

# 100%-Si / NCM lithium-ion full cell investigation based on columnar silicon anodes with a tailored microstructure

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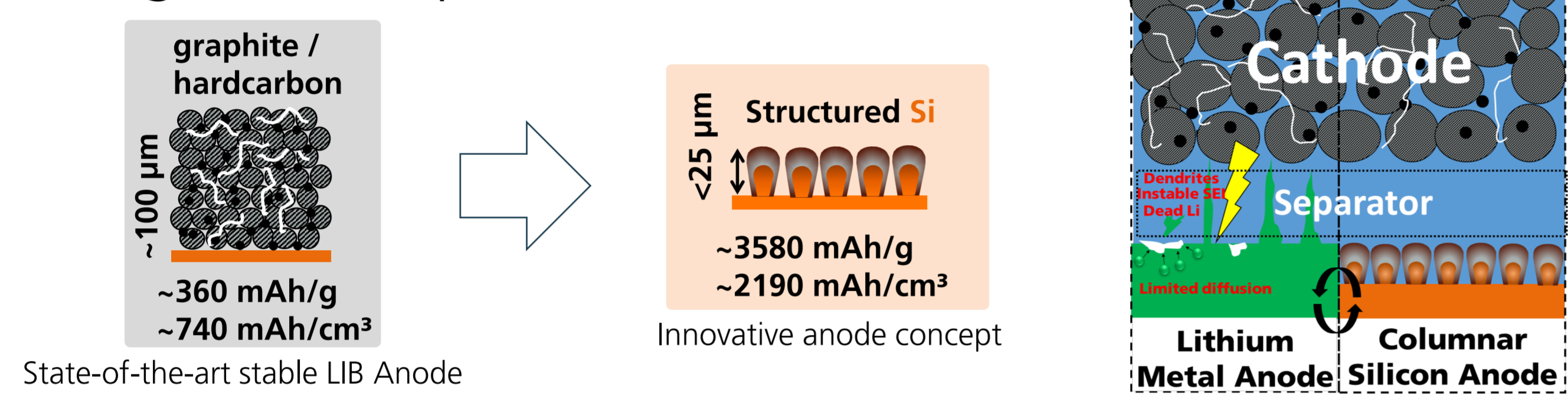
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## Motivation

- High volumetric energy density (> 850 Wh/L)
- Low  $SV$  ratio  $\rightarrow$  high ICE (>92%)
- Scalable production (PVD)
- High areal capacities (>4.0 mAh/cm<sup>2</sup>)

