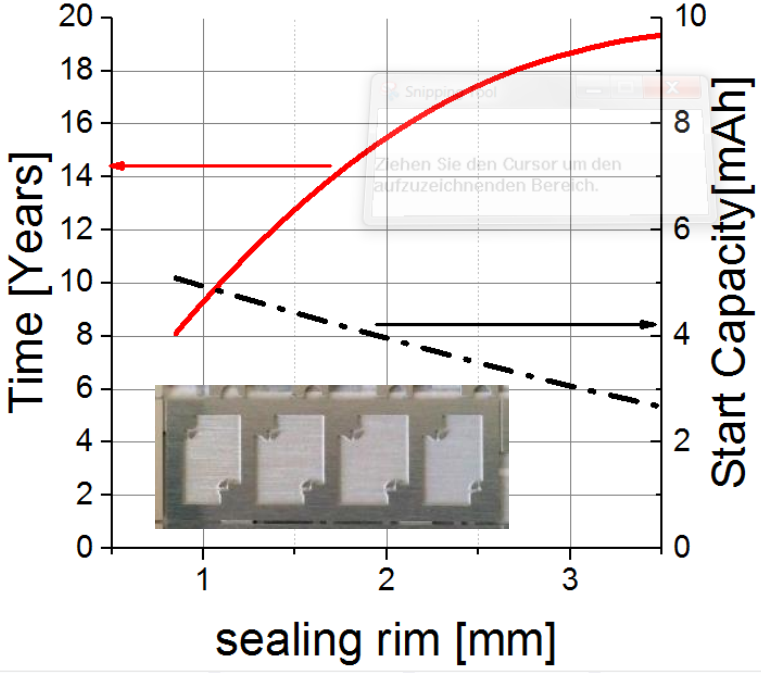
$$2\ Li + 2\ H_2O \rightarrow 2\ LiOH + H_2$$

Life time to 60% of initial capacity and optimum sealing width (25 µm thick adhesive, 21 ° C)

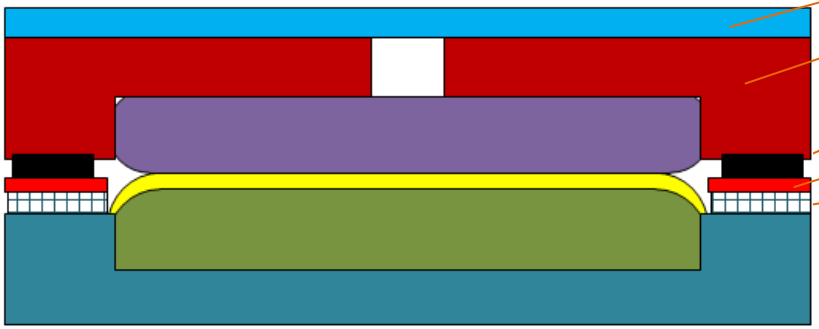
Foot print 10x12 mm² (0.6 mAh)



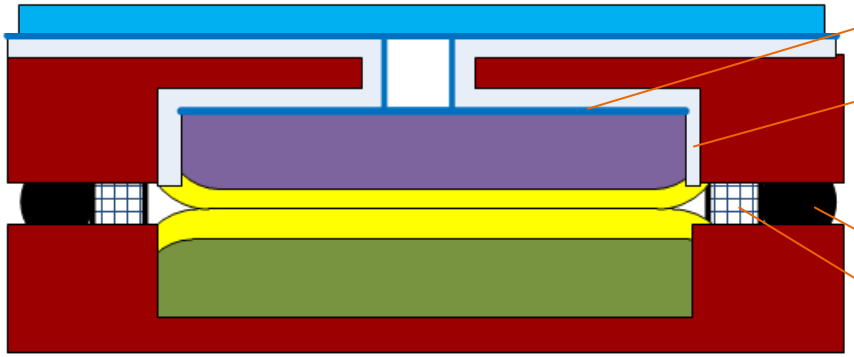
40 x 12 mm² (3 mAh)



Metal foil hermetic packaging

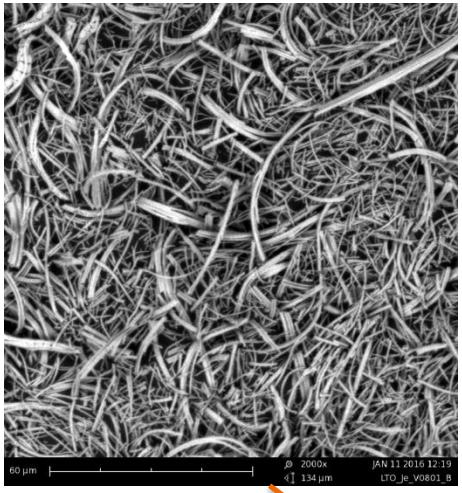


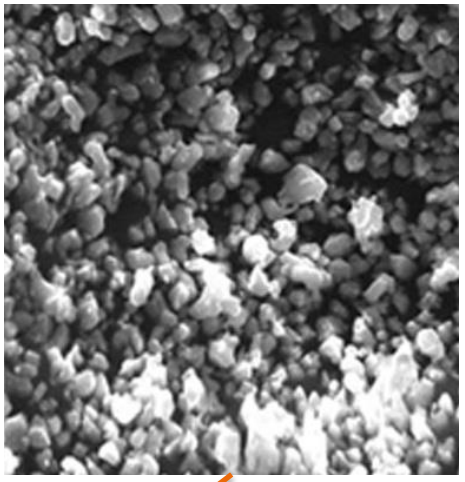
Top lid
Copper substrate
Solder
UBM
thin glass



Aluminum metallization
Dielectric layer
Solder
Polymer electrolyte barrier

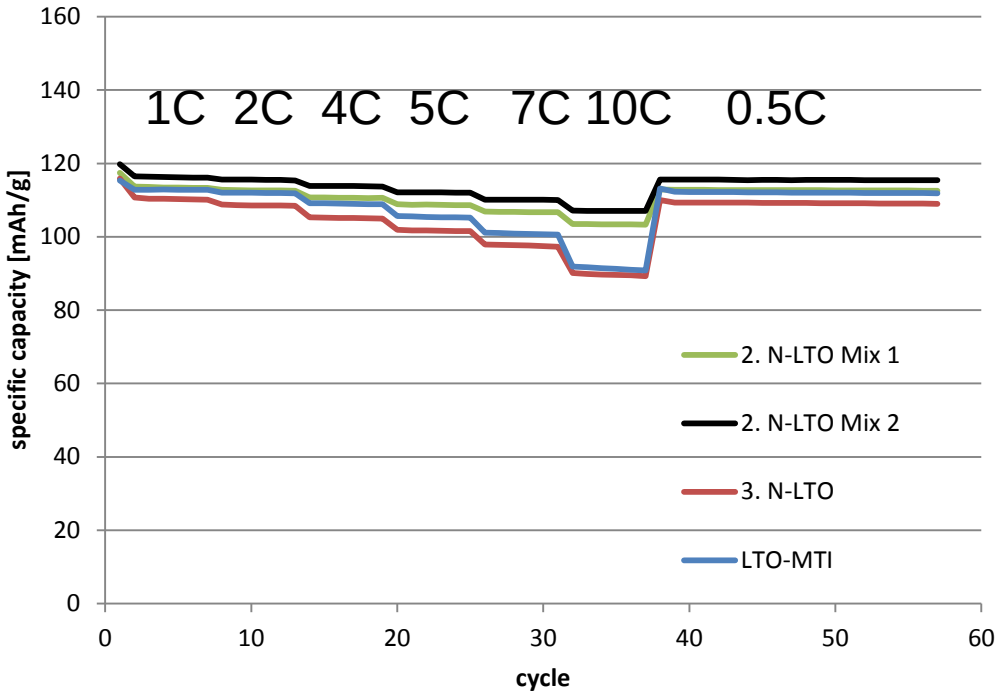
Battery materials





Anode:	$Li_4Ti_5O_{12}$ (LTO) fibers versus particles
Cathode:	$LiNi_{1/3}Co_{1/3}Mn_{1/3}O_2$ (NMC)
Separator:	glass particle paste
Binder:	CMC-SBR versus PVDF
Electrolyte:	EC:DEC 1:1 1M $LiPF_6$

