

Separators: The Forgotten Energy Storage Component

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ENTEK Technology Holdings LLC

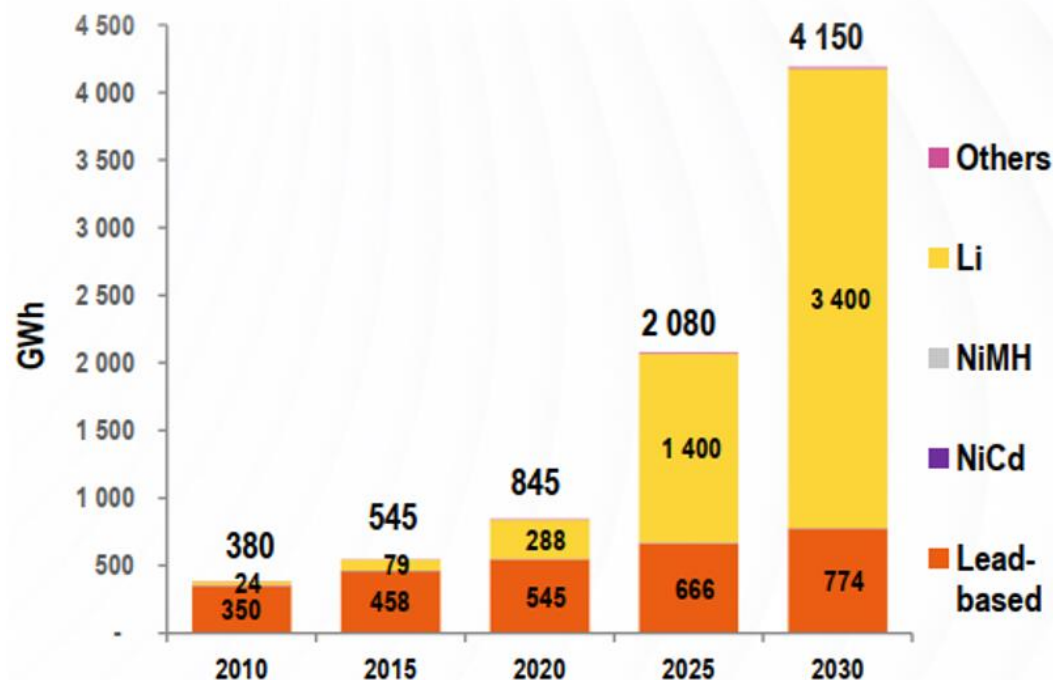
May 27, 2025

FENIBAT – May 25-27, 2025, Londrina, Brazil

- ☐ Battery market forecast
- ☐ Lead-Acid PE/SiO₂ Separators
- ☐ Lead-Acid AGM Separators
- ☐ Lithium Separators

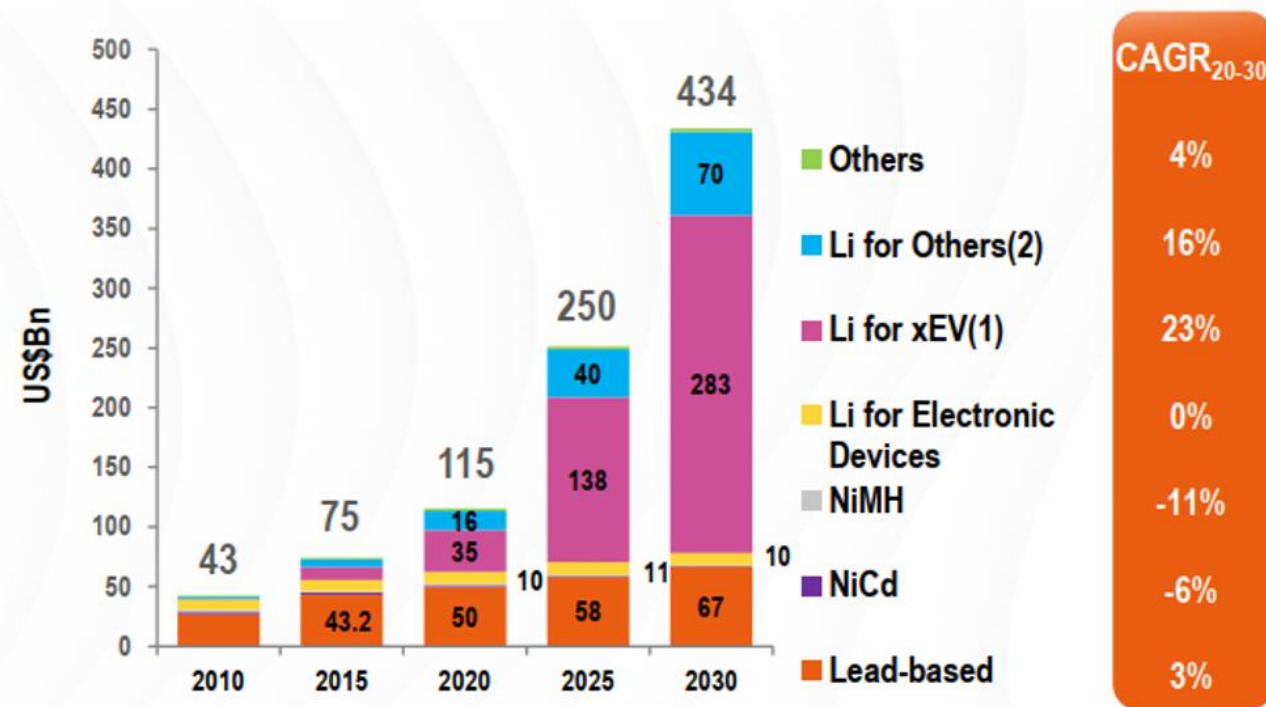
Lead-Based and Li-ion batteries will remain in 2030, the 2 most important markets and Will reach 4.15 TWh & US\$ around \$430Bn in 2030. The CAGR₂₀₋₃₀ in value is 14%

The worldwide battery market in value by chemistry, 2010-2030, GWh



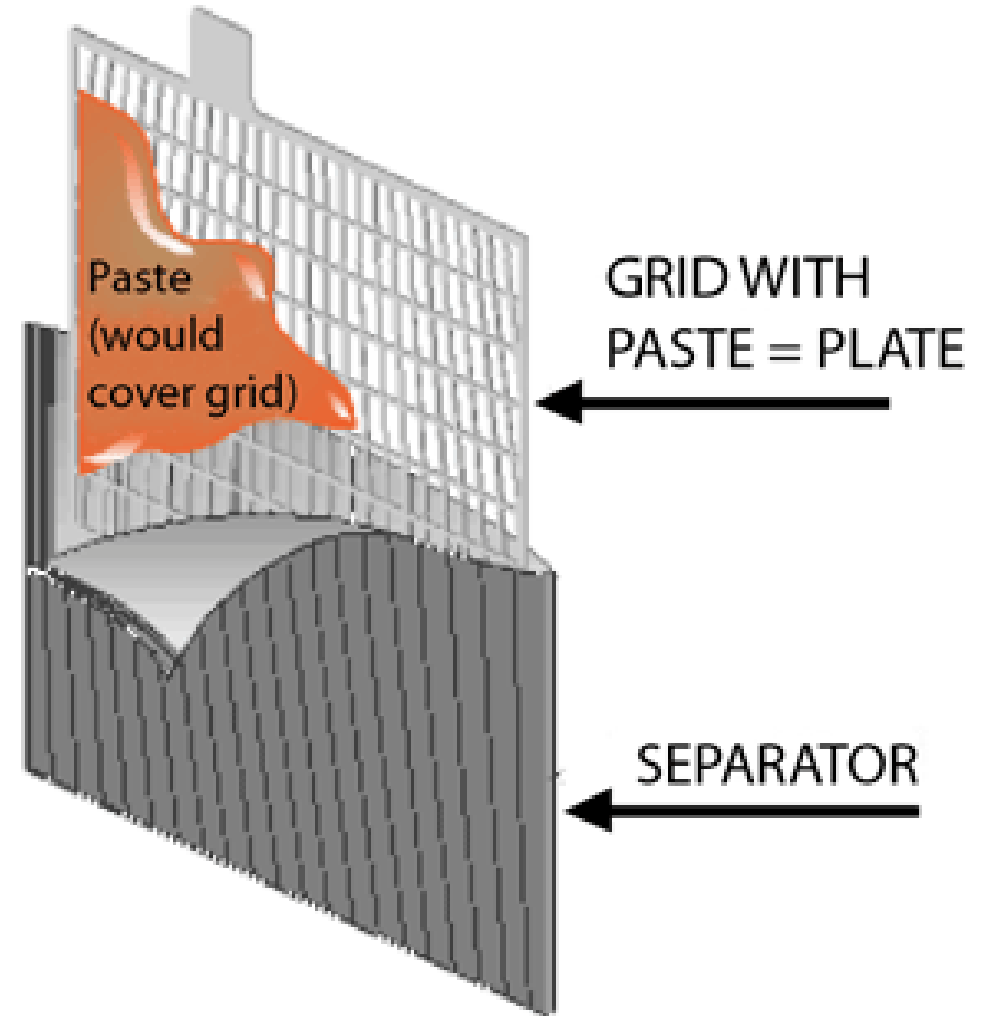
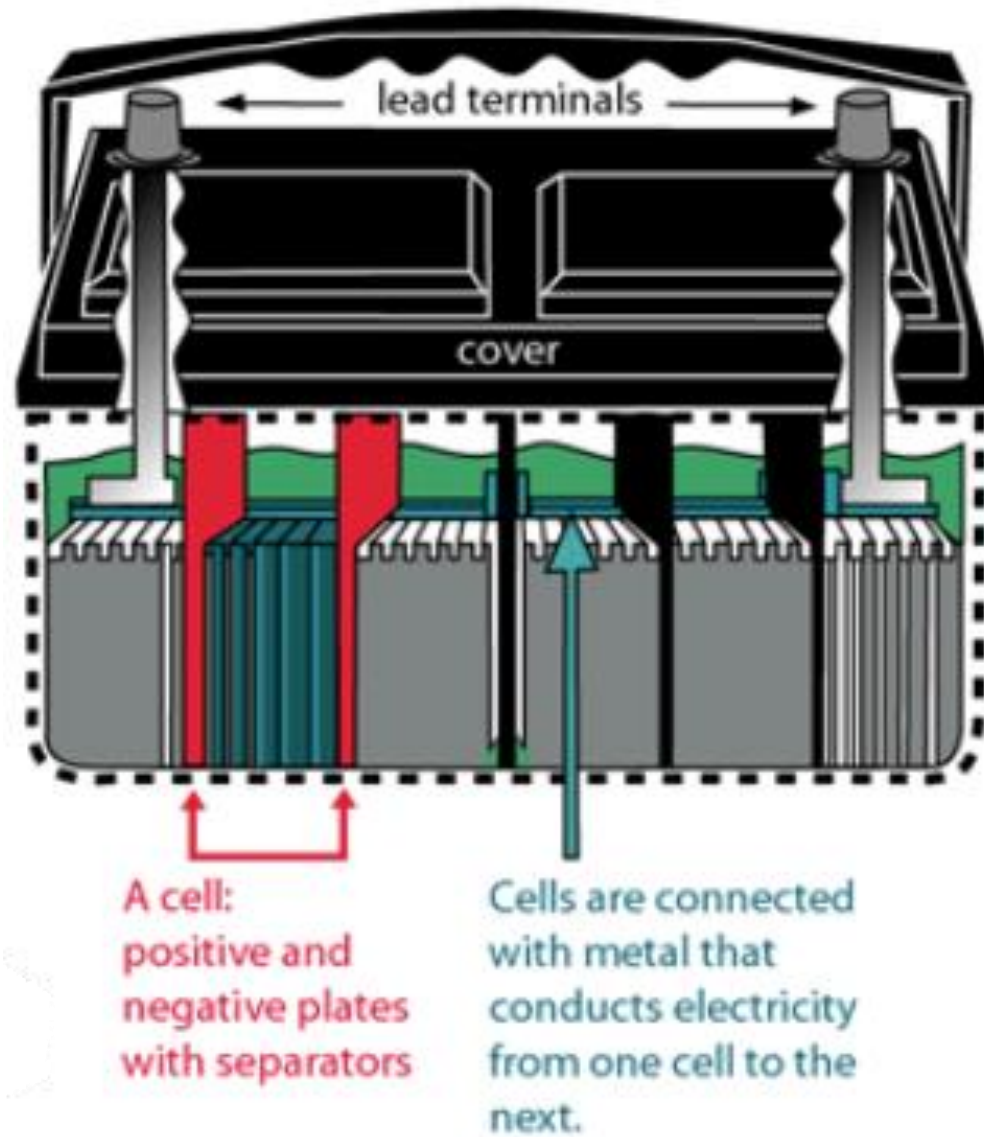
(1) Pack level: pack including cells, cell assembly, BMS, connectors – power electronics (DC-DC converters, invertors, etc.) not included

