Metal-On-Polymer Current Collectors: An Innovative Roll-to-Roll Production Process

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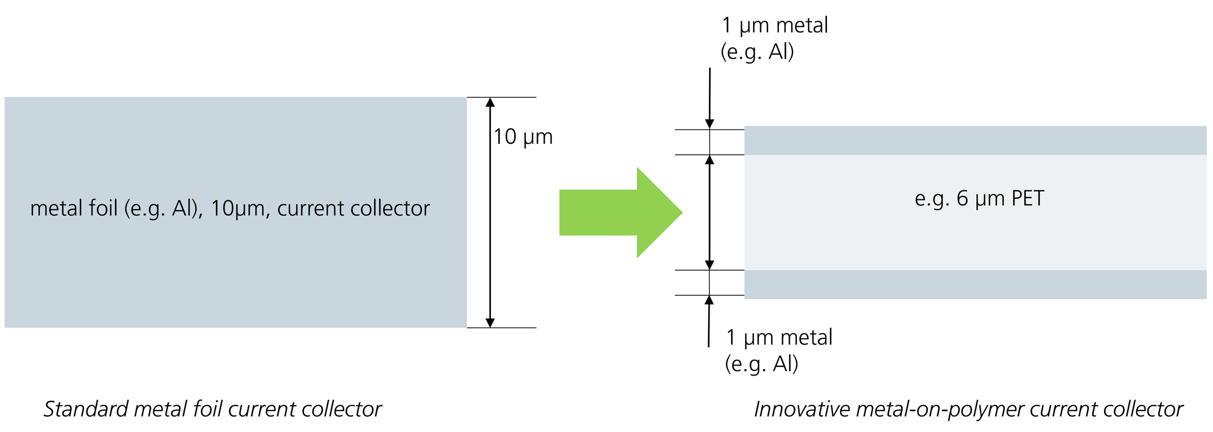
Introduction

Metal-on-polymer current collectors typically consist of polymer foils with thin film Al- or Cu-coating. They are a promising new material for enhanced battery safety and reduced weight.



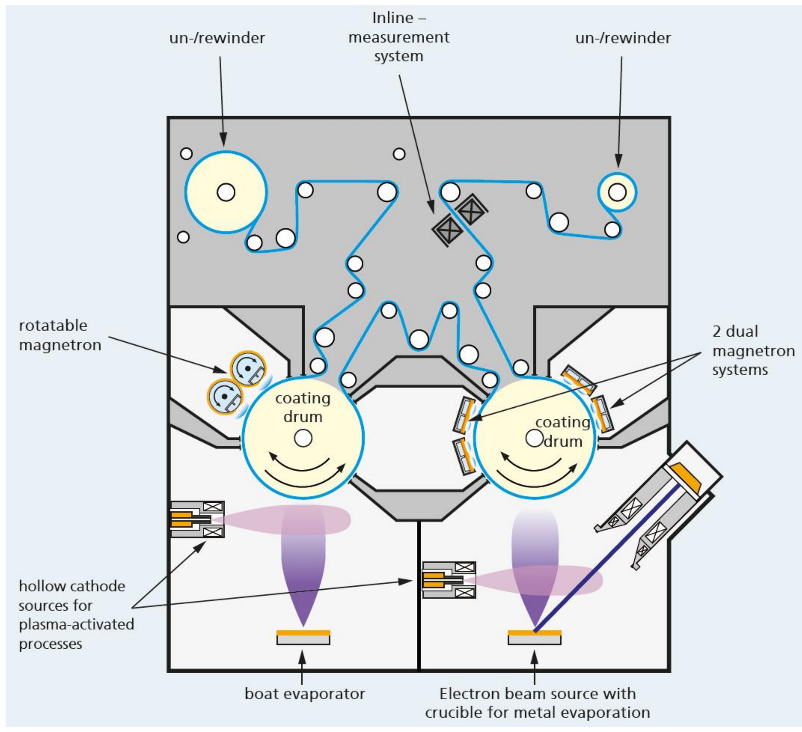
Schematic drawing of a metal-on-polymer current collector

Using polymer substrates with metal coatings on both sides could help to reduce the overall weight of the current collector. This results in a higher energy density of the cell.