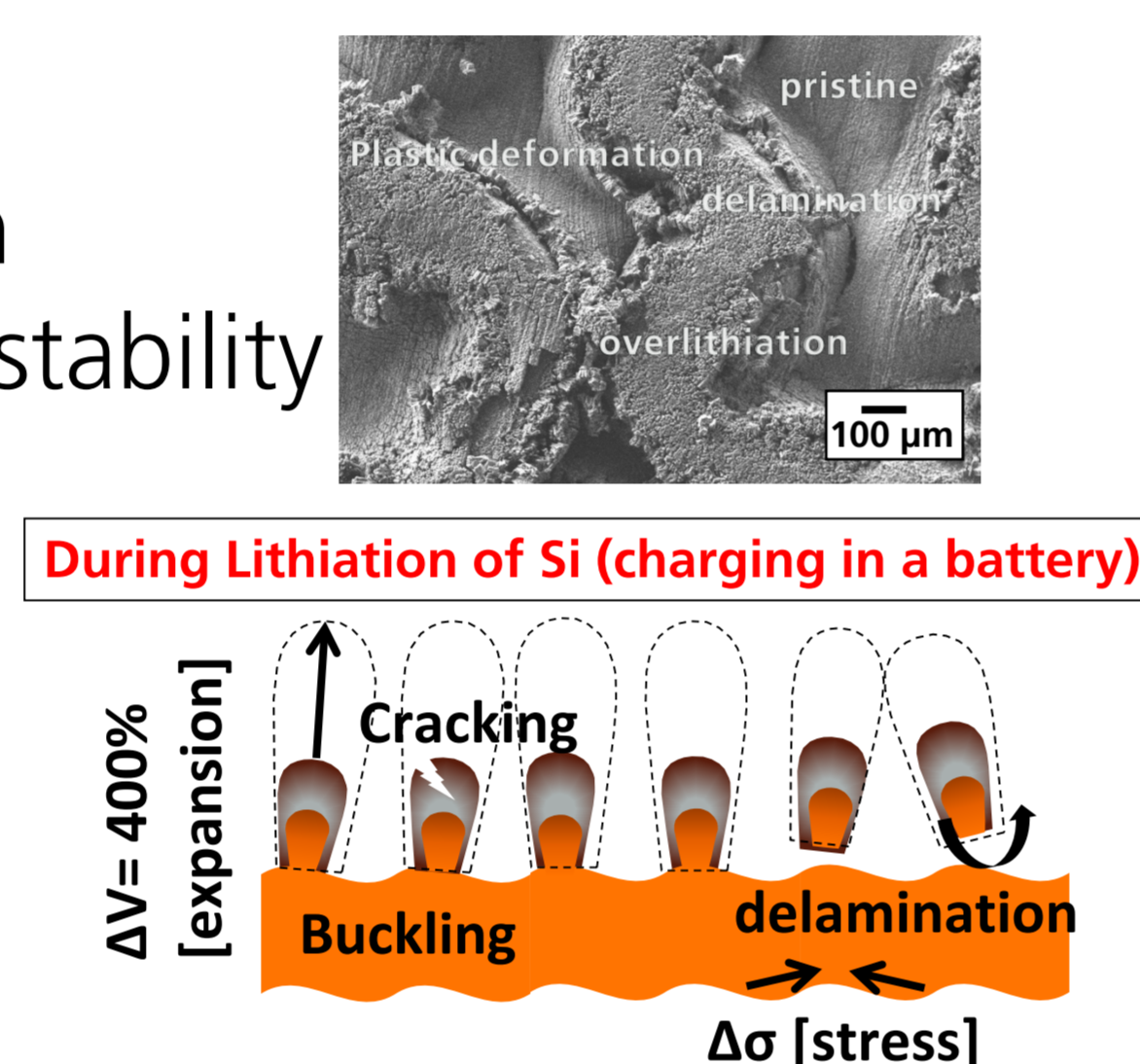


## Challenges

- Extreme volumetric expansion
- Si delamination  $\rightarrow$  Long term stability
- Residual and generated stress

