



Biobased Membranes for Redox-Flow Batteries



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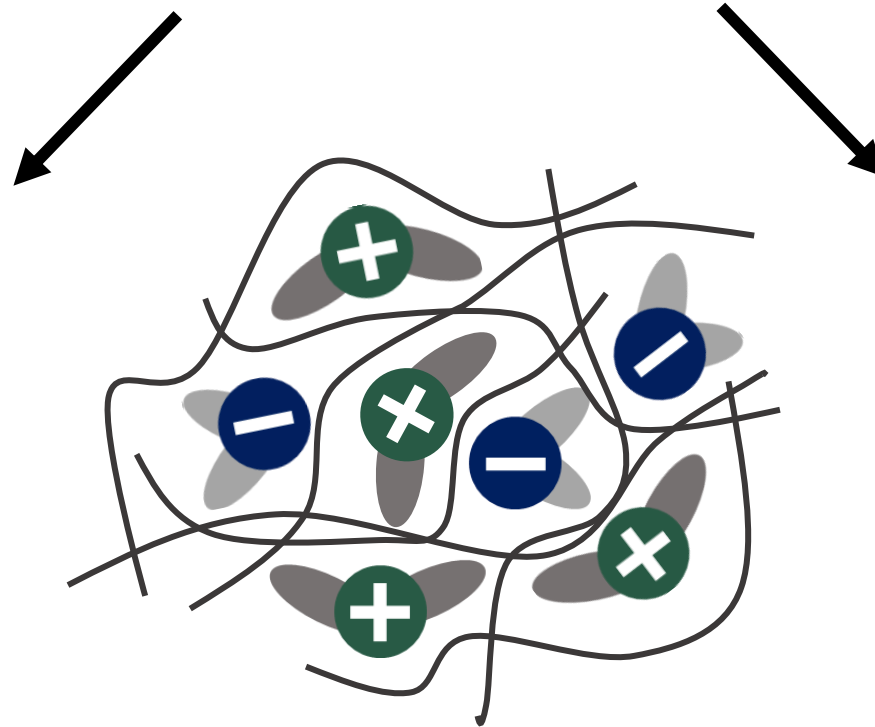


What is our Approach?