Market value at Pack level¹, 2010-2030, in US\$Bn

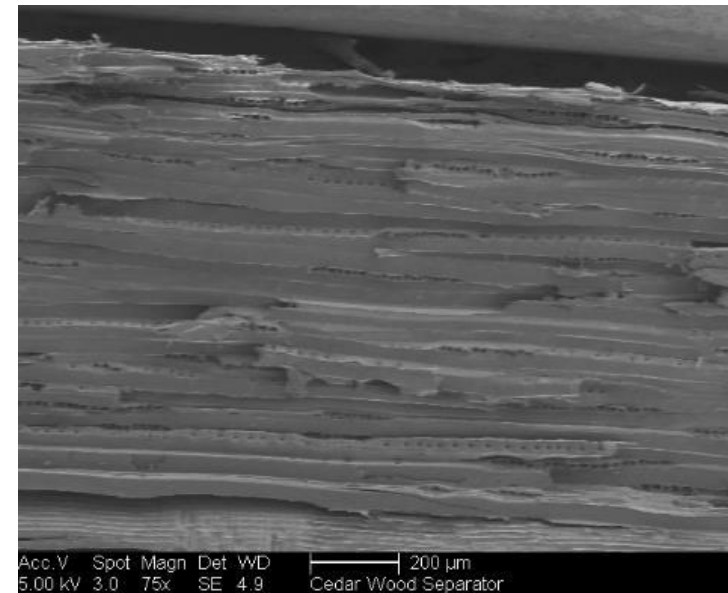
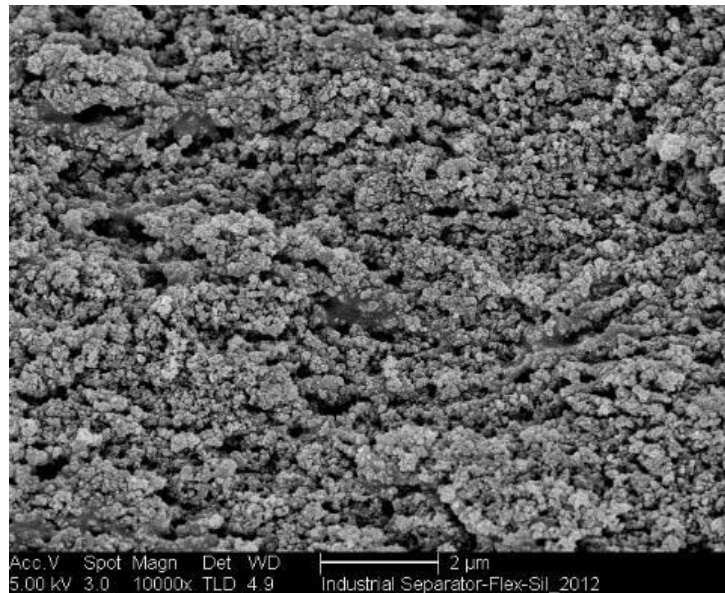
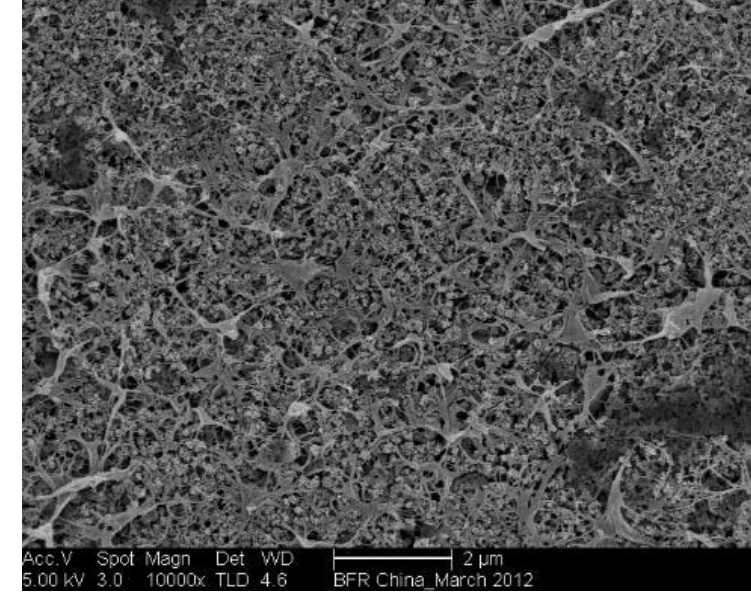
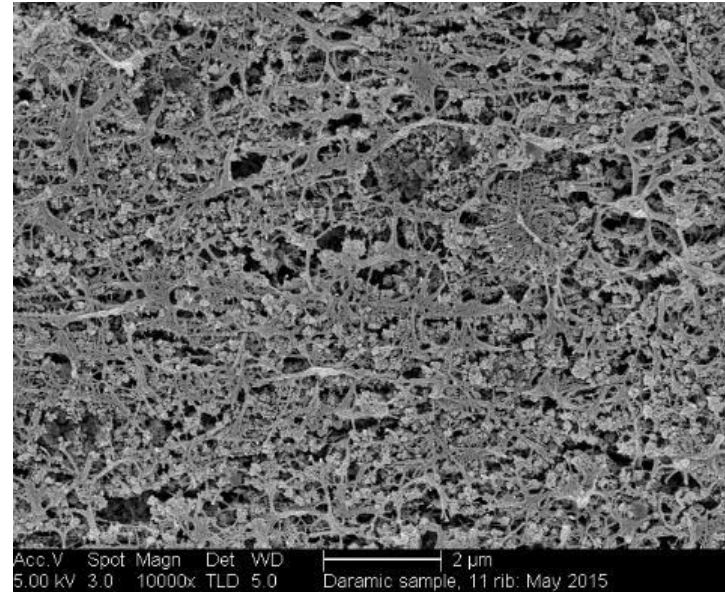
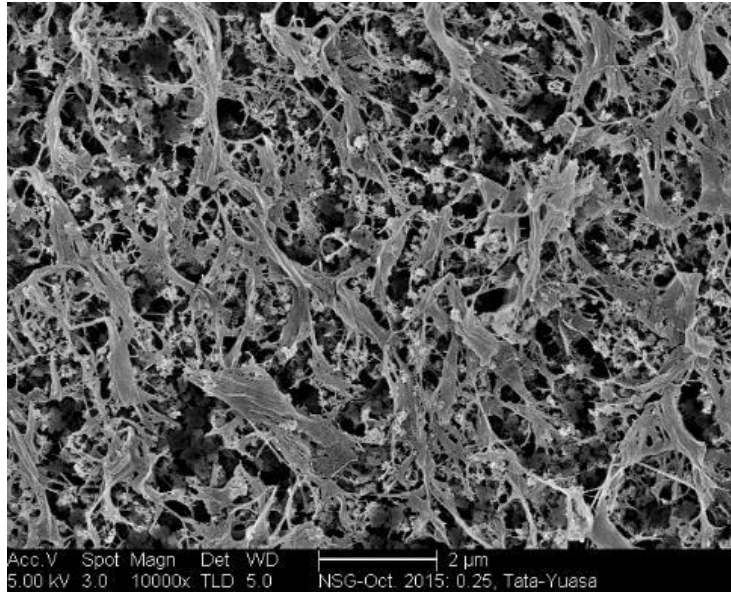


(1): Li for xEV including all kind of electric passenger cars HEV, PHEV & EV, E-buses, E-trucks, E-vans
(2): Others: automatic handling equipment, robots, forklifts, UPS, telecom, medical devices, residential ESS, grid ESS, drones, hoverboards, etc.