Half cell test of LTO-particles (MIT) vs. N-LTO fibers (PARDAM), PVDF binder



- no major difference between particle and fiber LTO
- US treatment is required for fiber material to reduce agglomerates

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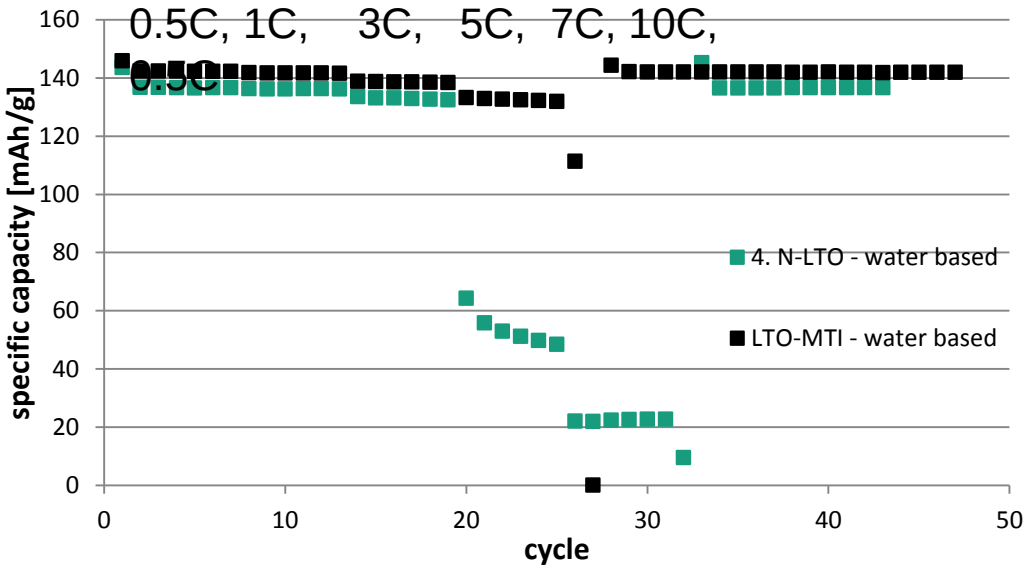
Change from PVDF to CMC-SBR binder (water-based)

- To reduce production cost, in particular in case of printing and dispensing large amount of solvent evaporation
- No hazardous components, less environmental impact

Half cell test of LTO-particles (MIT) vs. N-LTO Fibers (PARDAM), CMC-SBR binder



Electrode thickness:

Fiber: 80 µm
Particle: 65 µm

N-LTO fiber electrodes:

- higher capacity per volume
- much smaller agglomerates and better dispense print in comparison to PVDF binder
- less rate capability (> 5C) in comparison to powder

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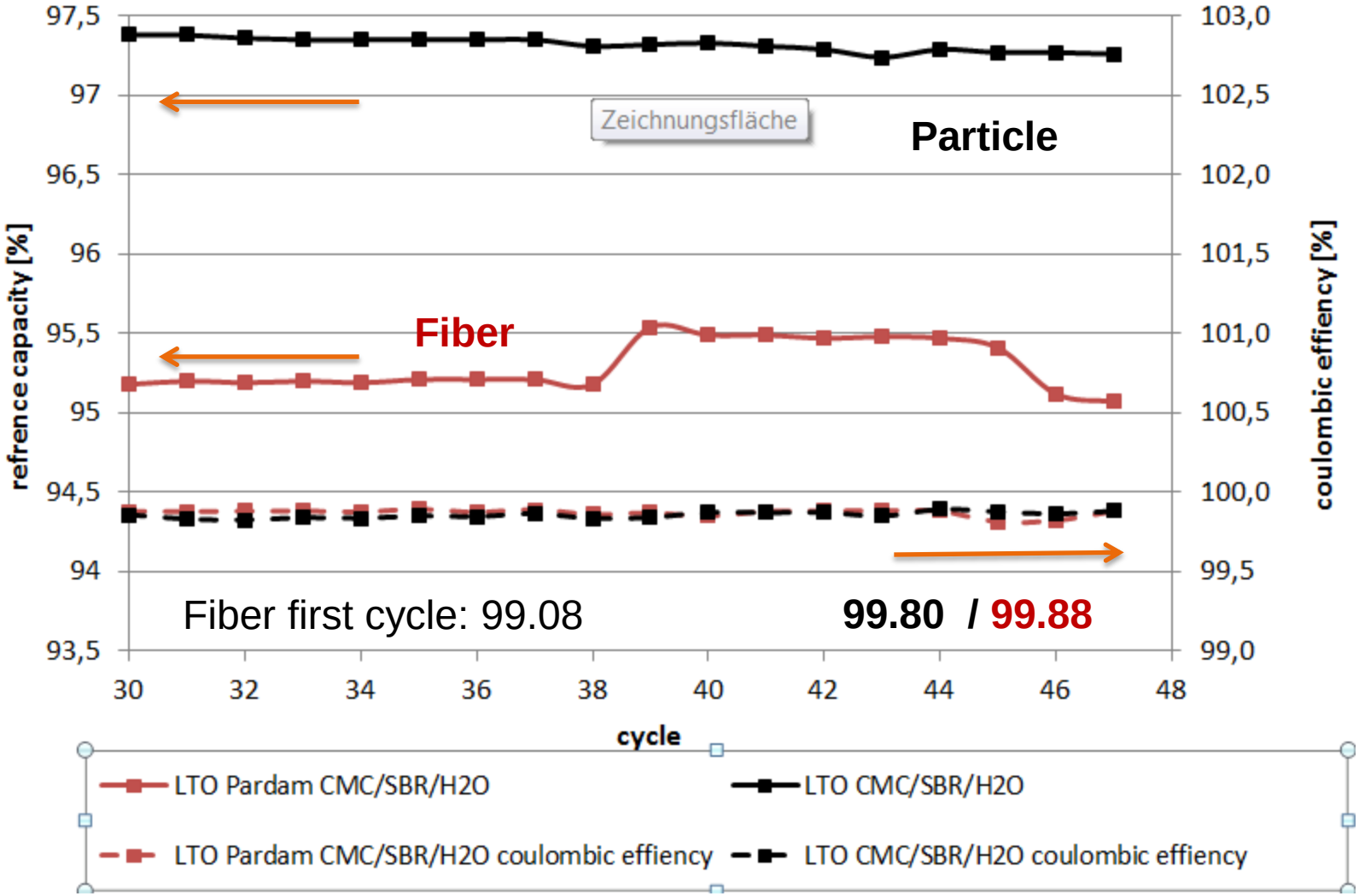
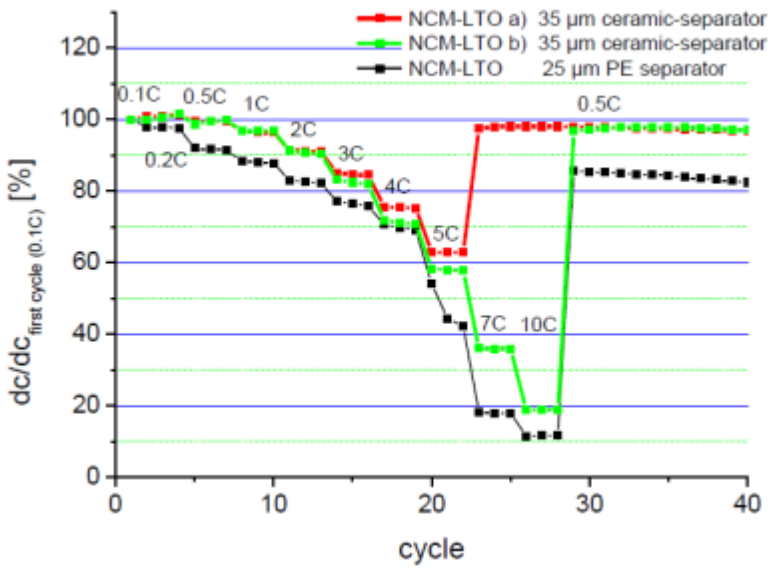
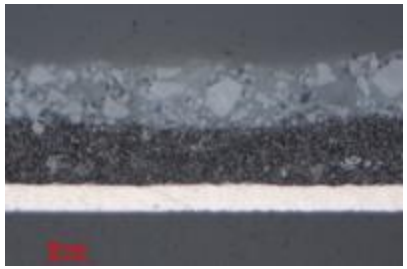
Cycle and coulomb efficiency, CMC-SBR binder