Composite material

Low cost support material

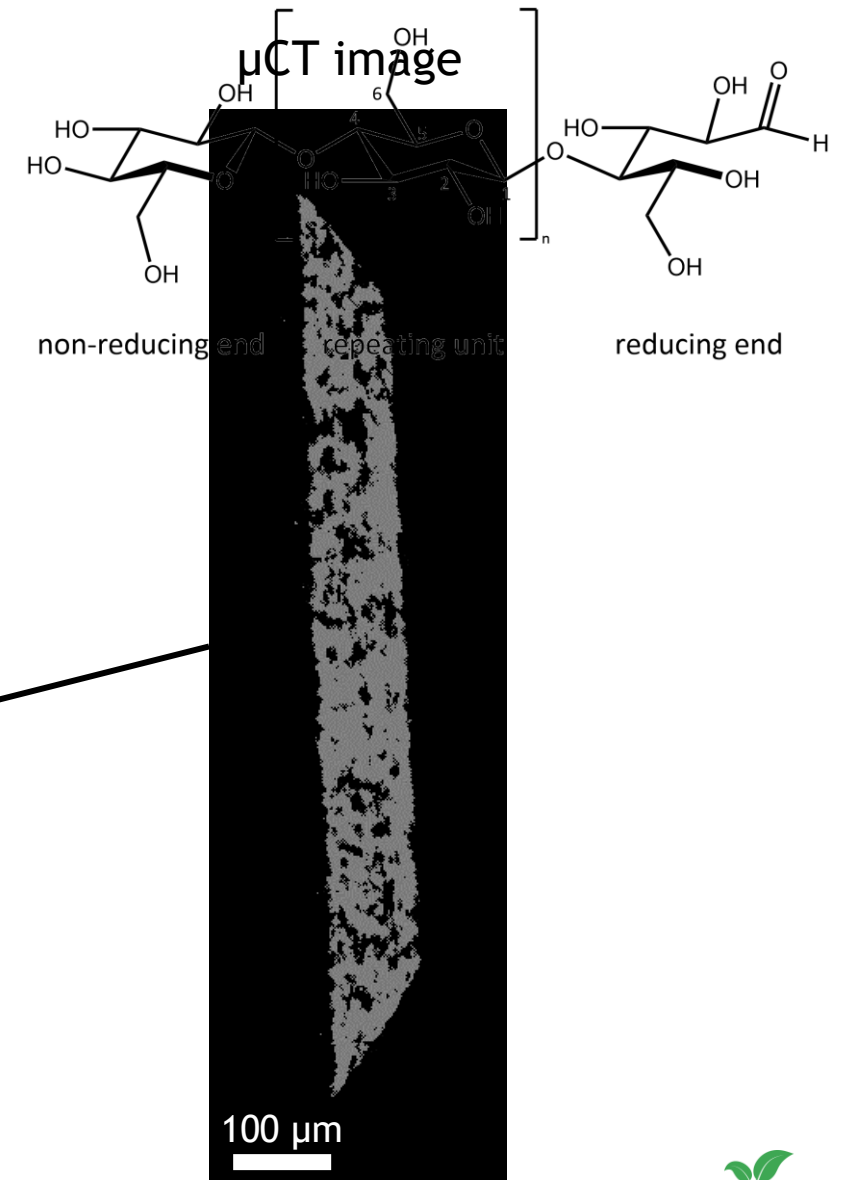
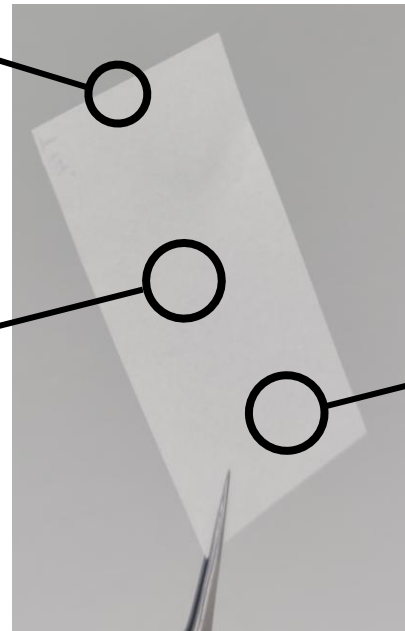
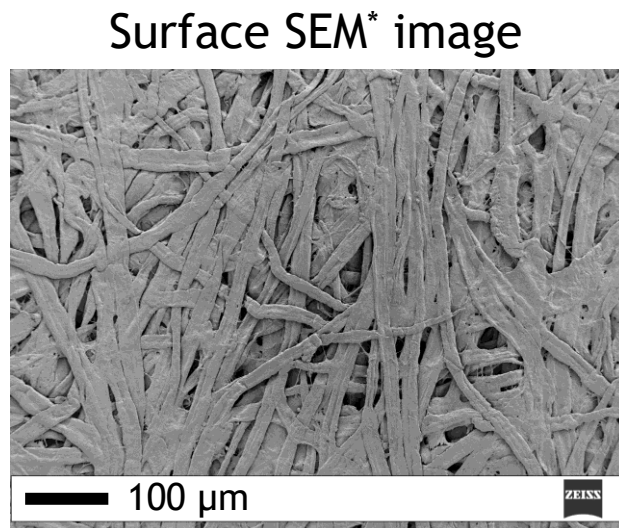
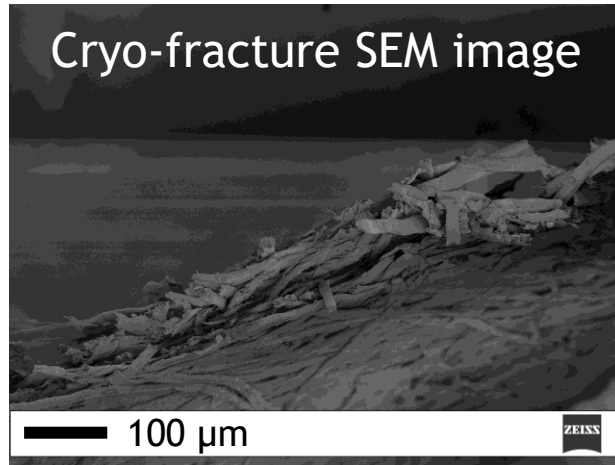
- Polyethylene
- Polypropylene
- Polystyrene
- Paper
- ...