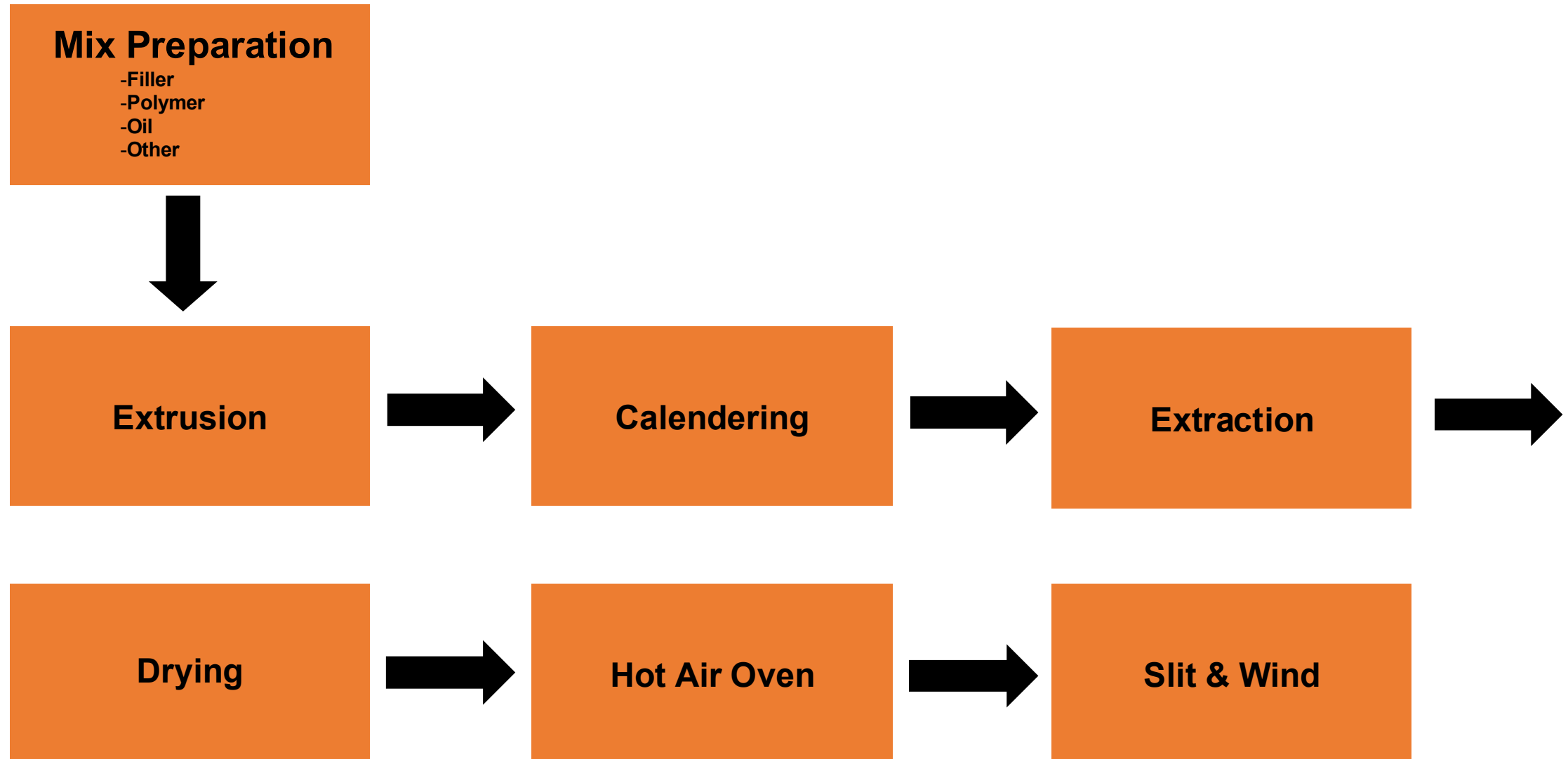
PB-ACID BATTERY CROSS-SECTION

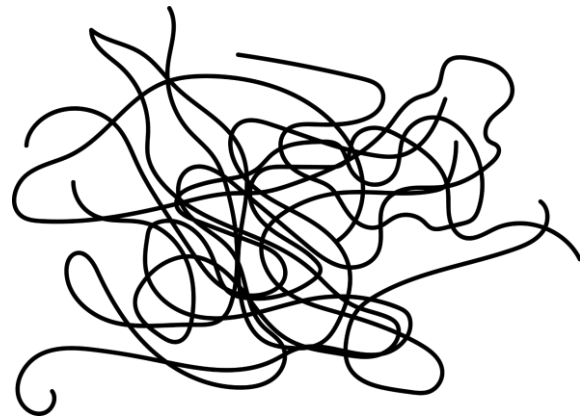


SEPARATOR COLLAGE

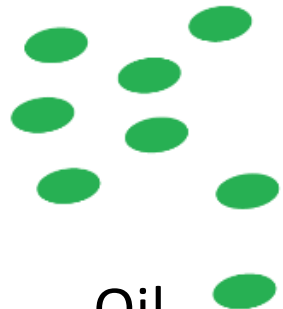


PB-ACID SEPARATOR – PROCESS FLOW

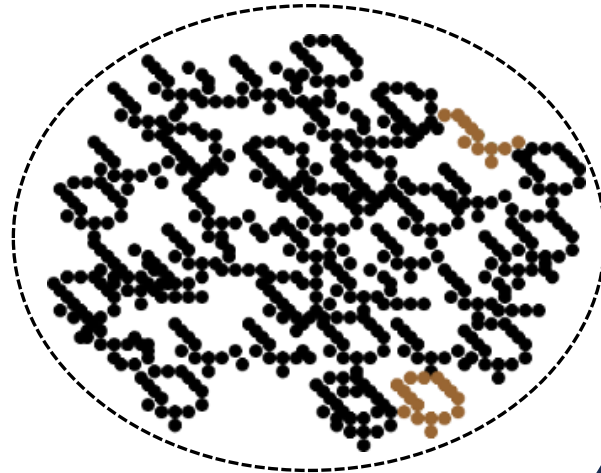




UHMWPE
 $(-\text{CH}_2-\text{CH}_2-)_x$



Oil



Silica

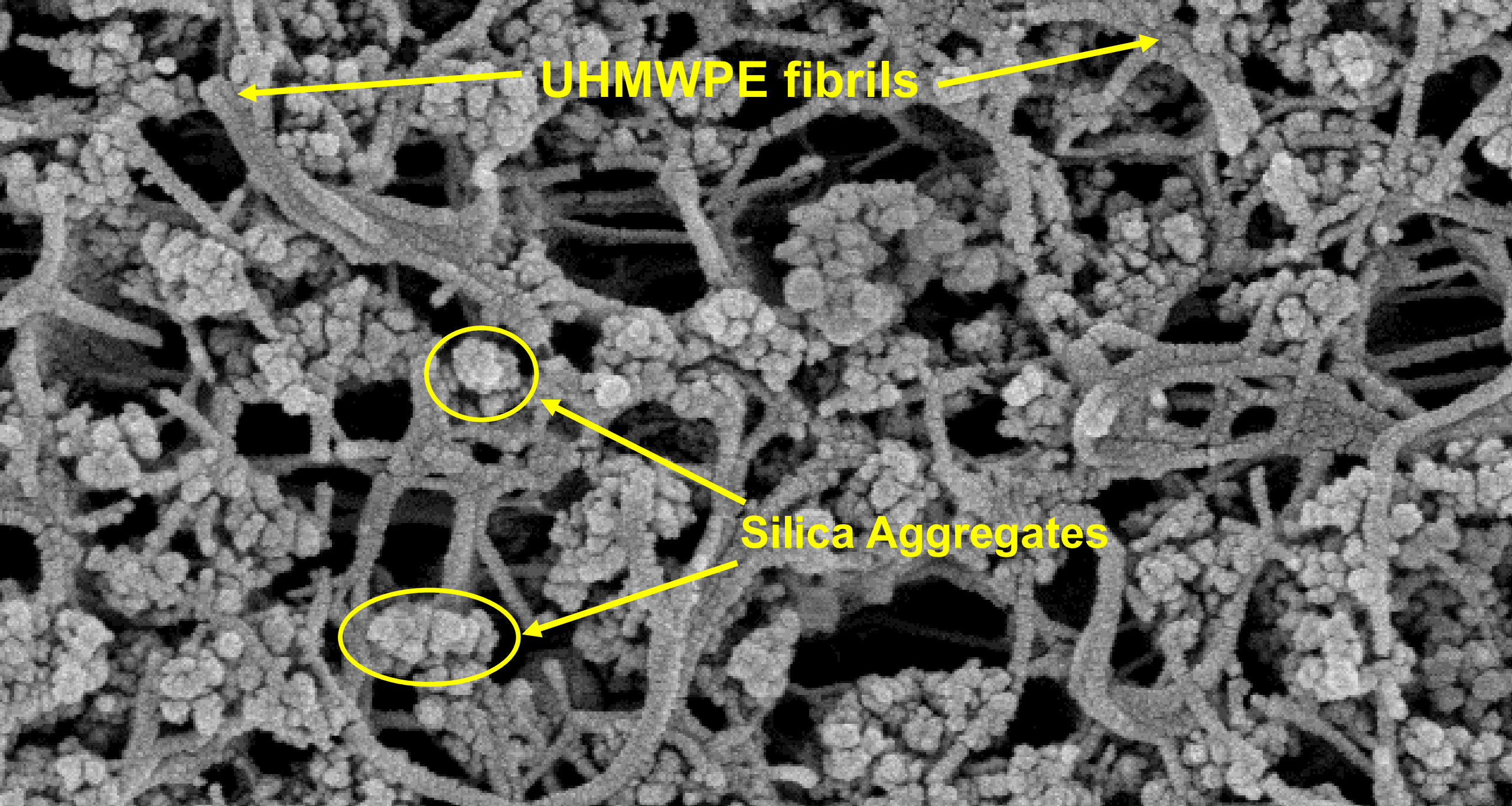
Twin-Screw Extrusion



PB-ACID SEPARATOR – SLITTING & WINDING



Pb-acid separator (150 -500 um)
ENTEK Global Capacity > 420 Million m2

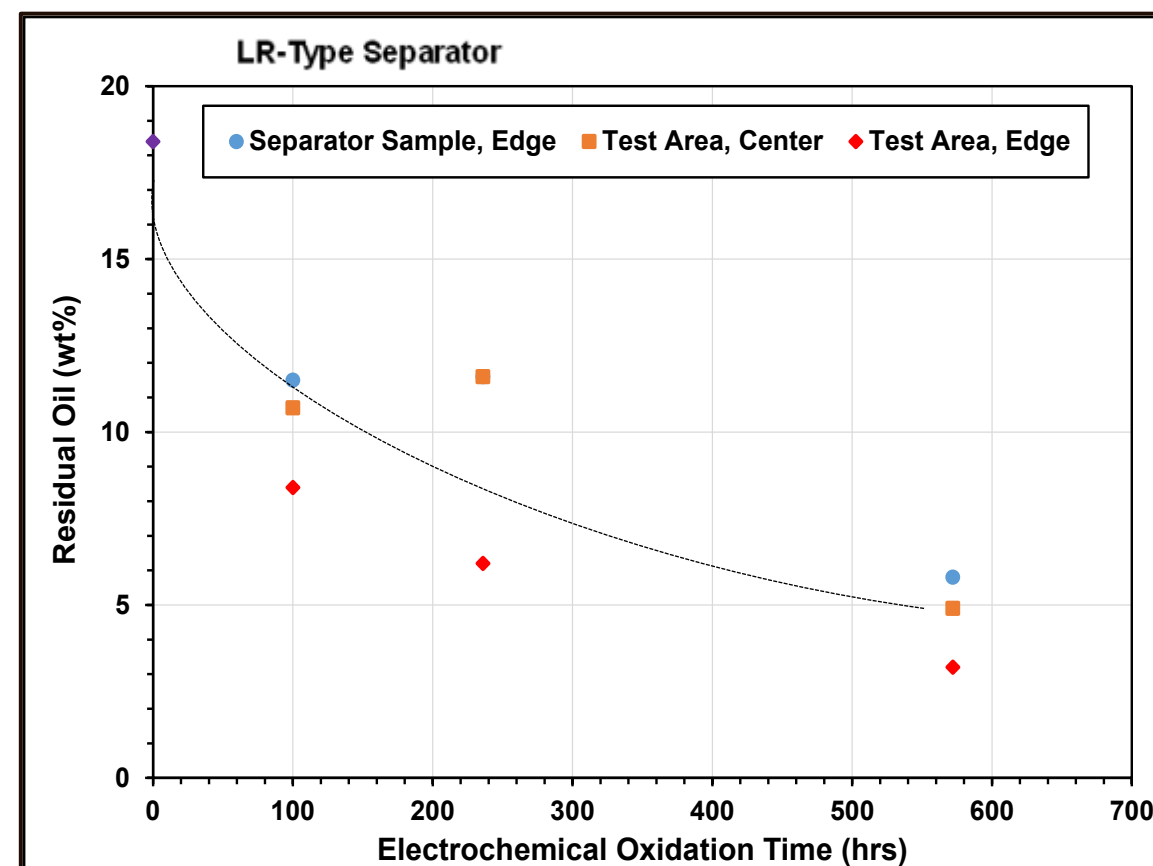
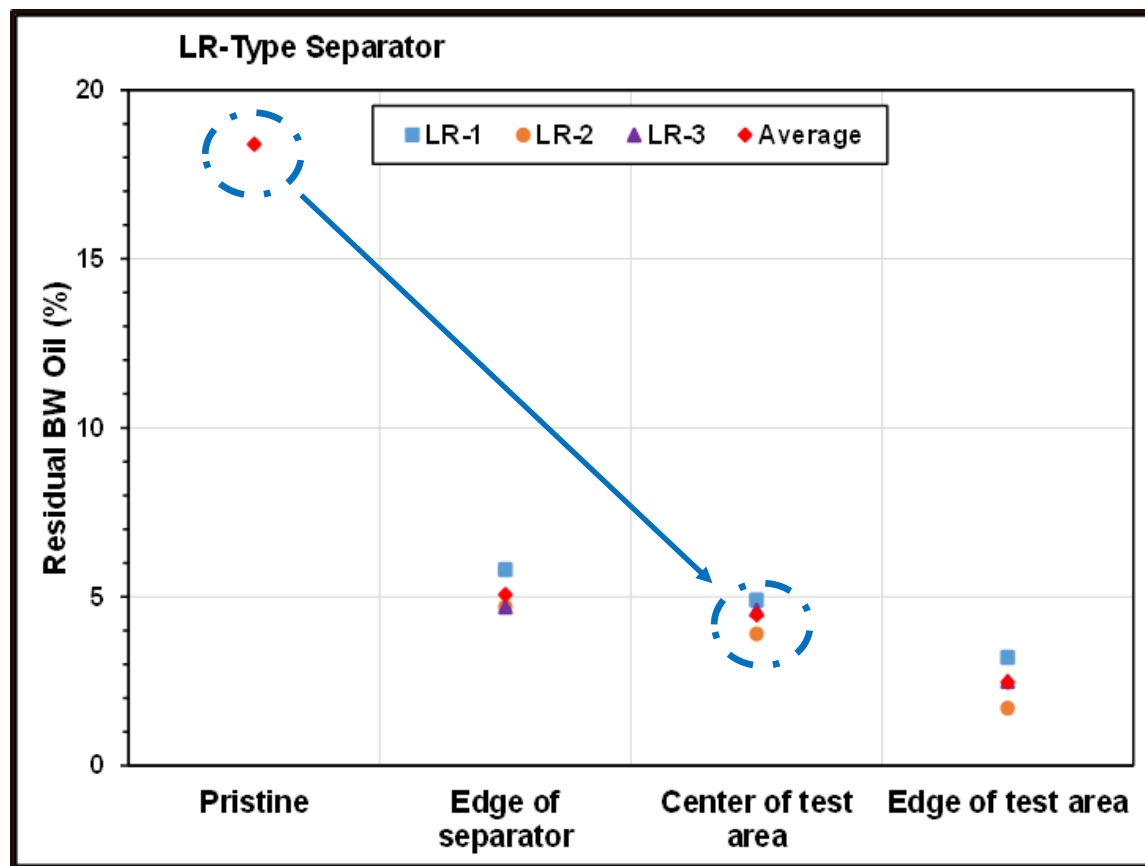