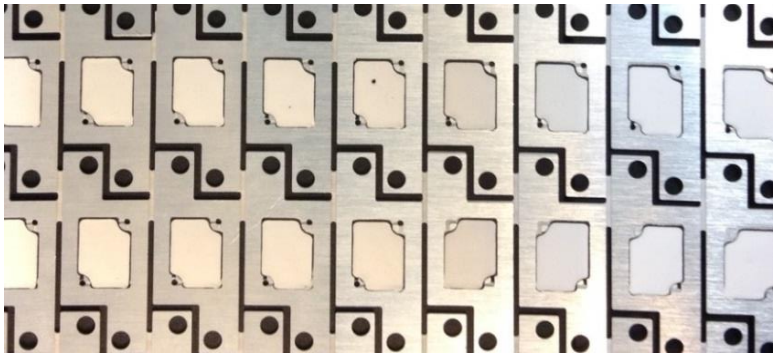


Printed separator, full cell test

Li^+ conducting glass $Li_{1+x}Al_xTi_{2-x}(PO_4)_3$ particles







LTO/NCM/ EC:DMC-$LiPF_6$

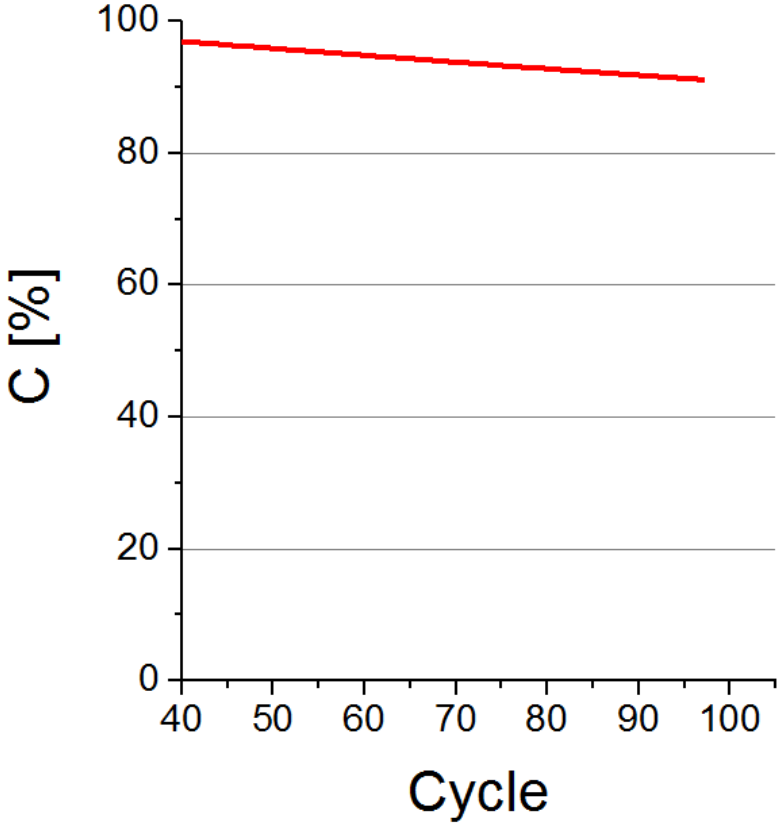
➔ good adhesion between electrode and separator

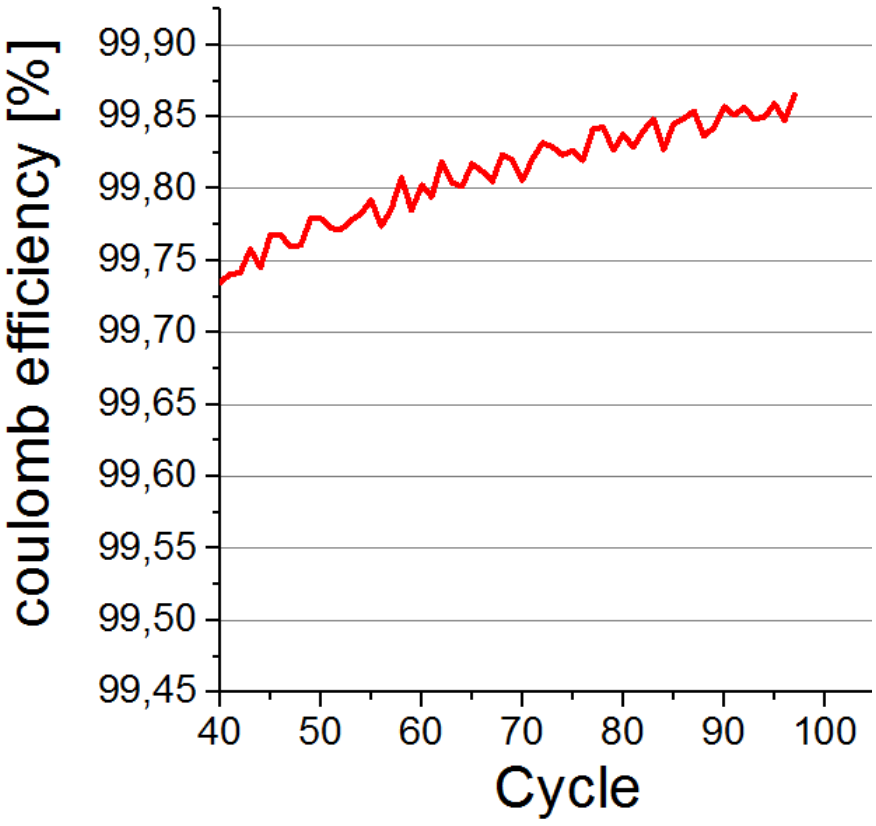
➔ reproducible performance, nearly similar to polymer foil separator