Moreover, there is a safety benefit: if a short circuit occurs in the cell, the polymer substrate melts and the current path is disconnected. No further heat is generated and a thermal runaway is prevented.

Process

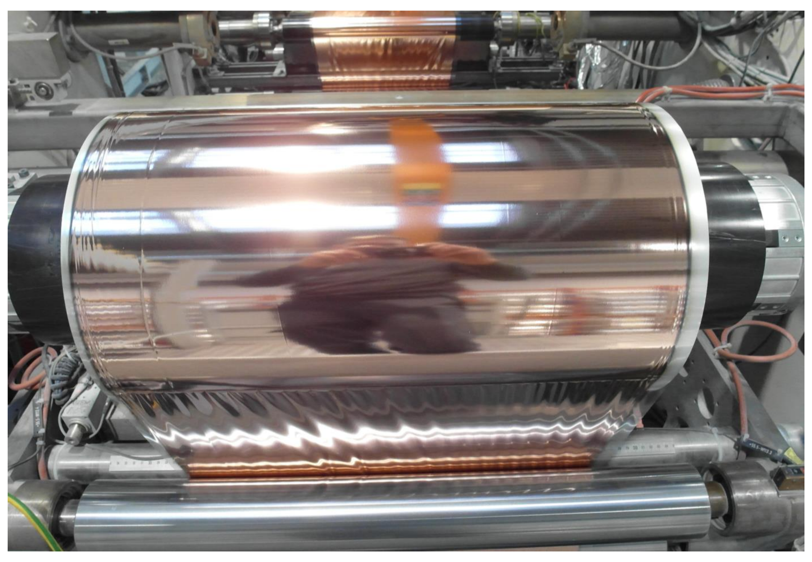
Deposition parameters	
Method	electron beam evaporation (Ub = 50 kV, P = 35…60 kW)
Coating width	up to 500 mm
Substrate	12 µm … 6 µm PET (commercially available)
Web speed	10…30 m/min.
Seed Layer	Cr (~10 nm)
Seed Layer deposition	magnetron sputtering (Inline)



Pilot Roll-to-Roll Coating System novoFlex® 600

The deposition of the metal layers was done in the *novoFlex® 600* Pilot Roll-to-Roll Coating System via E-Beam evaporation. A special cooling method, a gas cooling drum provided by VON ARDENNE was used. This special cooling method minimized the temperature of the foil during the deposition.

Results



Wrinkle-free metal-on-polymer current collector coil after deposition. Coil width 550 mm