UHMWPE fibrils

Silica Aggregates

Acc.V Spot Magn Det WD

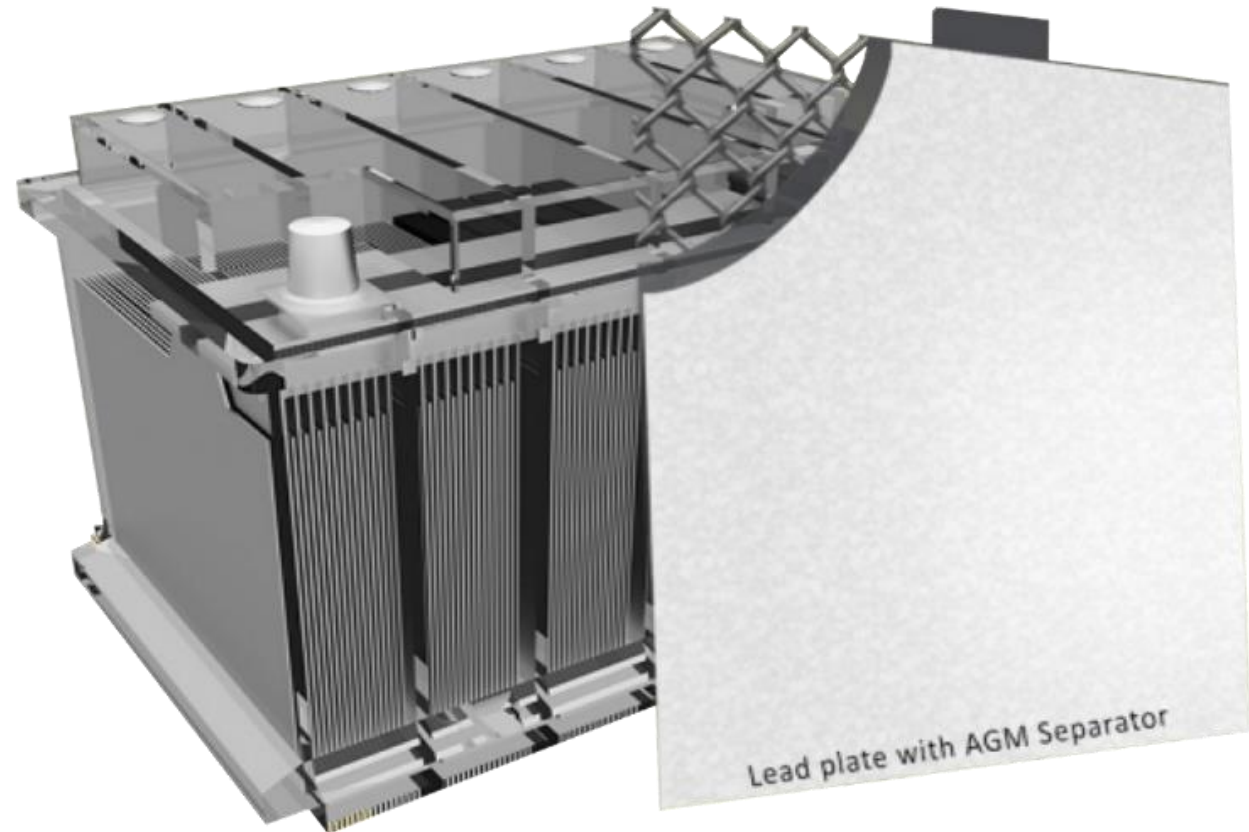
500 nm



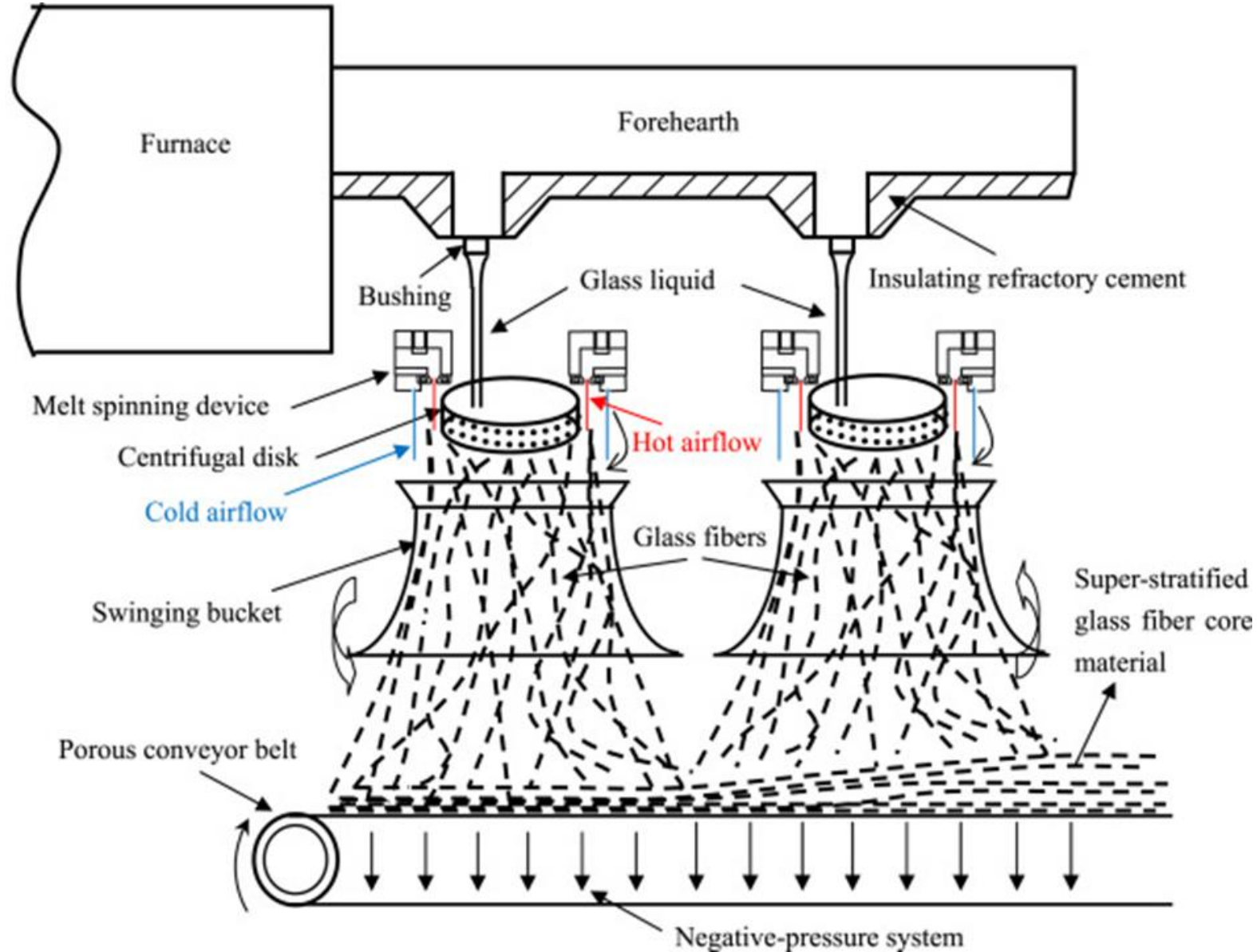
- ❑ All separator types show a significant reduction in oil content in the electrochemical test area
- ❑ Key considerations for improving oxidation resistance
 - Oil composition
 - Oil / UHMWPE ratio

VRLA batteries are used in a variety of applications that require certain features of the AGM separator. Depending on the customer need, ENTEK AGM is available in three types and can be generally described as follows.