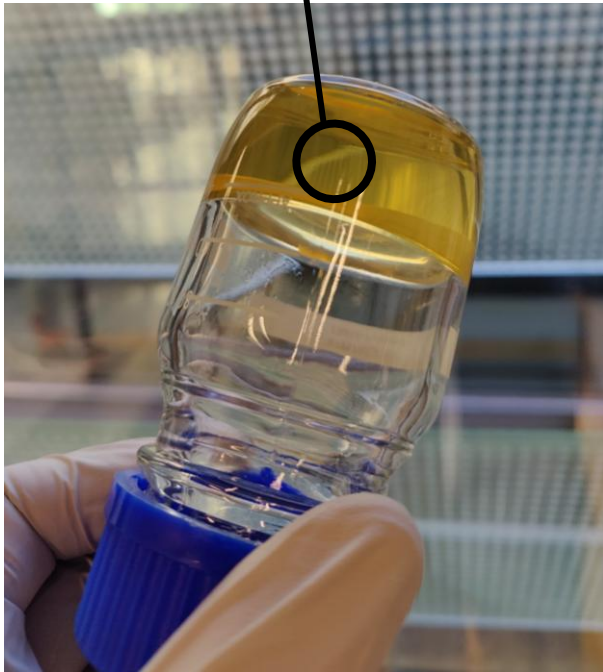
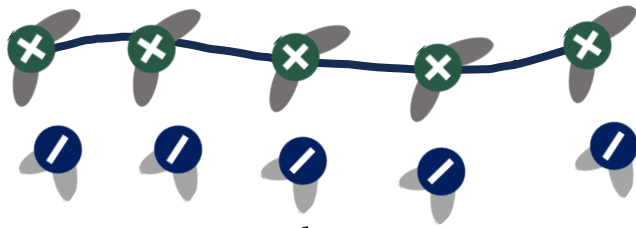
Ion conductive material

- Perfluoroalkylsulfonic acid (PFAS)
- Sulfonated poly(ether ether ketone)
- Poly(ionic liquids)
- ...