Printed separator full cell test

LTO/NCM/ EC:DMC-$LiPF_6$

PVDF binder





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The micro battery prototyping line

Official opening of new micro battery labs at IZM 15.3. 2016

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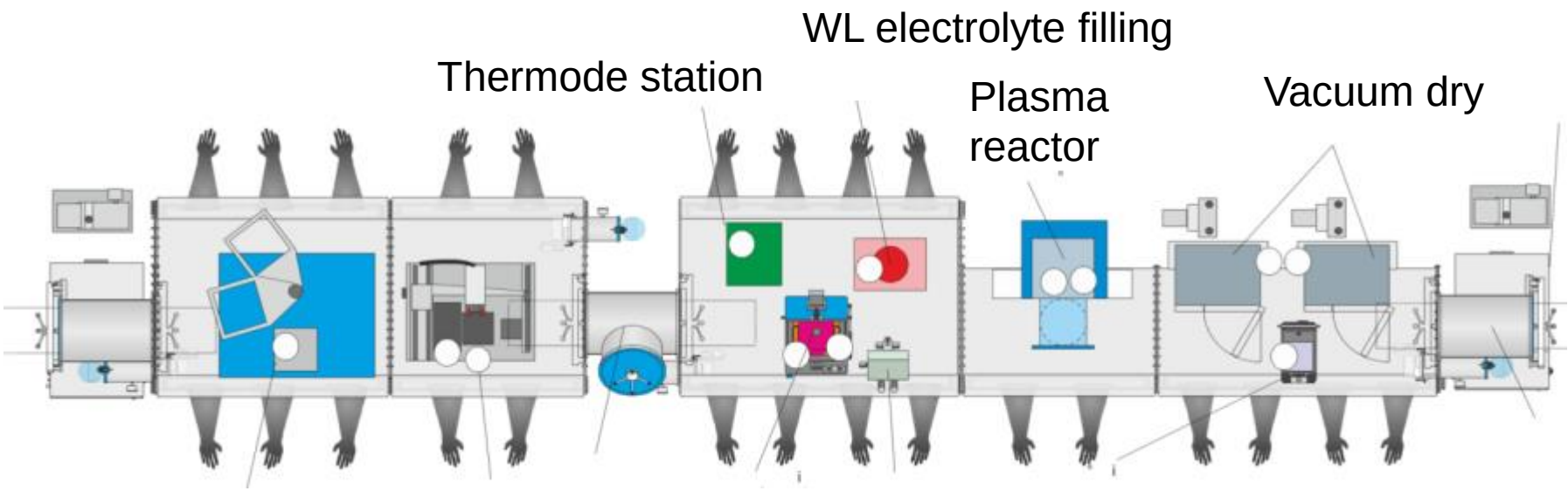
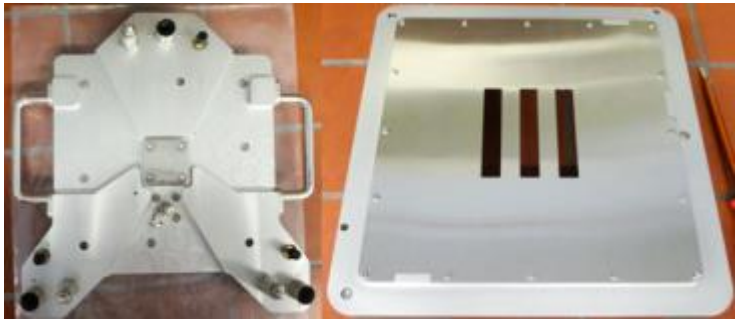
The micro battery prototyping line