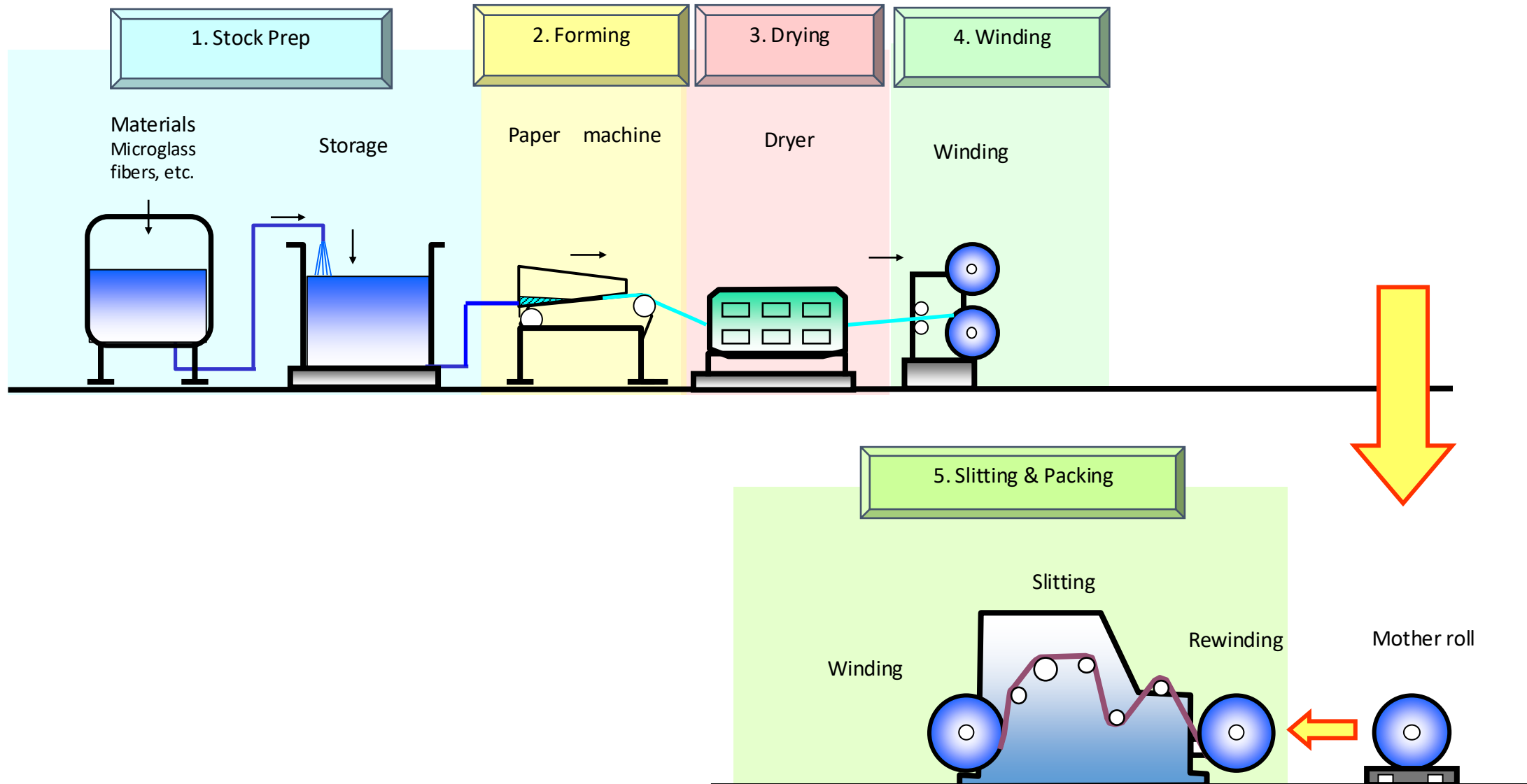
1. **All-glass fiber AGM:** typically used in applications where maximum capacity and battery life are concerned.
2. **Hybrid-AGM:** Used where mechanical strength is important, for example high-speed battery assembly.
3. **Hybrid-PLUS-AGM:** Used in similar applications as Hybrid-AGM, especially where there is a requirement for long-life cycle batteries.