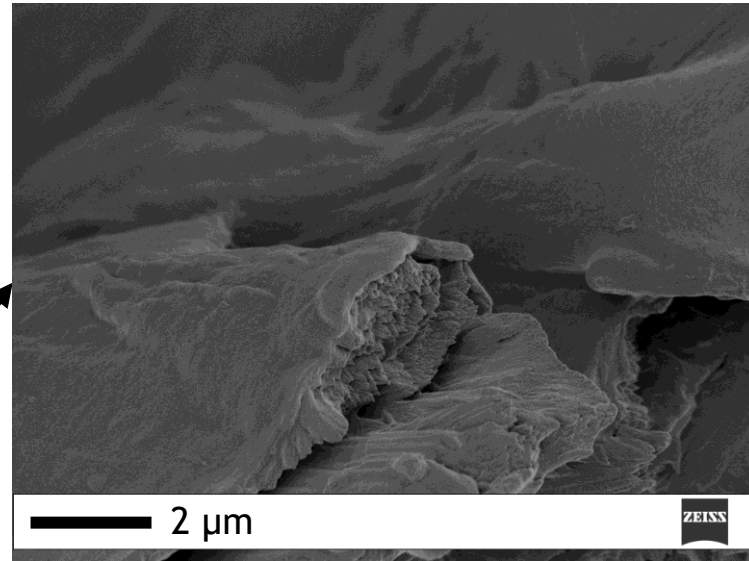
Paper Substrate



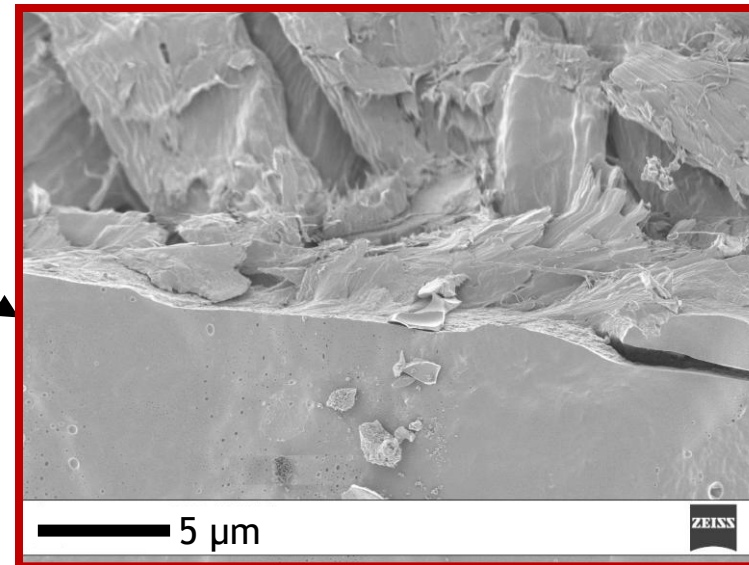
Conductive Polymer



Poly(ionic liquid)