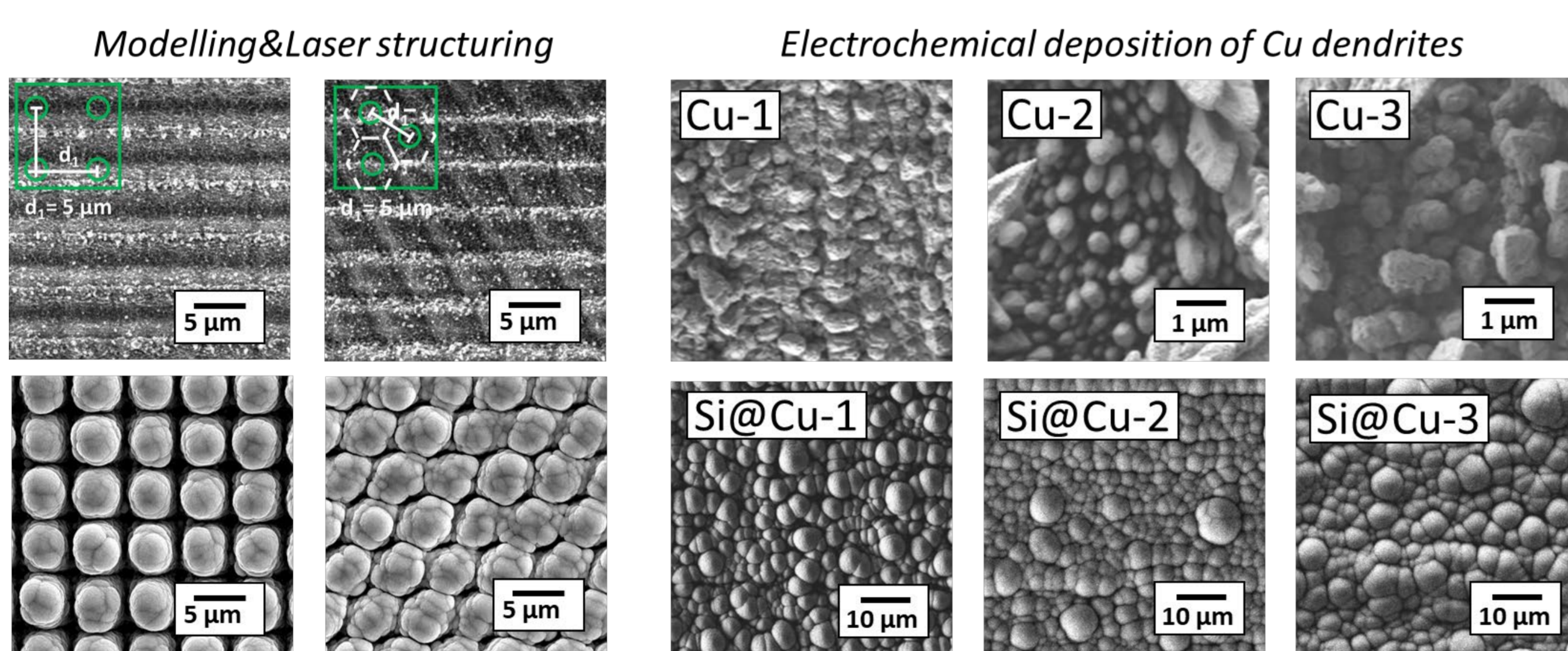
Key optimization parameters

- Si-Loading
- Substrate mechanics
- Adhesion strength
- State of charge (SoC)