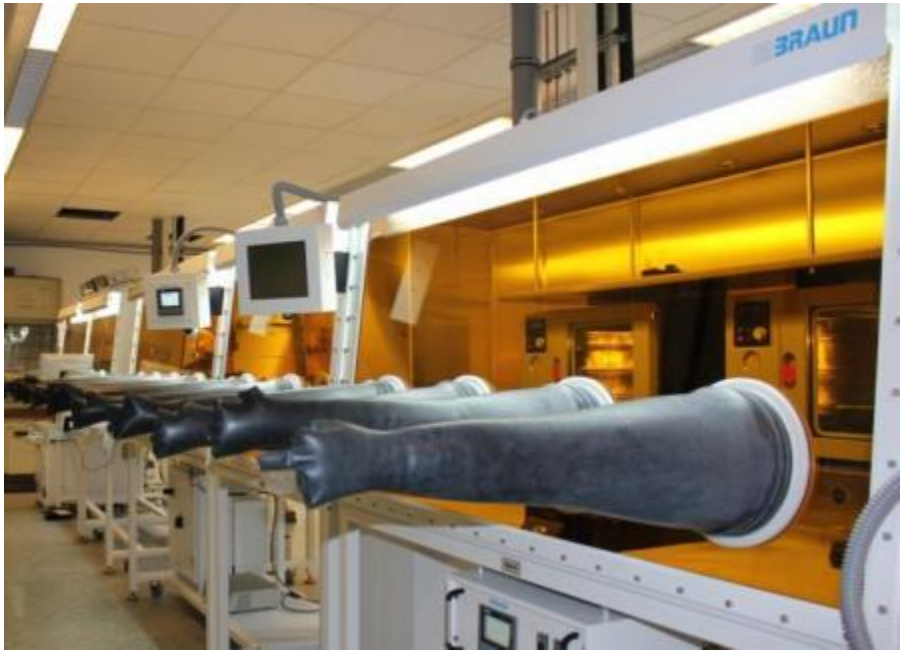


Battery assembly equipment inside glovebox line



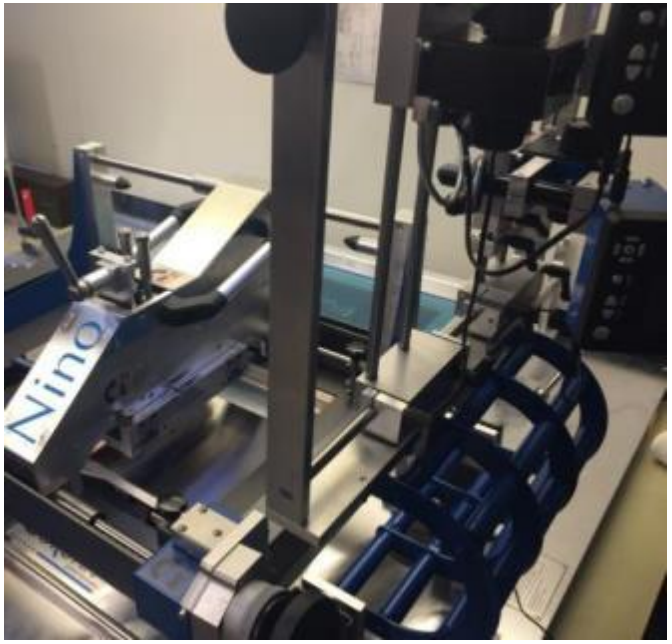
Ozone clean

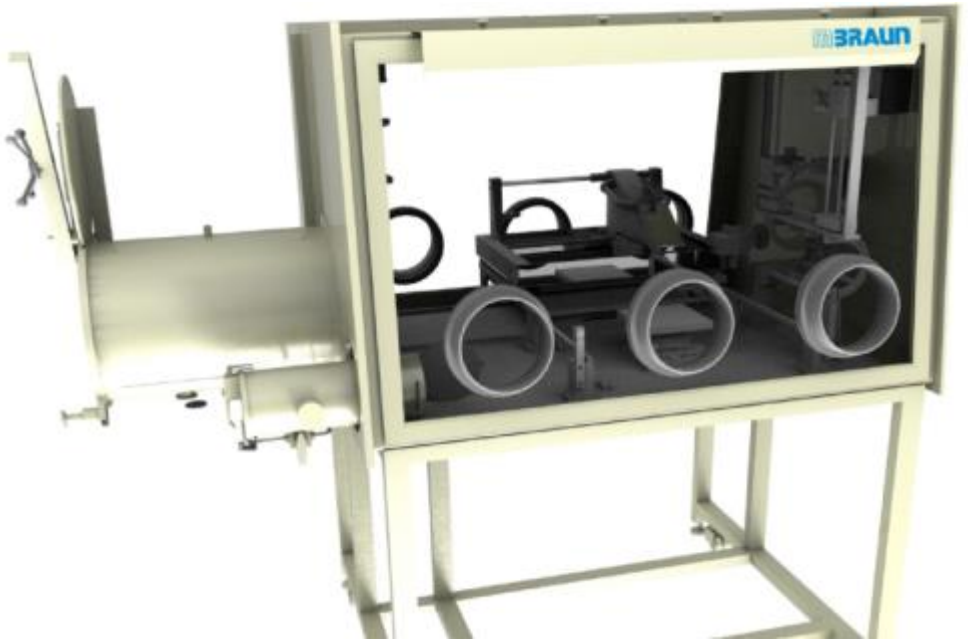
UV-Press, substrate lamination

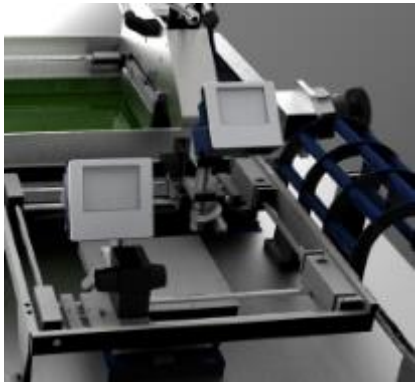


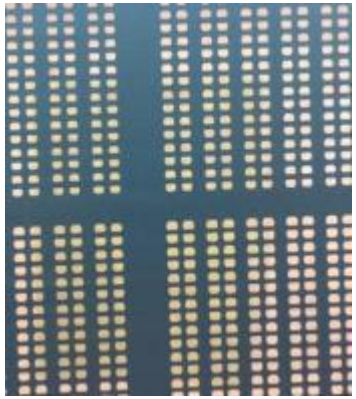
Plasma etch

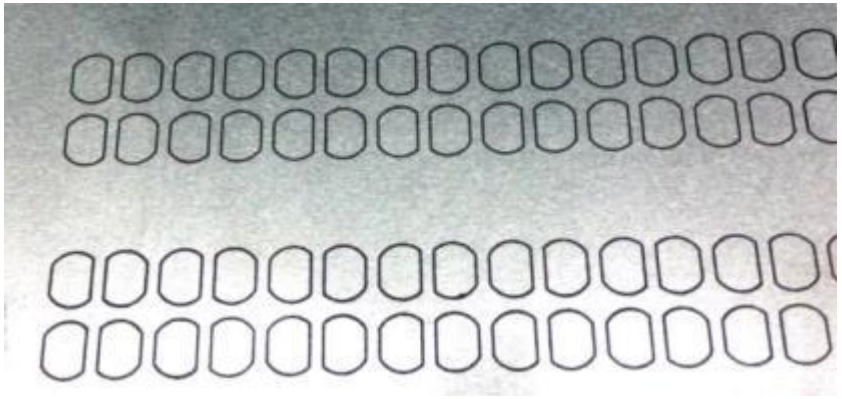
High precision and stacked screen print



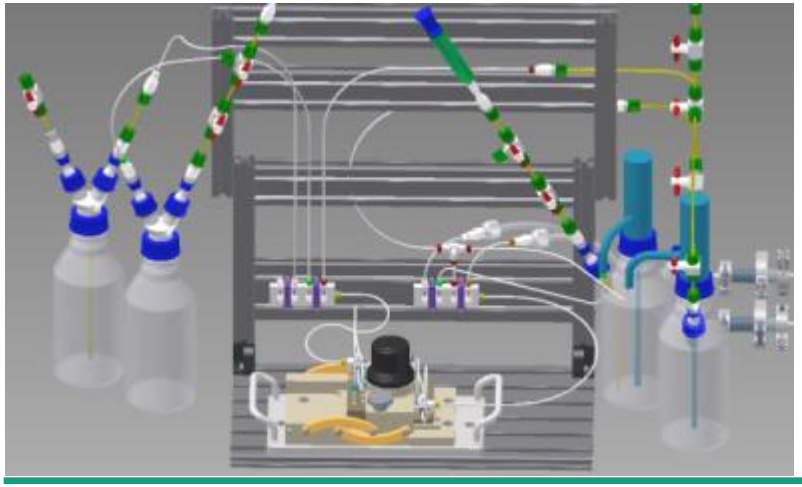


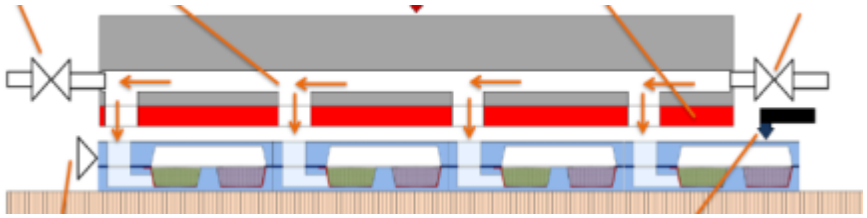