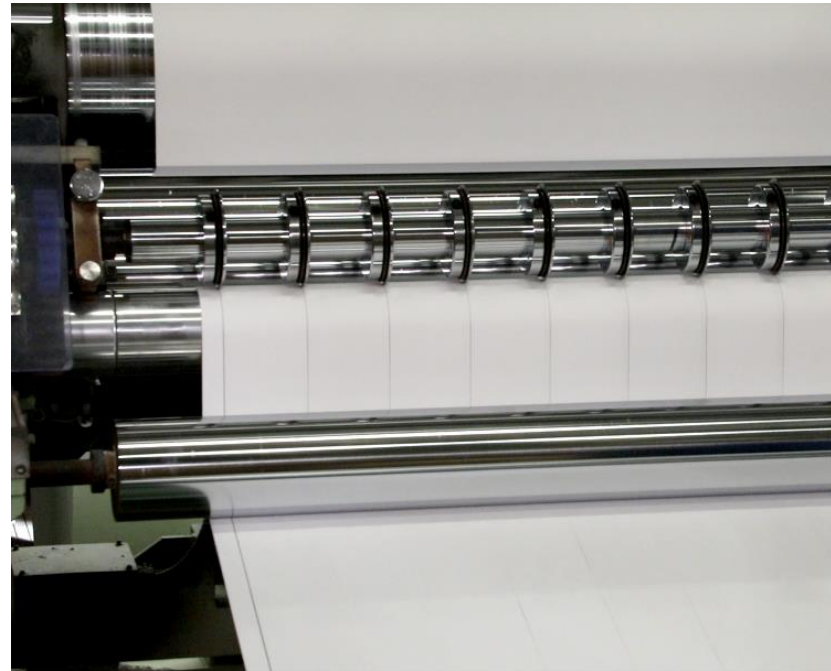
ROTARY ATTENUATION PROCESS



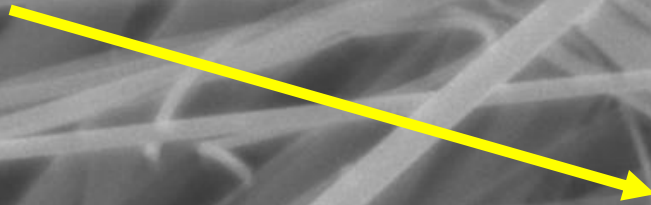
AGM PAPER MANUFACTURING



AGM SLIT ROLLS ARE DELIVERED TO CUSTOMERS



Micro Glass Fiber



X 1,000

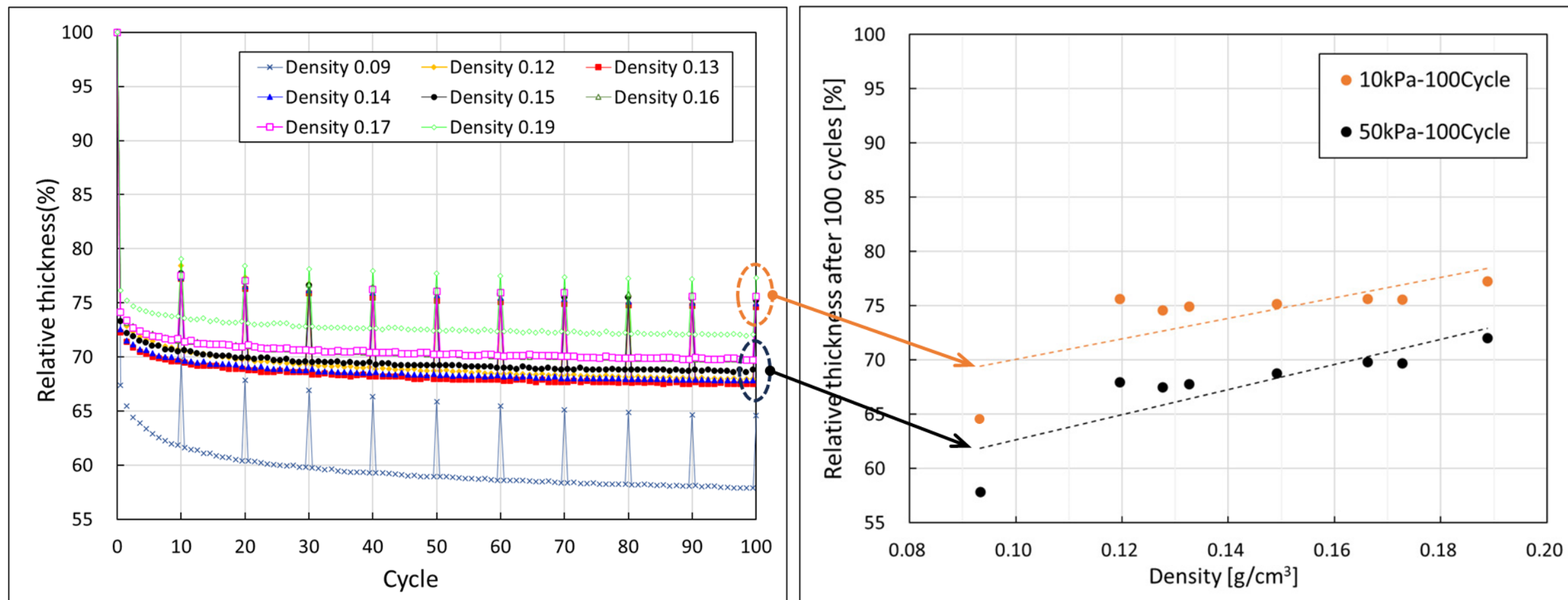
1.50kV SEI

10μm
SEM

JEOL

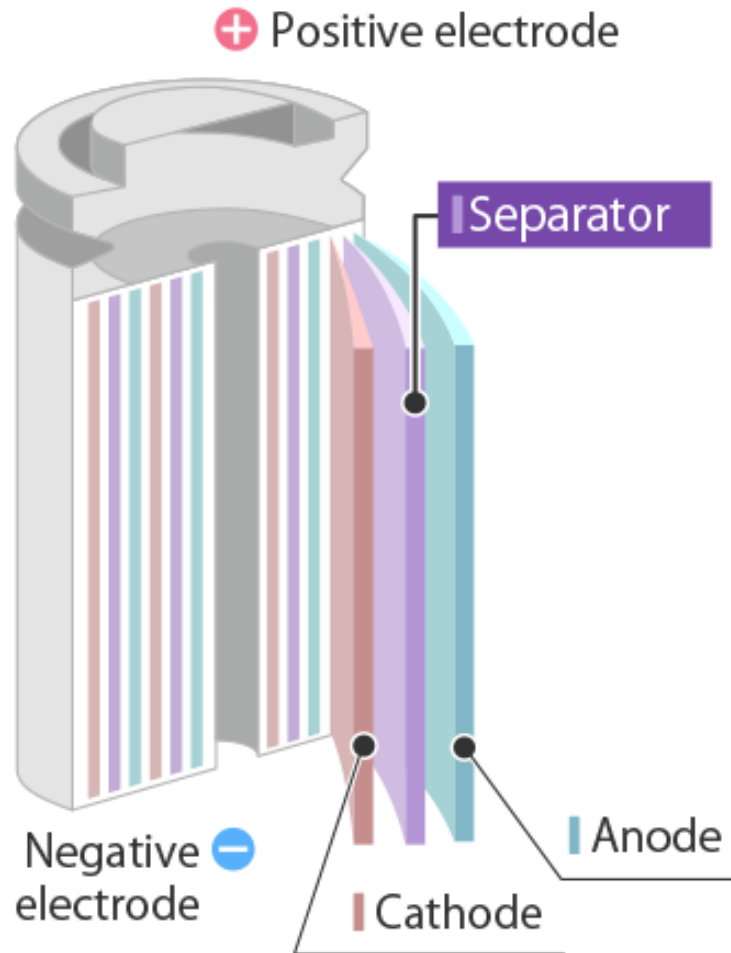
2024/07/09
WD 10.8mm 13:55:59

IMPROVED COMPRESSION/RECOVERY FOR LONGER CYCLE LIFE

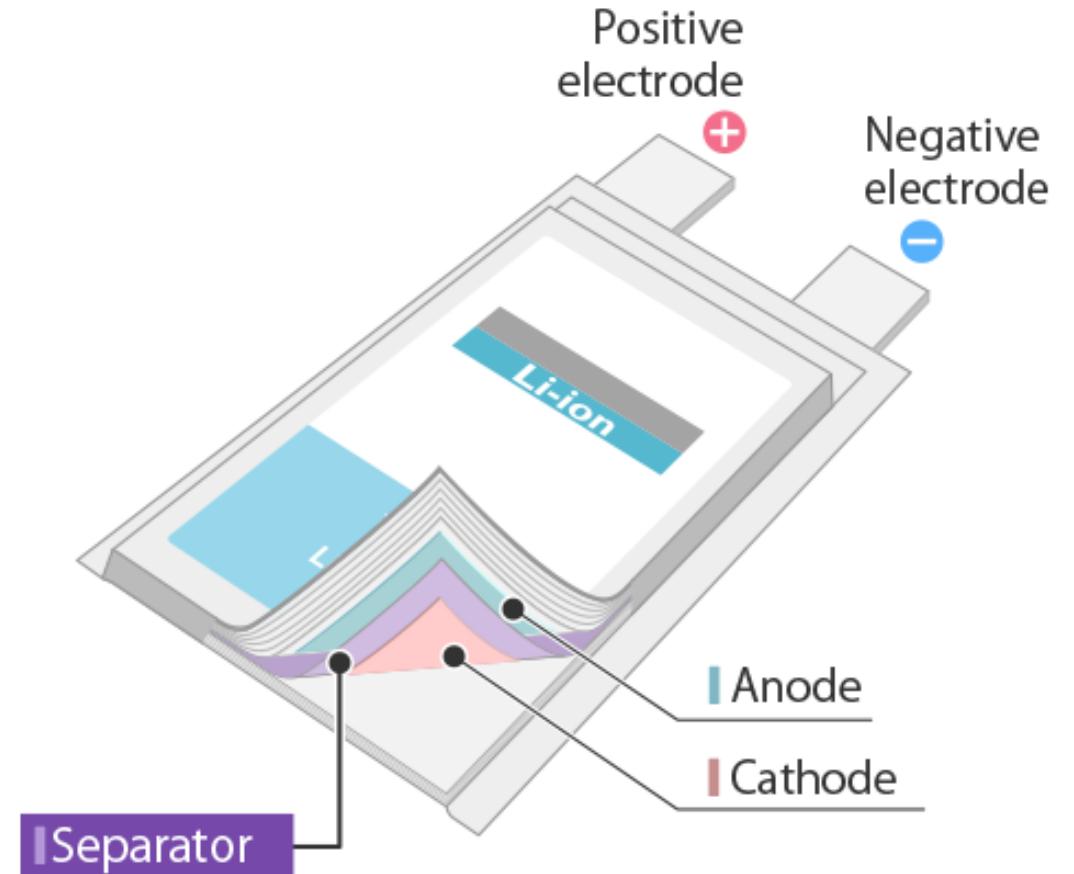


- In **wet conditions**(H_2SO_4), the AGM was repeatedly compressed between 10kPa and 50kPa **100 times**.

Cylindrical-type battery

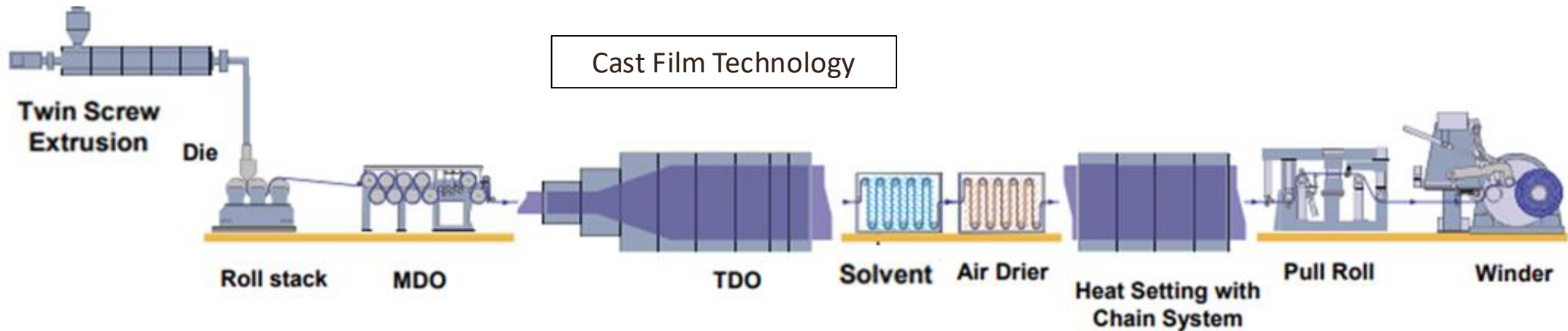
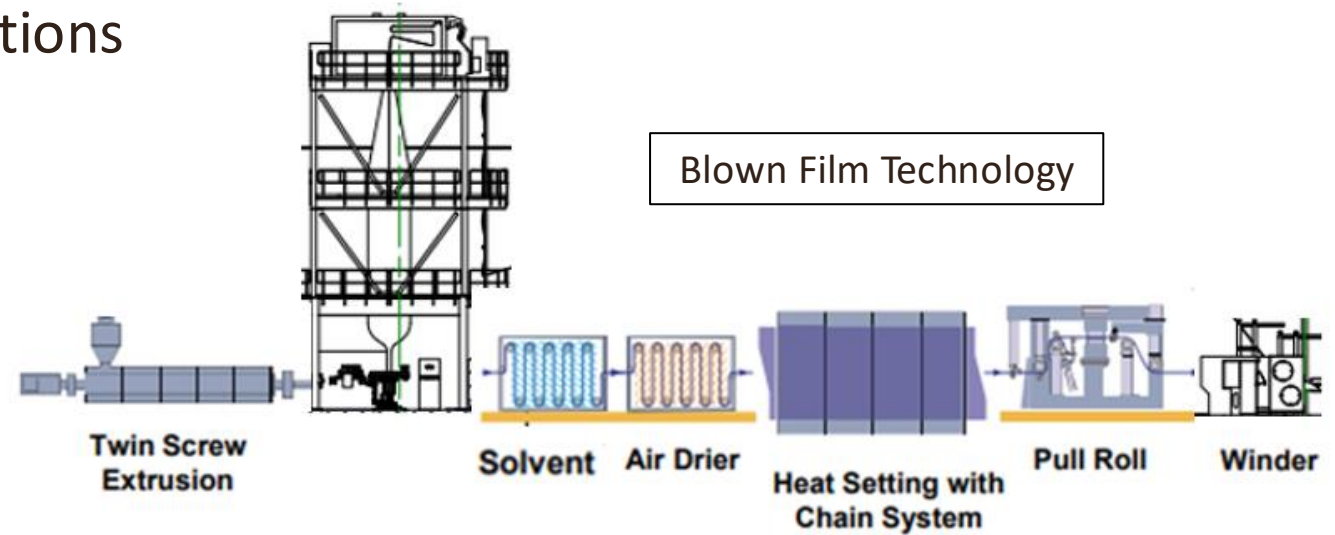


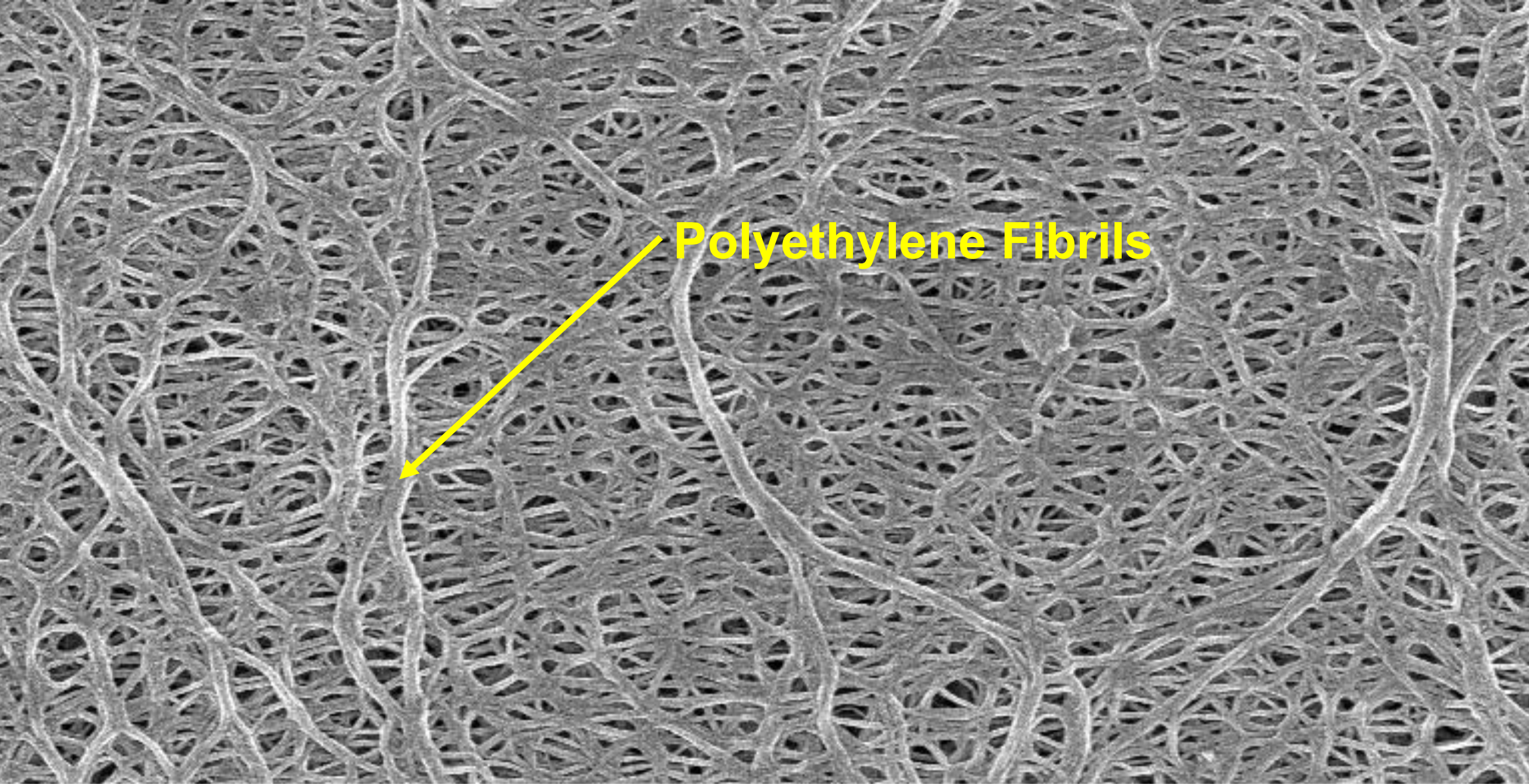
Laminated-type battery



□ “Wet Process” used at both locations

- PE / oil phase separation
- Biaxial orientation
- Solvent extraction
- 5-25 μm thickness