## Results

### Substrate modification



### Electrochemical characterization

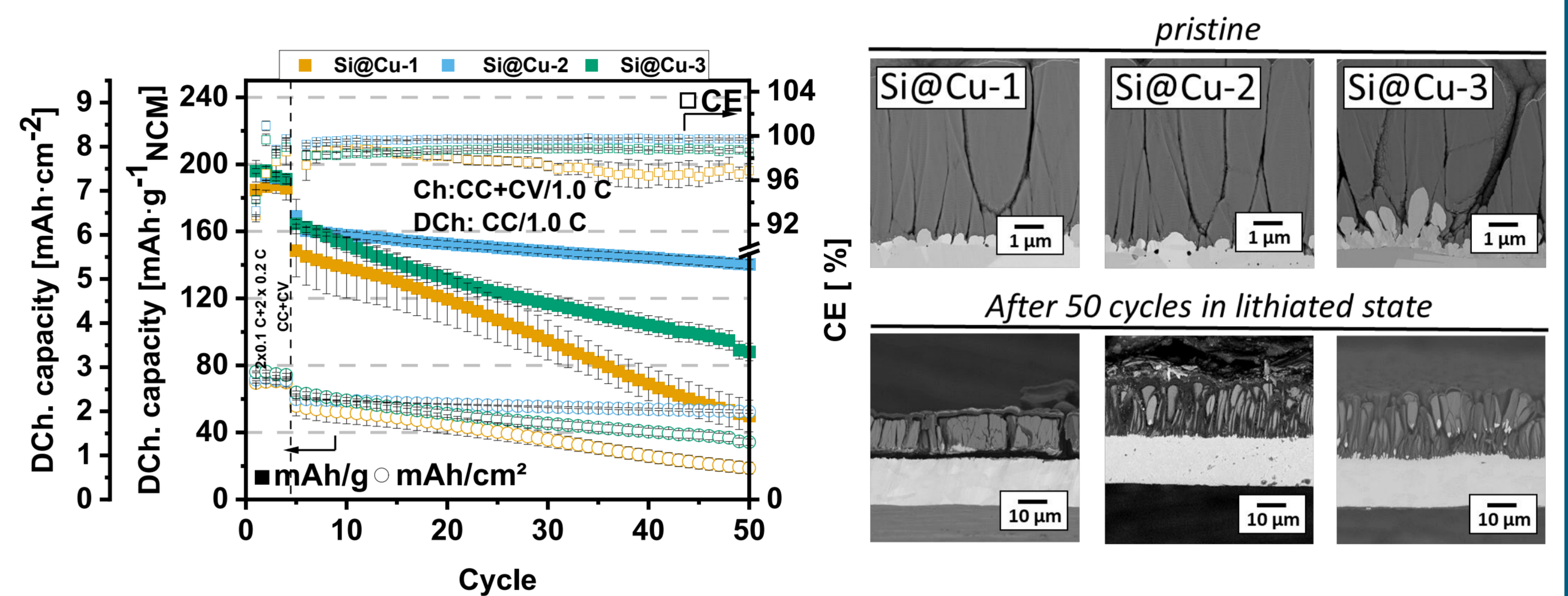
#### Tuning of Si loading

Post-mortem analysis after 50 cycles in lithiated state (Half-cell)

Si film			
Copper Substrate			
$V_{Si/Cu}^*$	0.27	0.54	0.74

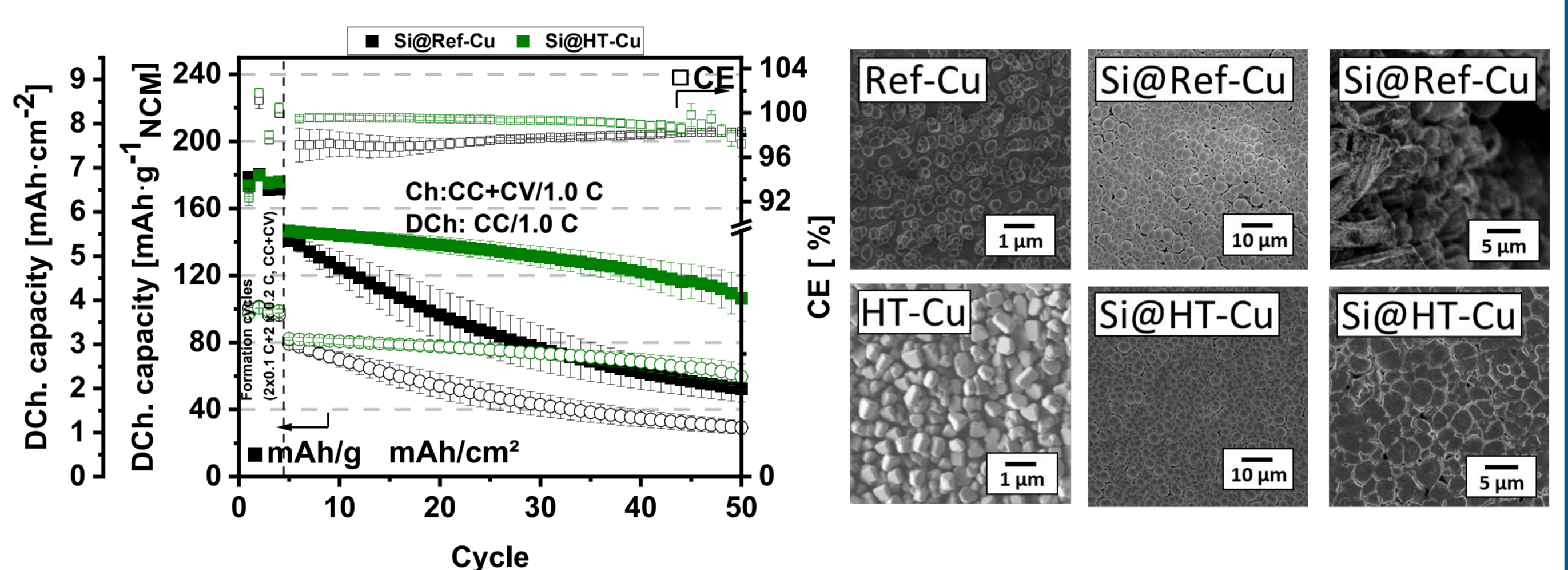
\*ratio of silicon film to copper substrate thickness

### Tailored substrate surface morphology



Electrochemical performance of silicon films deposited on 18 μm dendritic copper foils (left) and their post-mortem SEM analysis (right); Reduced Si detachment by increasing contact area.