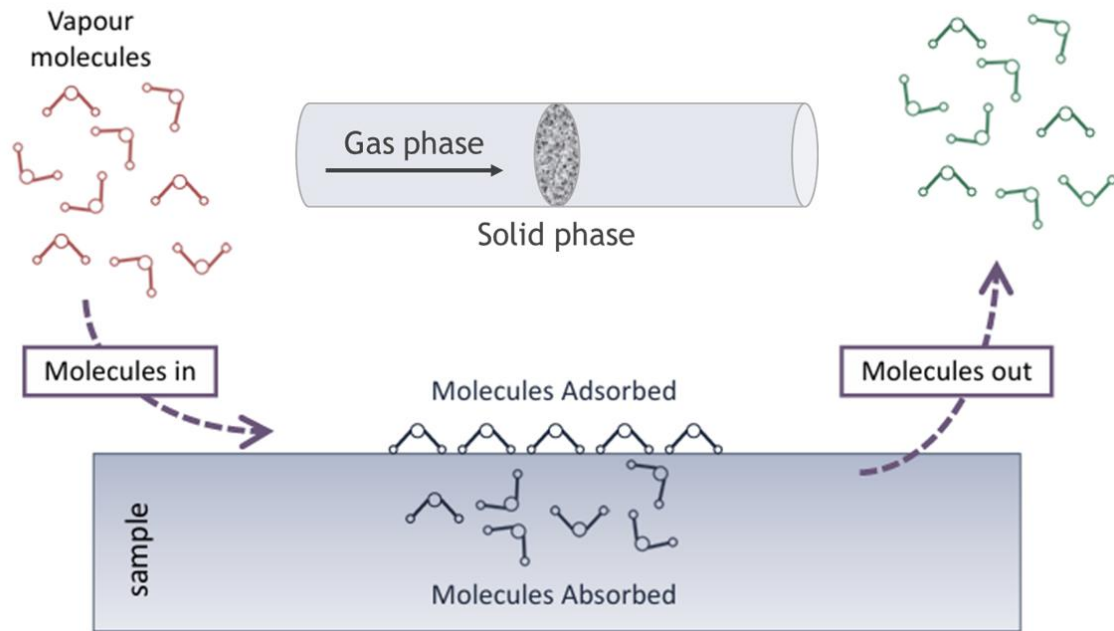


Cryo-fracture image of single fiber

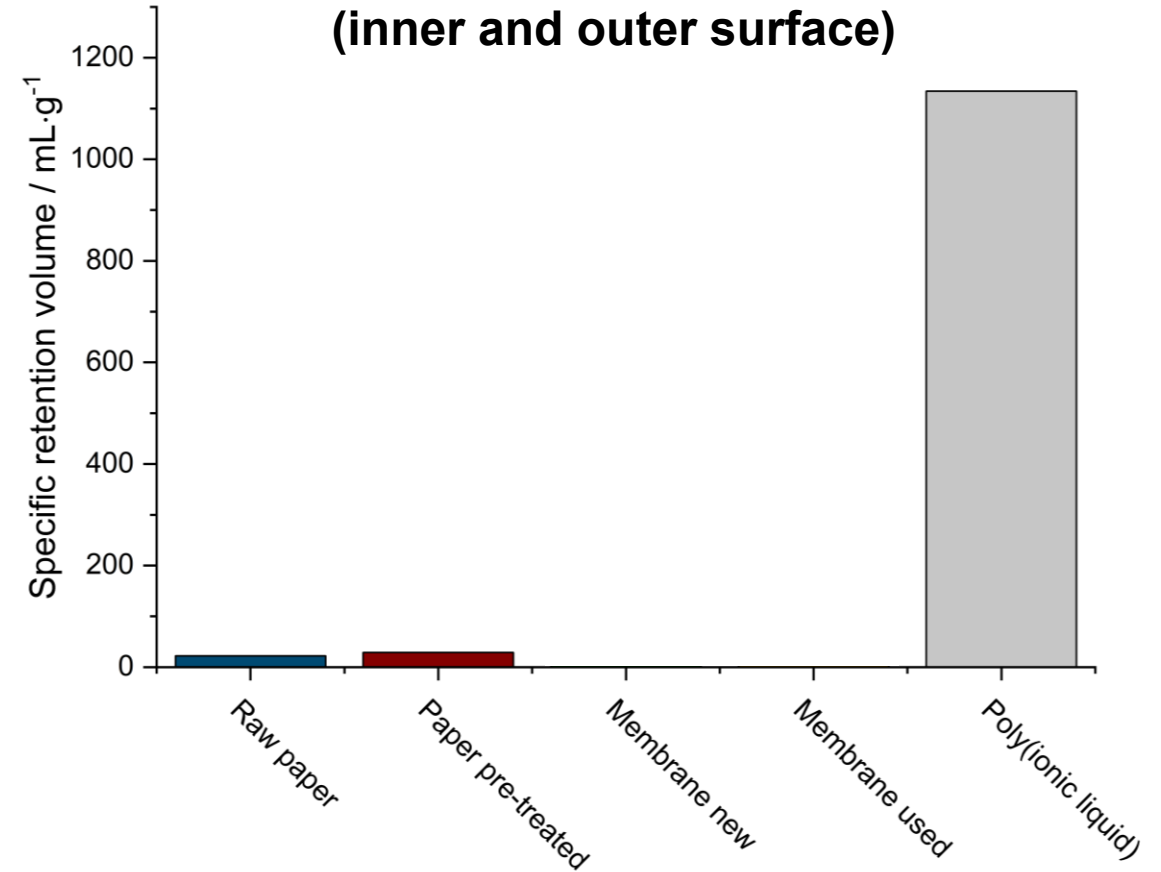


Cryo-fracture image of paper surface

Inverse Gas Chromatography (IGC) and SEM