Polyethylene Fibrils

❑ Base Film

- 9- 12 um thickness
- Homogeneity
- Controlled pore structure
 - Impedance
 - Wettability
- Good mechanical properties
 - Stiffness
 - Puncture resistance
 - Toughness
- Thermal response
 - Shutdown
 - Meltdown



❑ Ceramic Coating

- Provides oxidation resistance
- Inhibits dendrite penetration
- Imparts high temperature dimensional stability

❑ Adhesive

- Lamination to electrodes in certain cell designs
- Mixed into ceramic layer
- Outer acrylic or PVDF copolymer layer

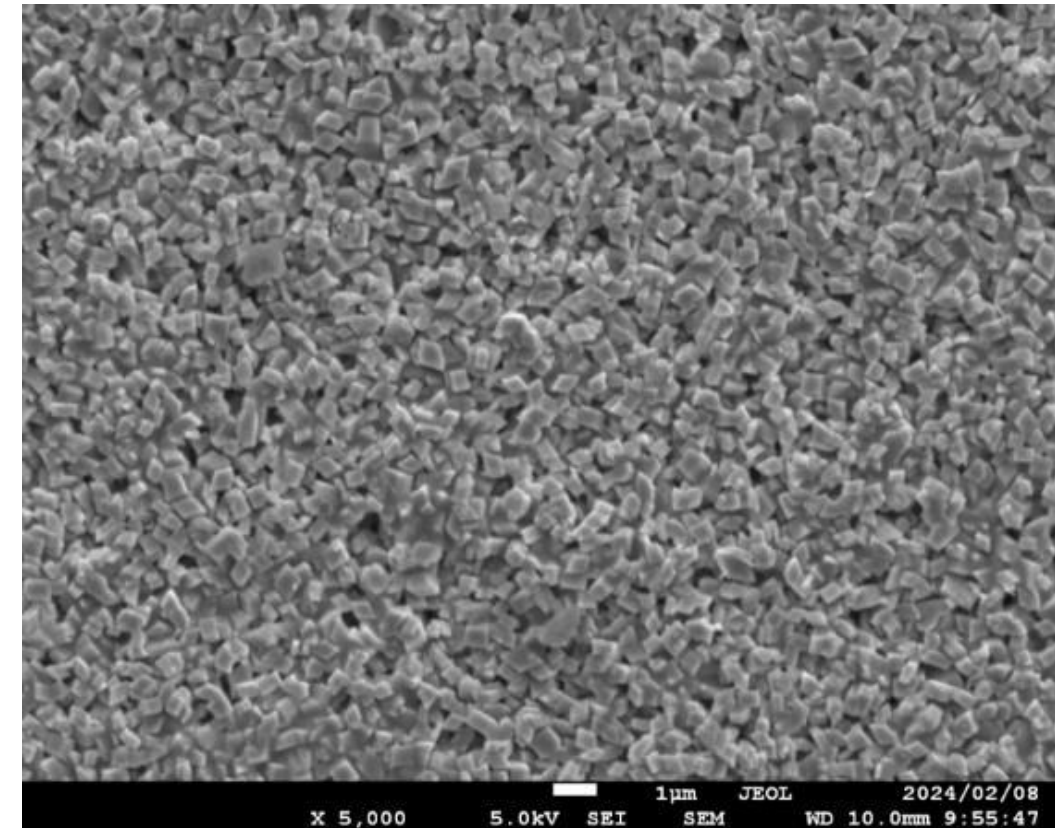
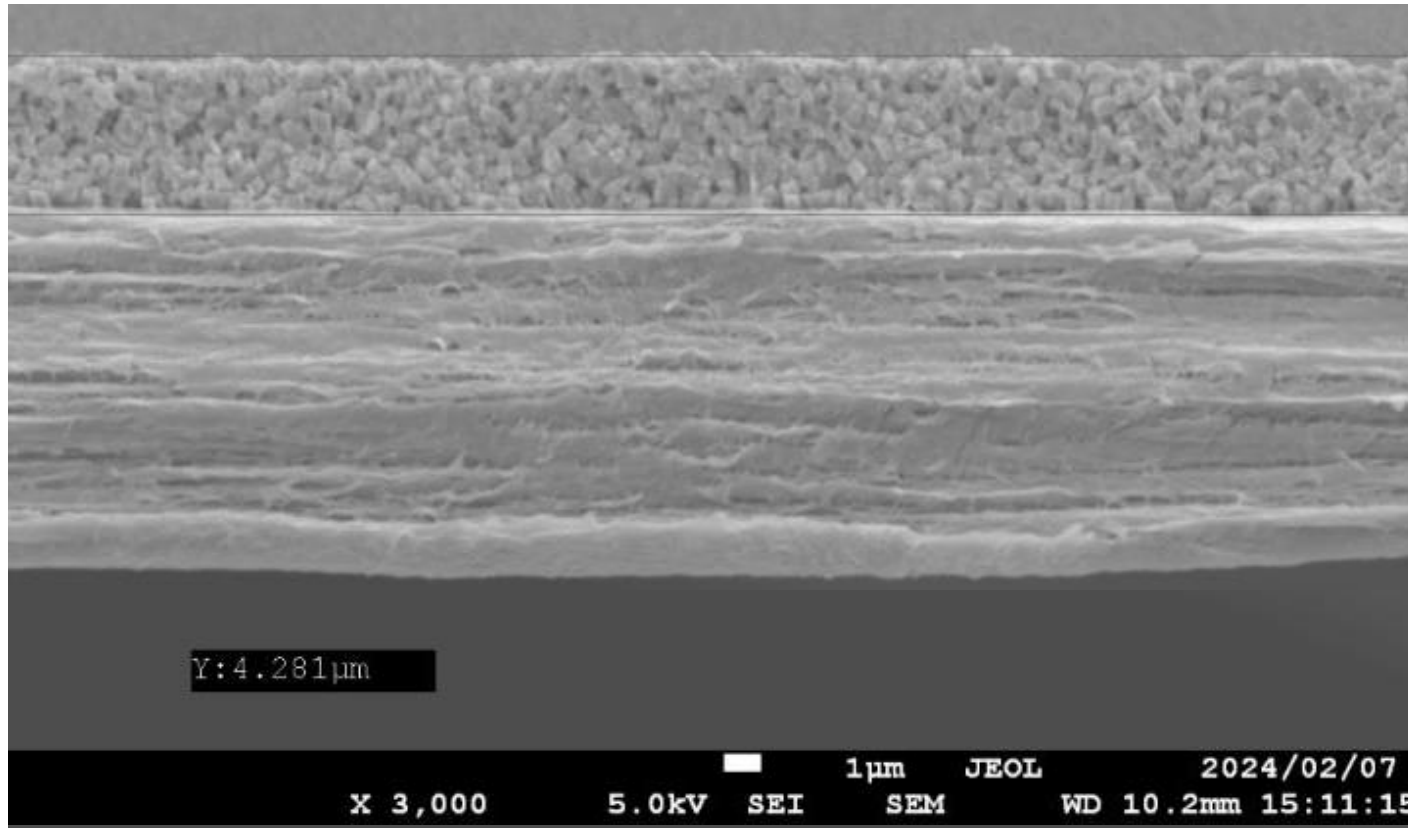
Adhesive

Ceramic Coating

Base

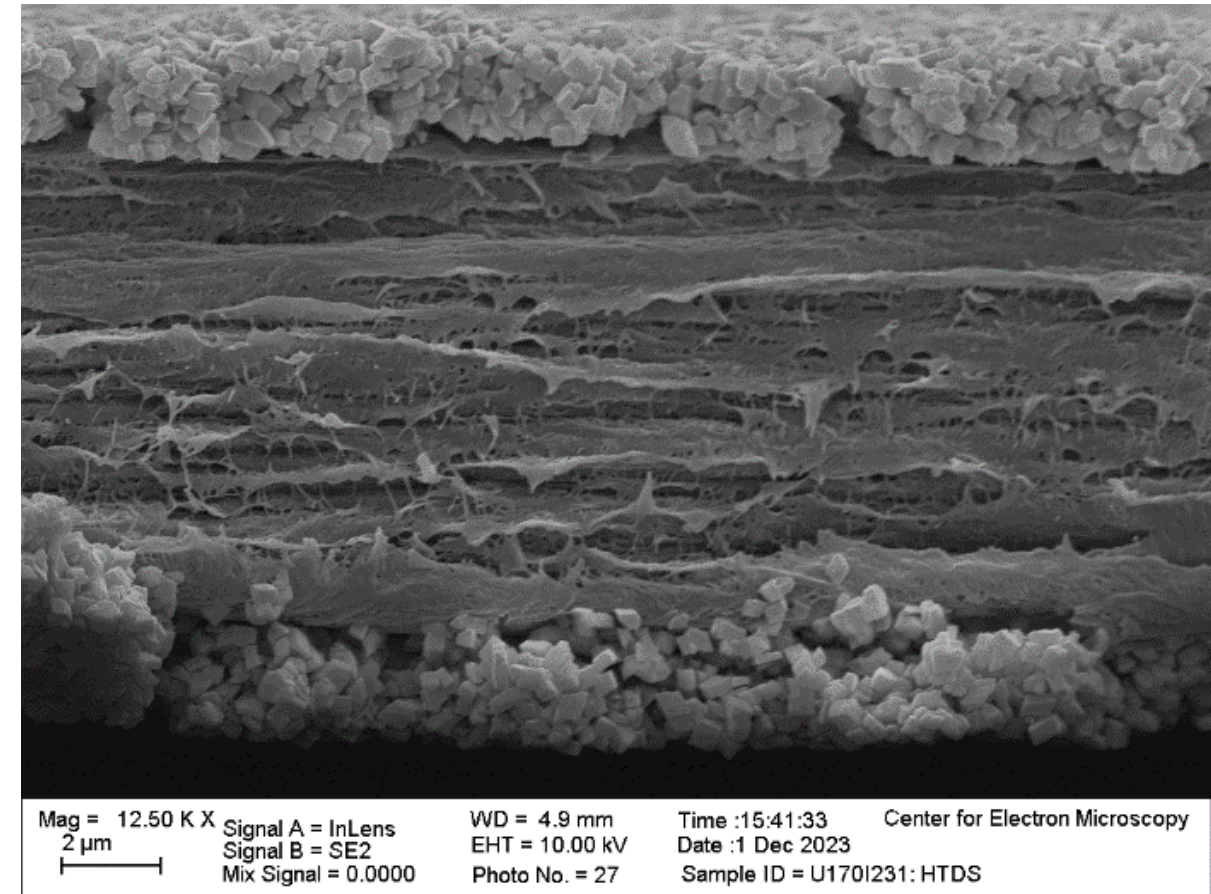
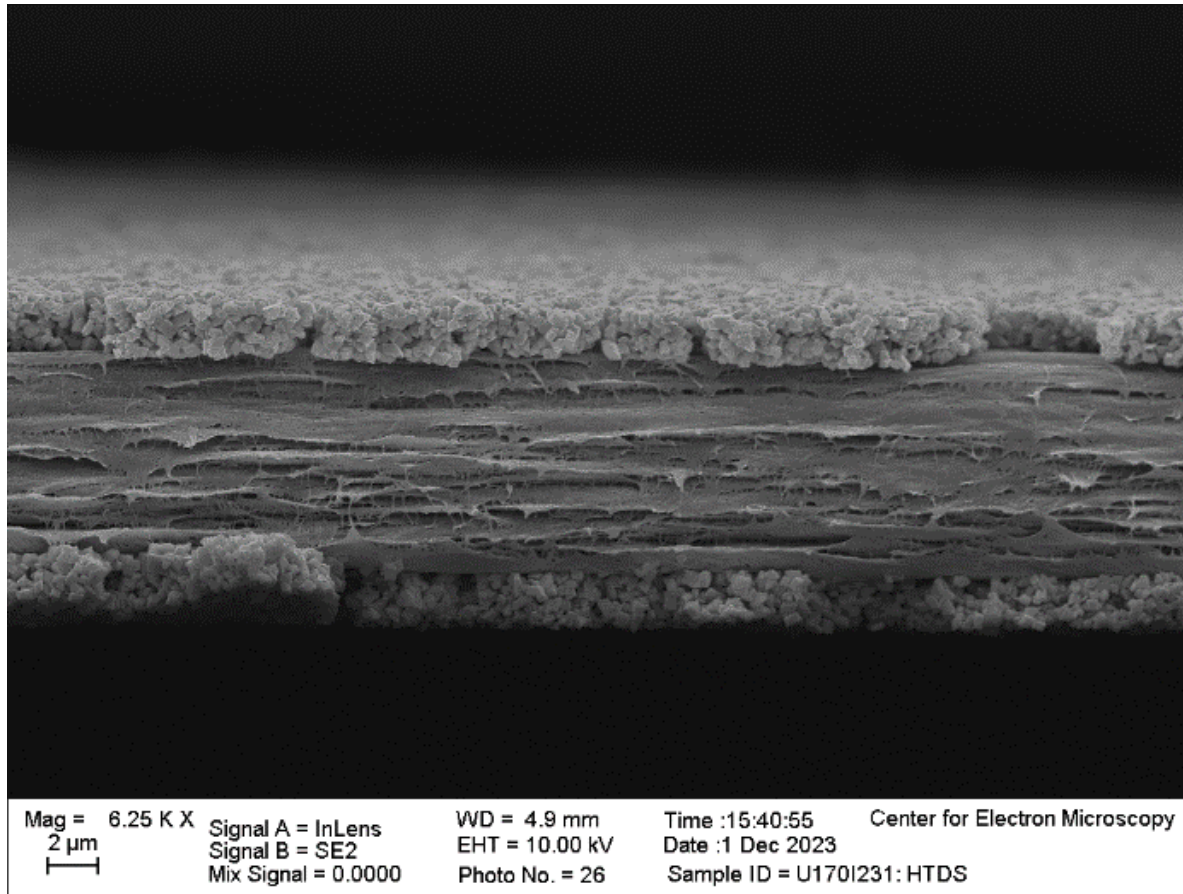
Ceramic Coating