### Adaption of 10 μm Cu with high tensile strength

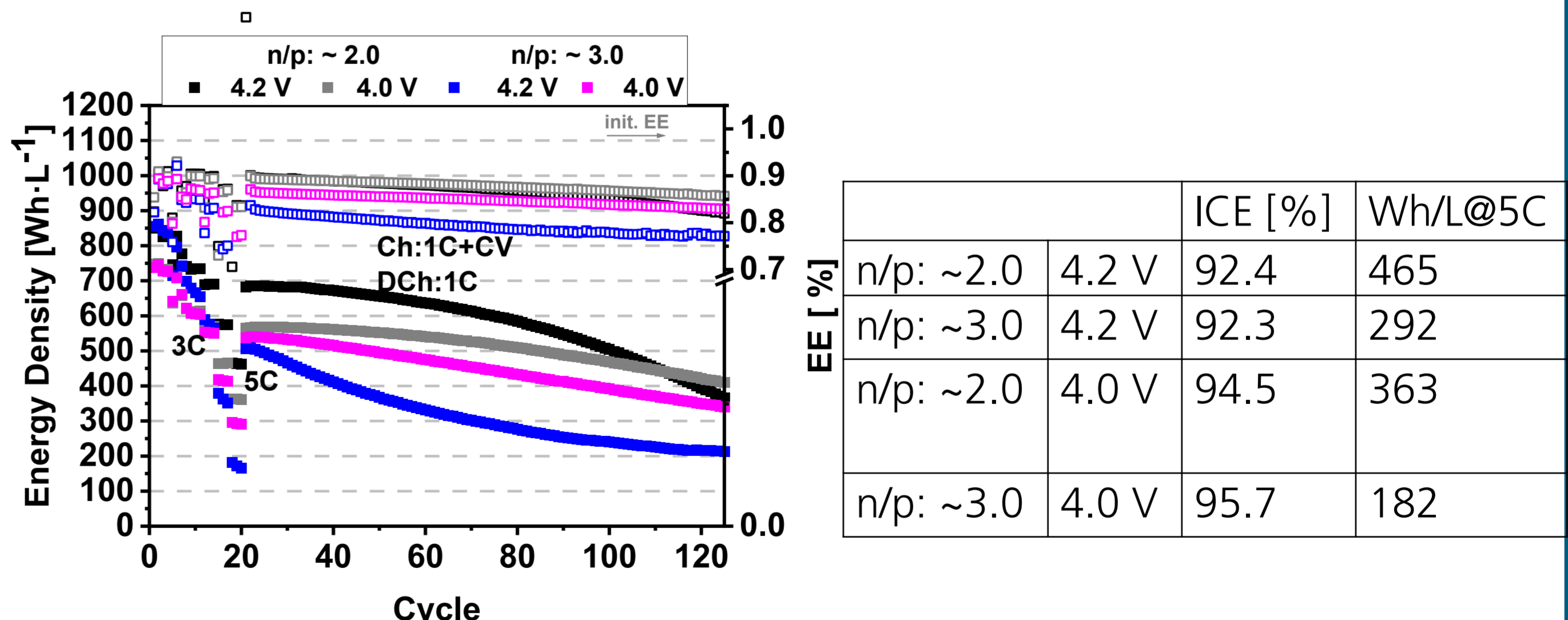


Comparison for 10 μm standard (Ref-Cu) and tailored high tensile Cu foil (HT-Cu): Electrochemical performance (left) and their post-mortem SEM analysis (right); Suppressed electrode deformation.

### Evaluation of balancing factor in pouch cells

#### Cell Configuration

- Cathode: ~2.0 mAh/cm<sup>2</sup>
- Anode: ~4.0 or ~6.0 mAh/cm<sup>2</sup>
- Separator: 12 μm PE
- Electrolyte: LP30+10v%FEC
- Electrolyte loading: 7 μL/mAh



## Conclusion

- Deformation-free Si electrodes ( $V_{Si/Cu} < 0.27$ )
- Tailored dendritic structure for standard 18 and 10 μm high-tensile Cu foils  $\rightarrow$  Intimate adhesion
- Optimized balancing factor (n/p: ~2.0)  $\rightarrow$  Energy density > 850 Wh/L, rate capability up to 5 C, 125 cycles