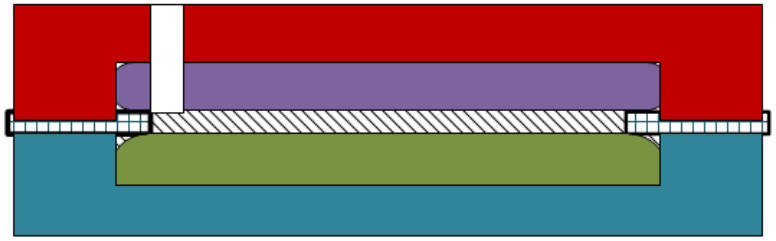
Electrolyte fill adapter



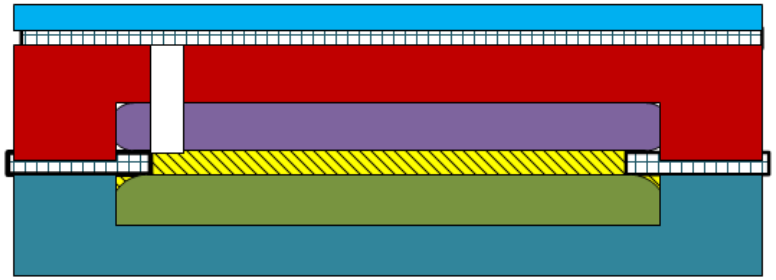


IZM Battery Process Flow

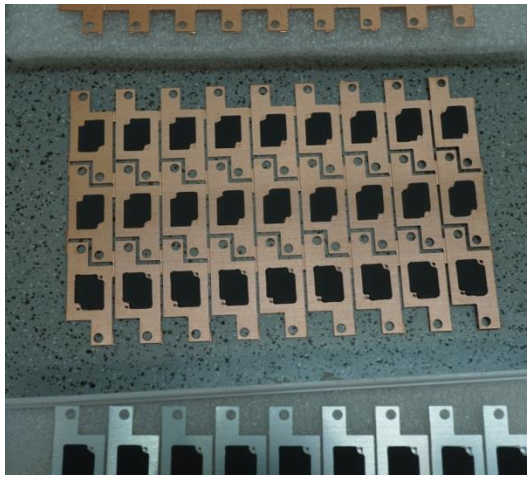
Electrodes and separator deposition on pre patterned metal foils



Lamination of top and bottom foils



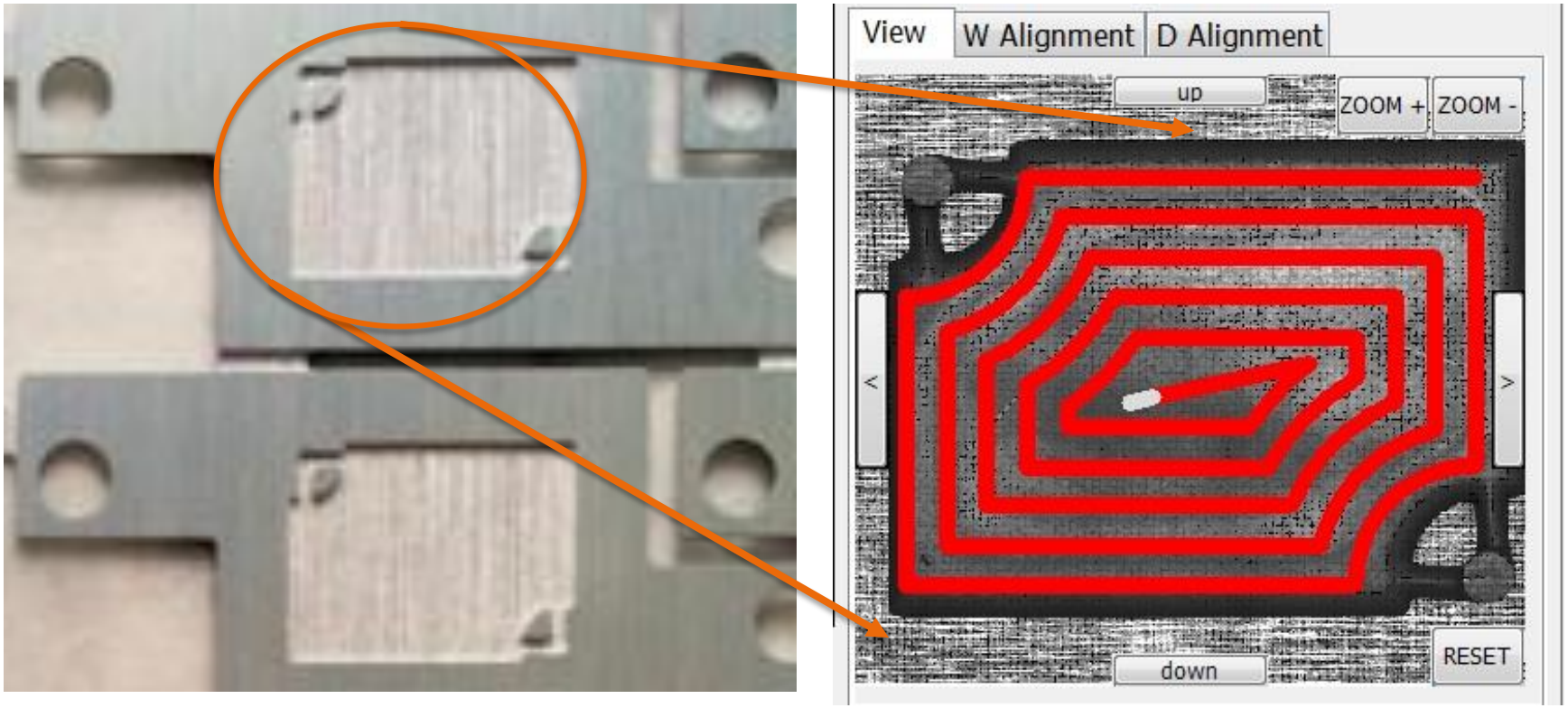
Electrolyte fill and final seal



Dispense print of electrode /separator pastes

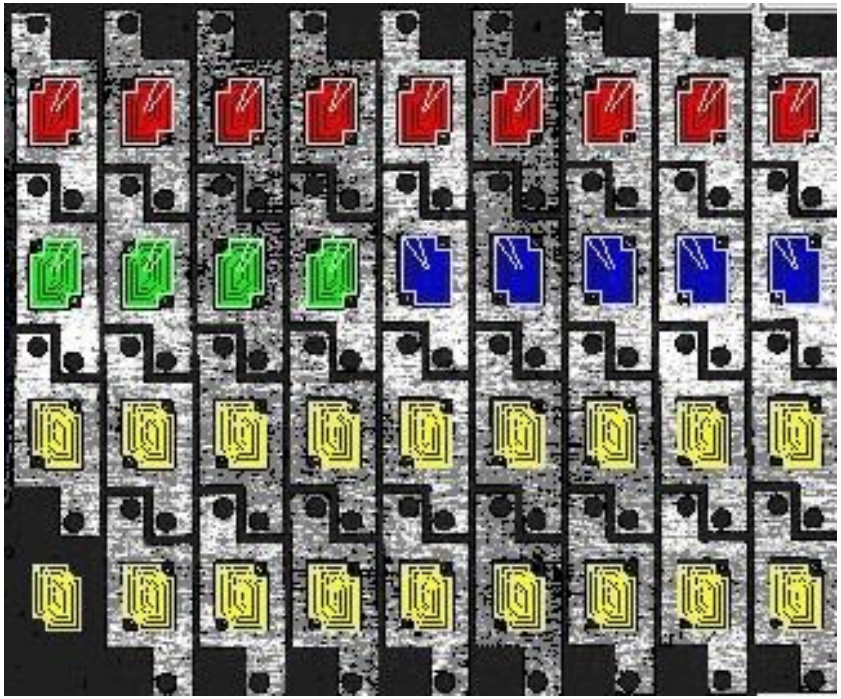
Multi layer paste dispense in metal foil cavities