Adhesive



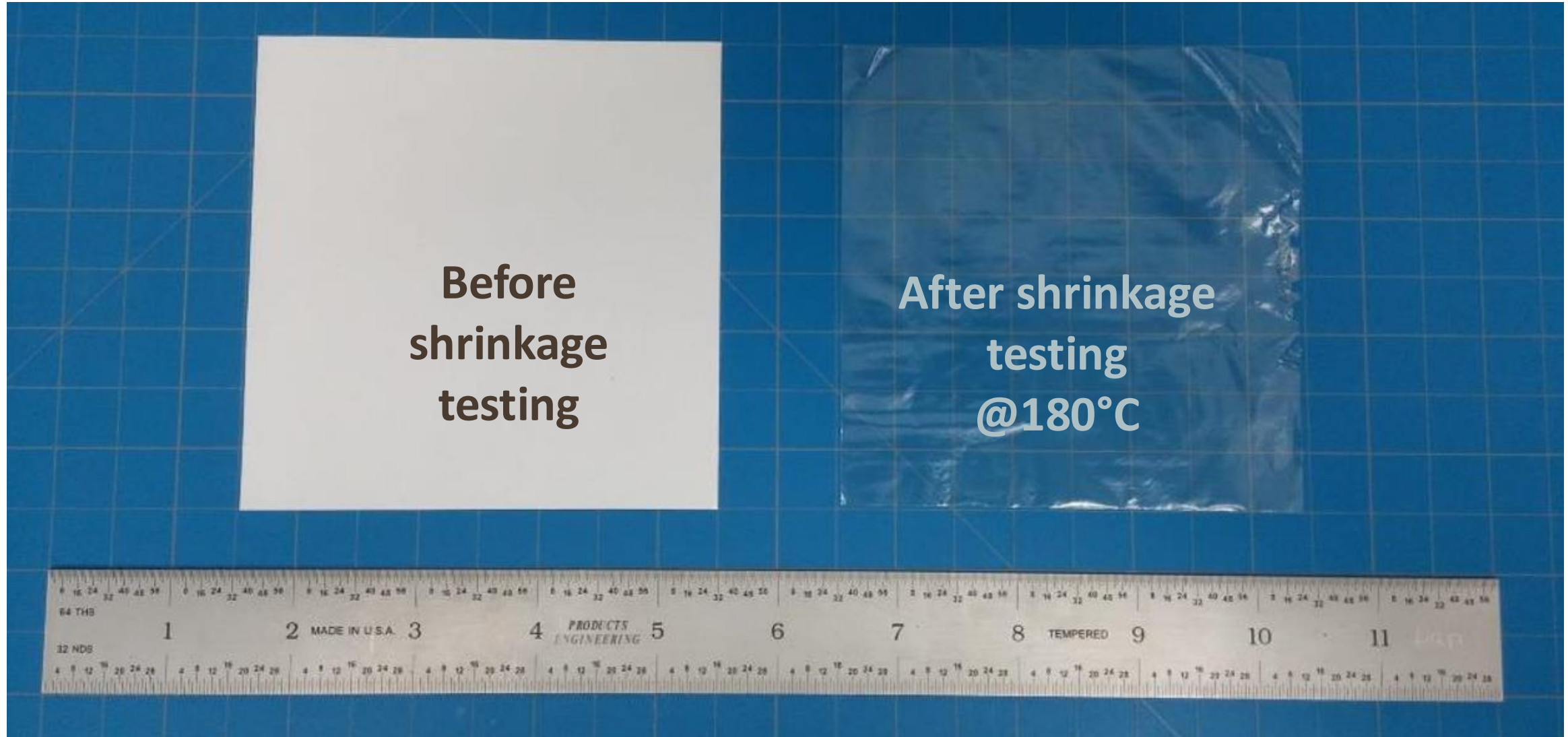
Separator produced during pilot line coating trials in Japan

FRACTURE SEM – DOUBLE SIDE COATED SEPARATOR



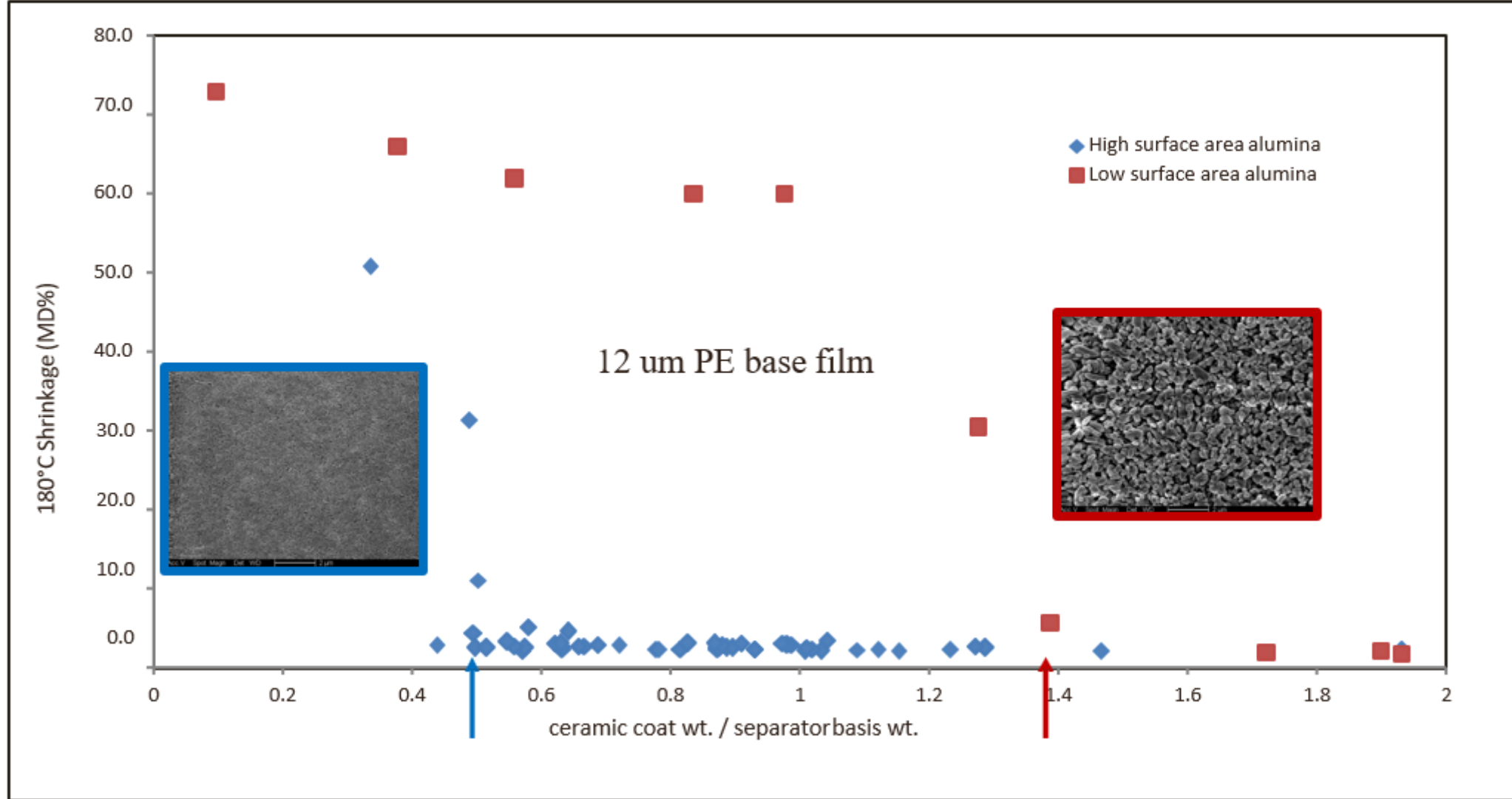
Separator produced during pilot line coating trials in Japan

THERMAL SHRINKAGE TEST



ENTEK ceramic coated separators exhibit < 5% shrinkage in both the machine and transverse directions after being heated for 1 hr at 180 C

IMPACT OF PARTICLE SIZE AND COAT WEIGHT



ENTEK separator with alumina nanoparticle coatings required 60% less ceramic to achieve high temperature dimensional stability at a lower raw material cost

NEW LI SEPARATOR PLANT UNDER CONSTRUCTION

Building 3

Building 2

Building 1

Equipment Ready
For Installation

Obrigado