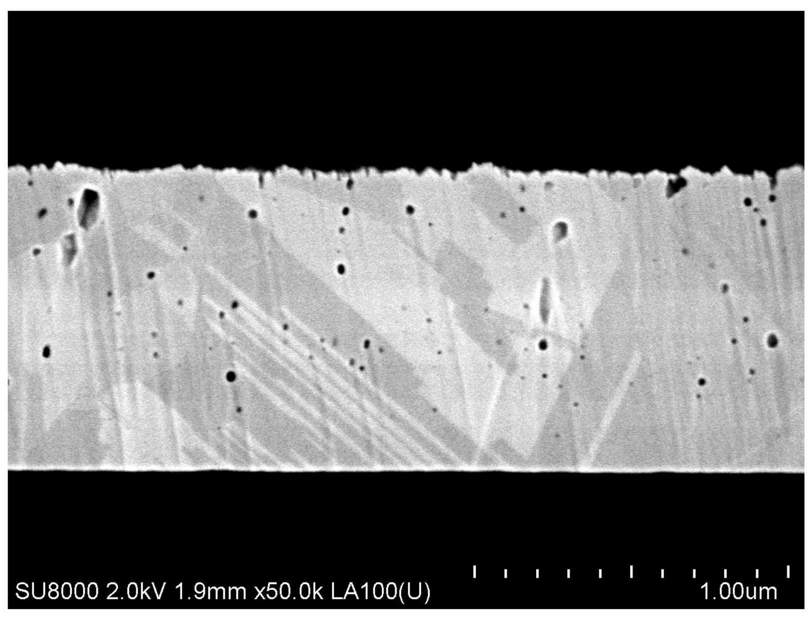
Copper

- Deposition of Cu on 12 µm PET via roll-to-roll process successfully shown
- Double sided coating via two step process possible
- SEM pictures show compact copper layer
- No substantial wrinkling of the foil after deposition, well suited for further processing e.g. electrode coating in battery production process

Aluminium

- Deposition of Al on 12 µm PET via roll-to-roll process successfully shown
- Double sided coating via two step process possible
- SEM pictures show strong columnar growth of the aluminium layer
- No substantial wrinkling of the foil after deposition, well suited for further processing e.g. electrode coating in battery production process

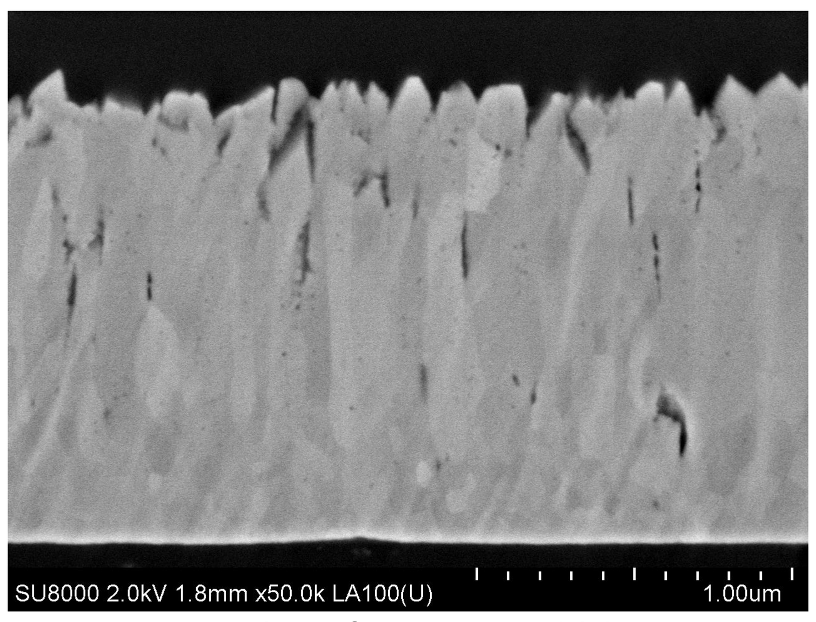
Wrinkle-free metal-on-polymer current collector coil after deposition. Coil width 650 mm



SEM cross section of a 0.78 µm thick copper layer on PET

Copper	
Layer thickness	up to 0.96 µm per side
Sheet resistance	down to 22 mΩ/sq.
Substrate	12 µm PET (commercially available)
Resistivity	down to 2.1 µΩ·cm
Material	copper
Dynamic Deposition Rate	up to 7.5 µm*m/min.

Aluminium	
Layer thickness	up to 1.44 µm per side
Sheet resistance	down to 34 mΩ/sq.
Substrate	12 µm PET (commercially available)
Resistivity	down to 4 µΩ·cm
Material	aluminium
Dynamic Deposition Rate	up to 25 µm*m/min.