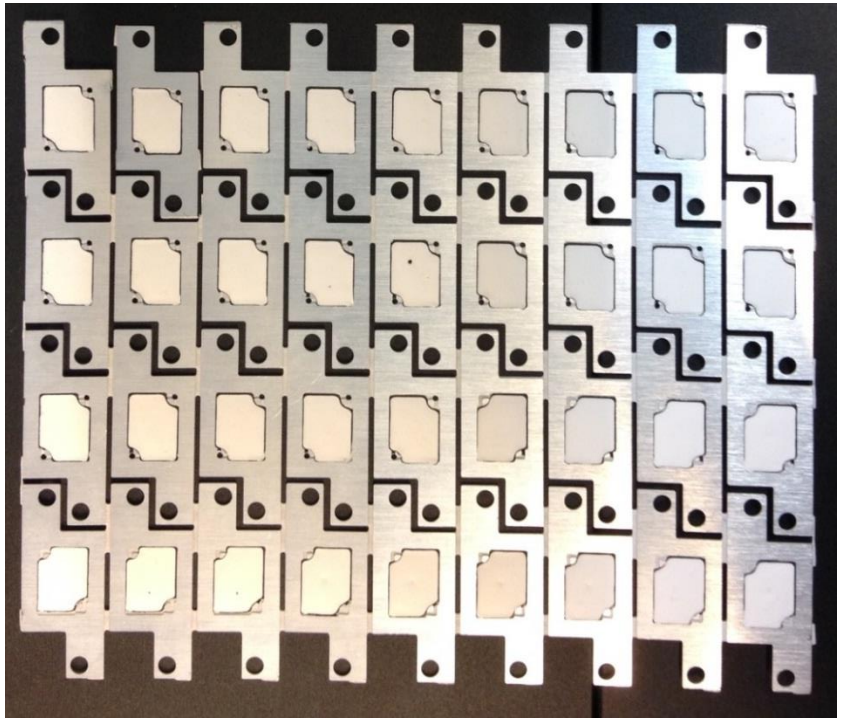
- Dispense path and parameters must be optimized for each material and layer thickness



Batch fabrication of electrodes and separator for MATFLEXEND battery

- Flexible adjustment for any layout possible
- Jetting for thinner layers and better reproducibility is in development

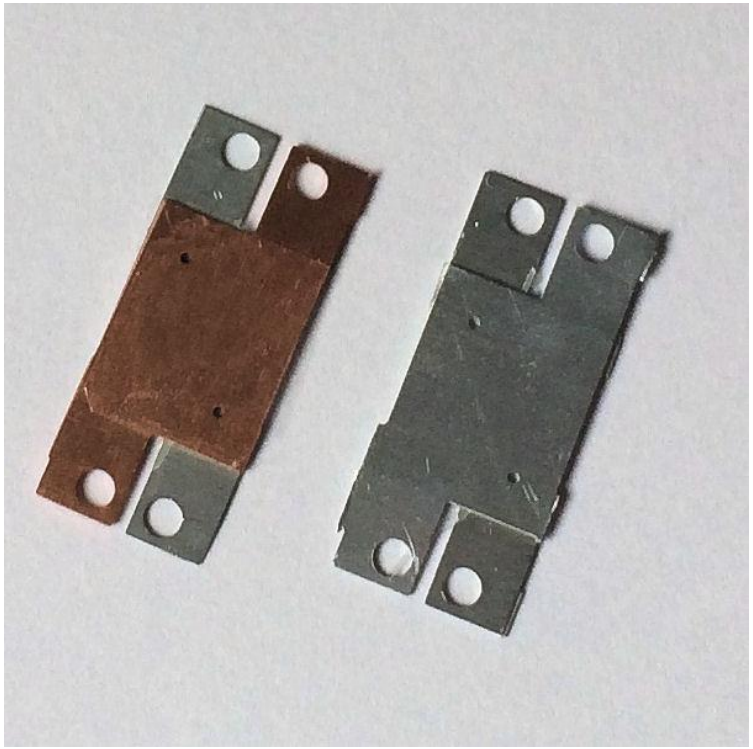




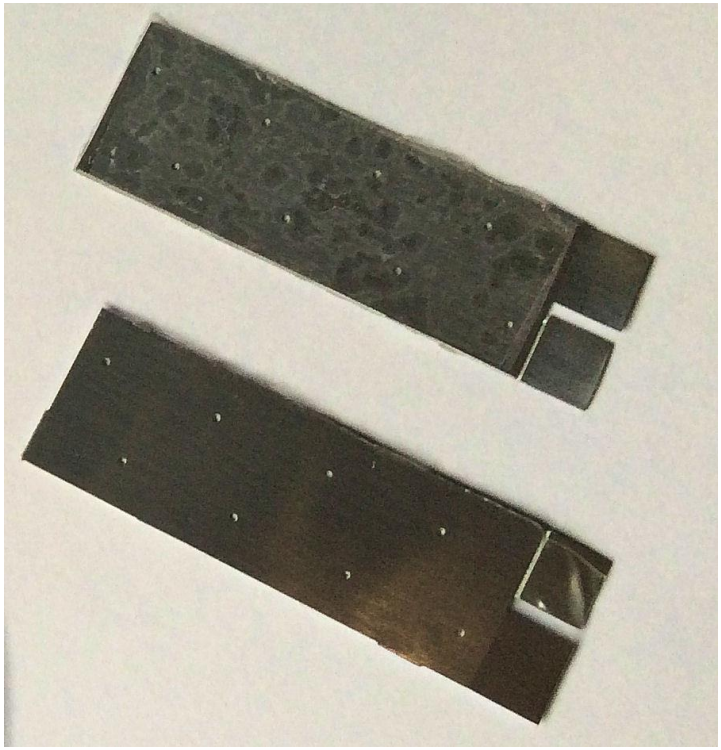
Battery Demonstrators

- Battery demonstrators, two sizes

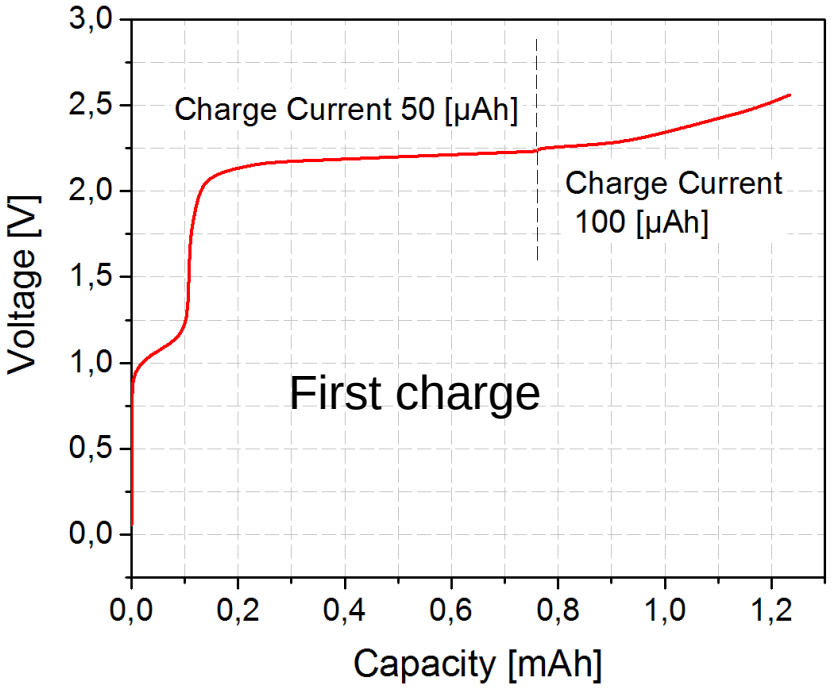
0.7 mAh

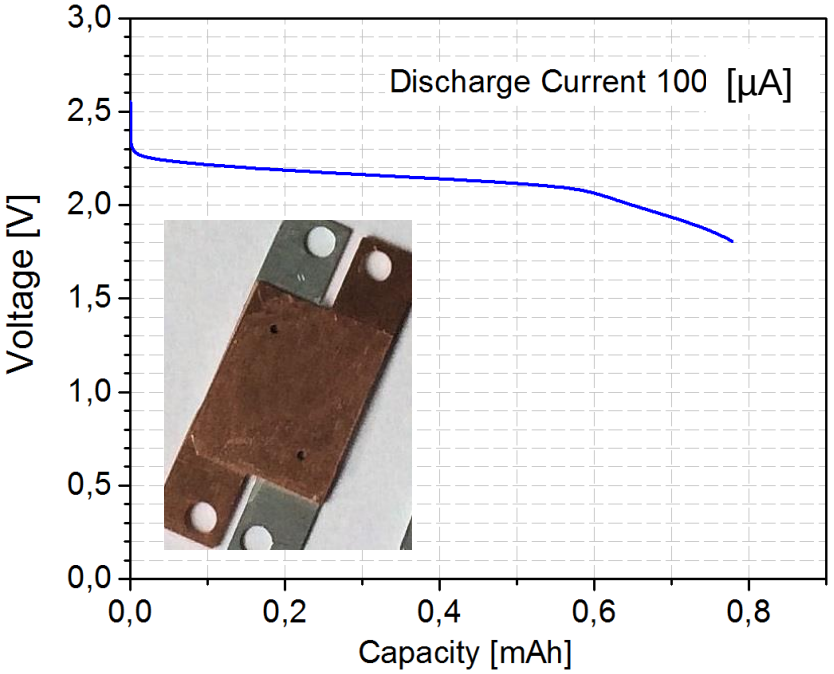


3 mAh



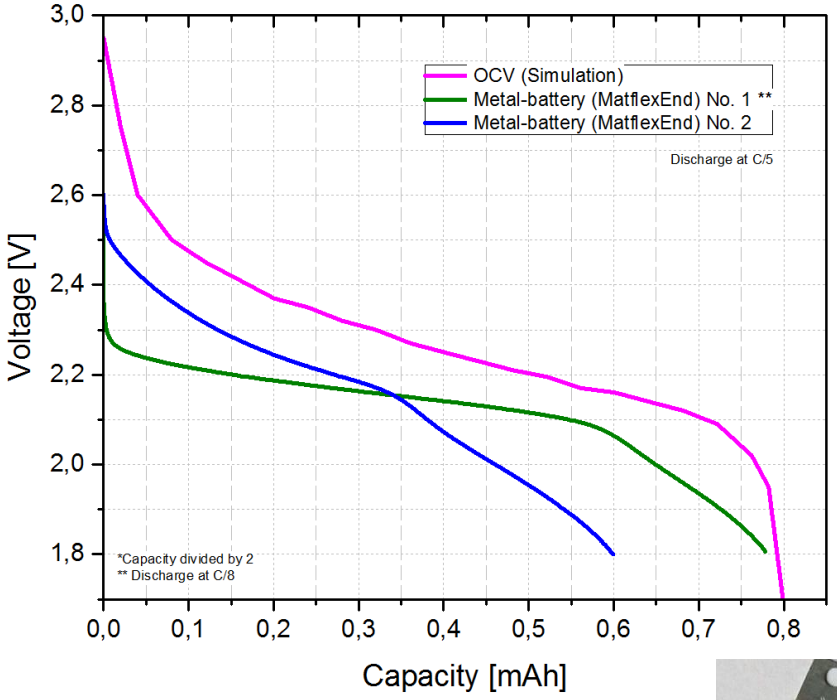
The first MATFLEXEND batteries, characterization

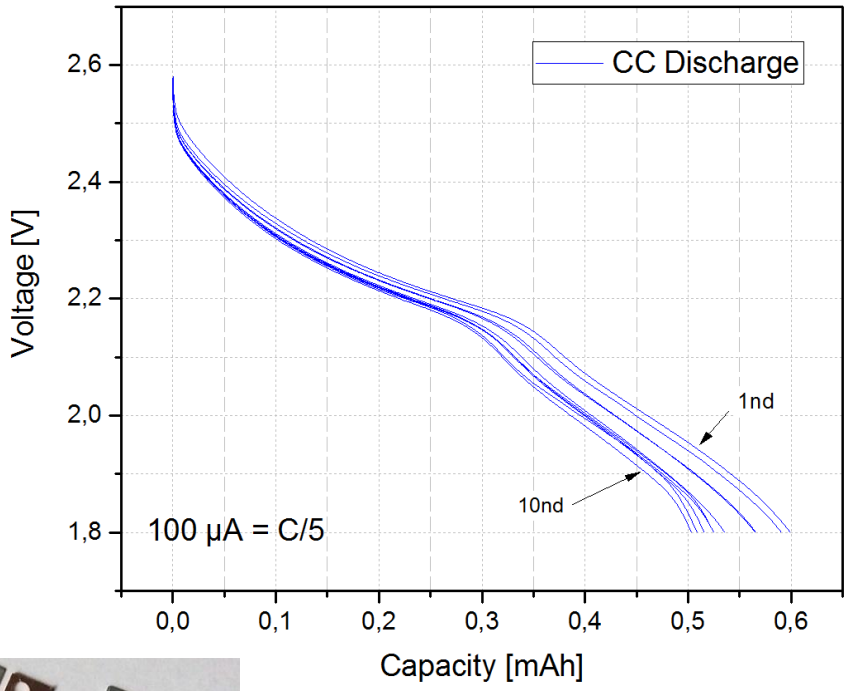


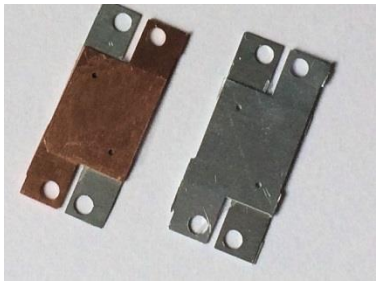


Anode: LTO, Cathode: NMC, Separator: SiO_2, Electrolyte: LP30

Electrical characterization







Summary

- First printed and metal laminated Li-ion batteries (6x8 mm^2, 0.7 mAh) have been fabricated and successfully tested
- All processes for micro battery fabrication have been established
- Electrode thickness must be better reproduced and both electrodes balanced
- Further work to reduce separator thickness and testing polyHiPE printable separator/electrolytes
- Long term tests of the battery packages are underway

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