SEM cross section of a 1.44 µm thick aluminium layer on PET

Electrochemical characterizations

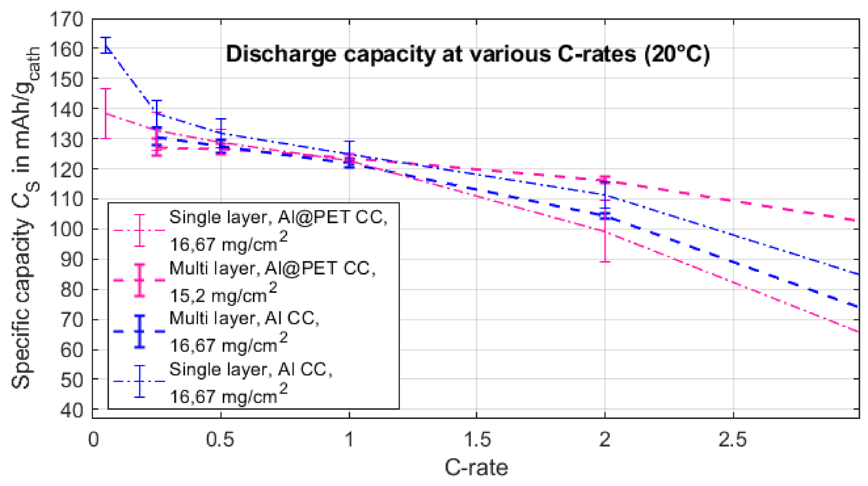
Pouch cells were built with aluminium metal-on-polymer current collectors for the cathode and were compared to reference cells

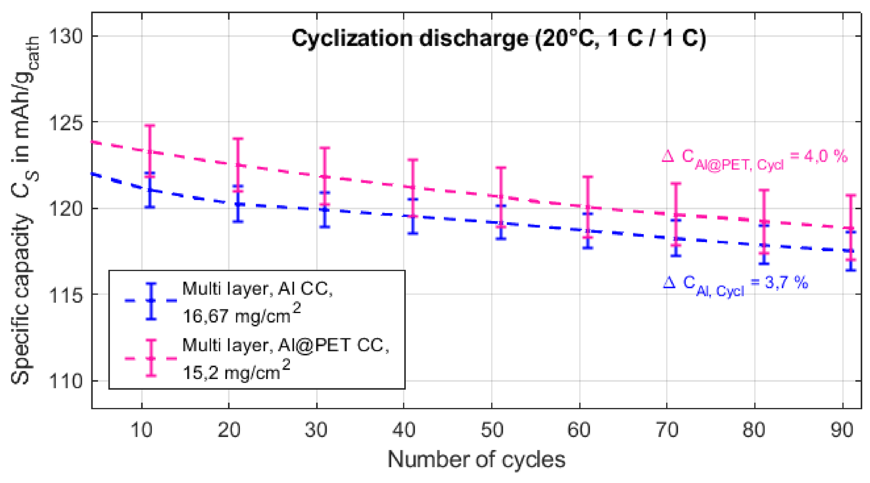
Cell-Material-System

- Pouch-cells NMC622/C
- Anode area: 35 cm²; cathode area: 29,25 cm²
- Multi layer: 6 anodes, 5 cathodes; double-side coated
- Single layer: 1 anode, 1 cathode; single-side coated
- Current collector (CC): anode: Cu; cathode: Al; Al@PET
- Separator: Celgard H2010; 46 % porosity; PP/PE/PP, 20 µm
- 1 M LiPF6 in EC:EMC (3:7) + 2 % VC

Results

- Similar performance at C-rates ≥ 1 C for cells with Al and Al@PET CC
- At C-rates < 1 C higher capacity at the cells with Al CC
  - ➢ Possibly caused by increased internal resistance at the Al@PET CC
- Similar progression of the performance at cyclization but slightly increased capacity loss at cells with Al@PET CC





Conclusion

- Metal-on-polymer current collectors have been made successfully with semi-industrial processes in a roll-to-roll technology
- Pouch cells have been made and tested

Outlook

- Further developments:
  - improvement of layer quality in terms of morphology (for aluminium) and resisitvity
  - test of other suitable metals
  - test of other polymers suitable for higher process temperatures (e.g. PEN, PI)
- Additional vacuum thin-film deposition of pure silicon anodes on top of copper coated polymer current collectors for use as anodes in LiION batteries
- Integration into battery cells

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