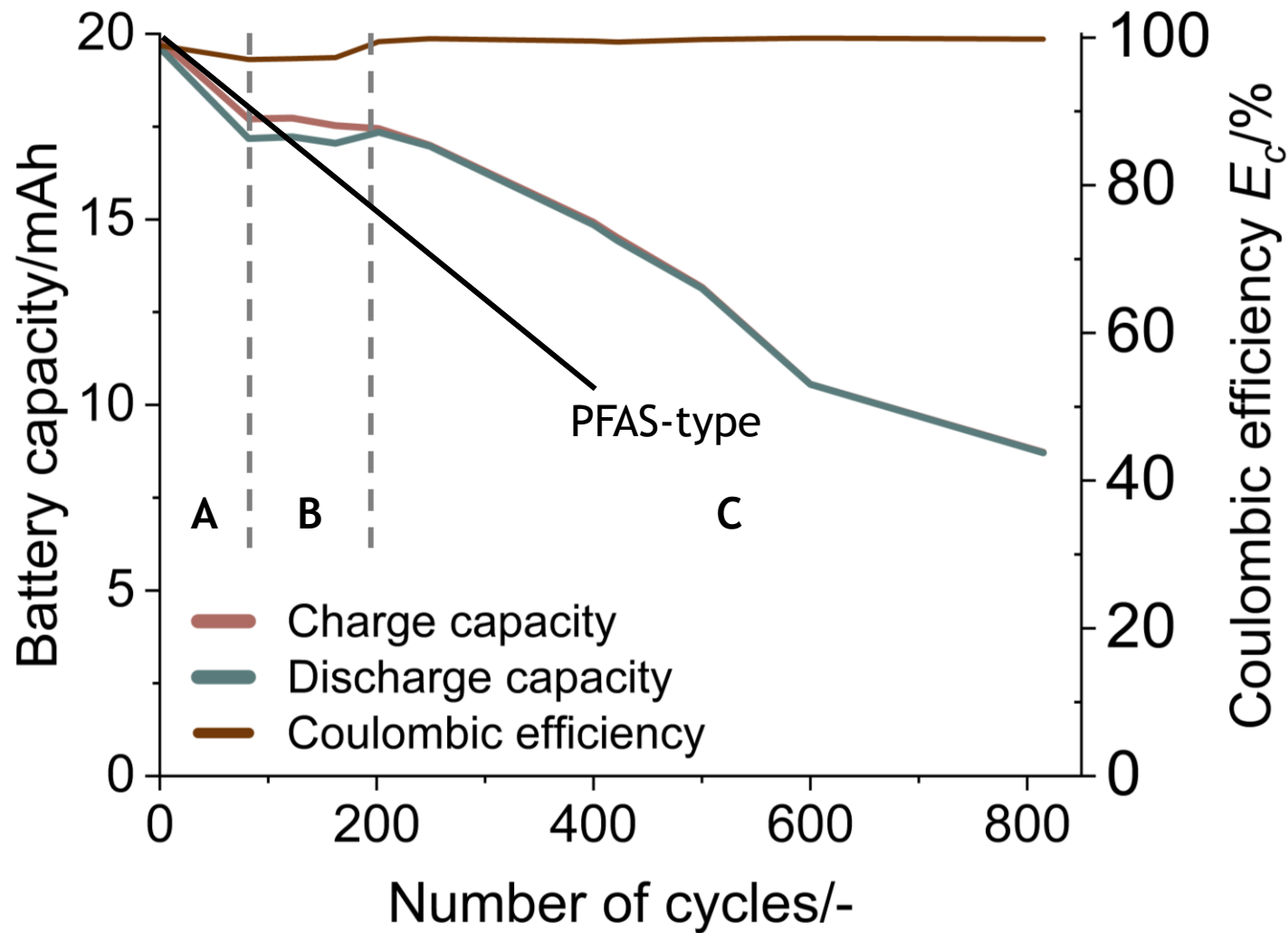


→ Fiber coverage of ~15%
(inner and outer surface)



Measured by acetonitrile adsorption

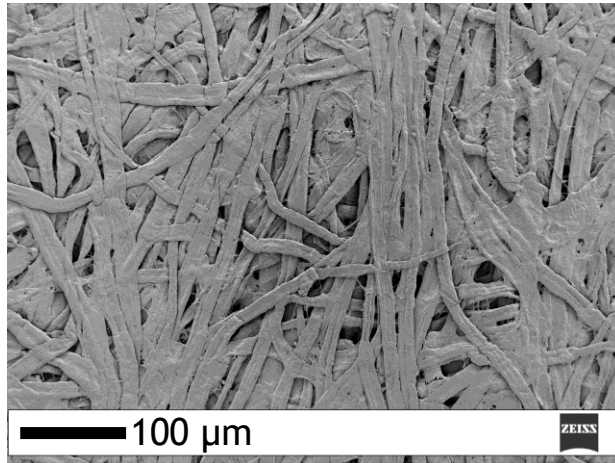
Battery Test



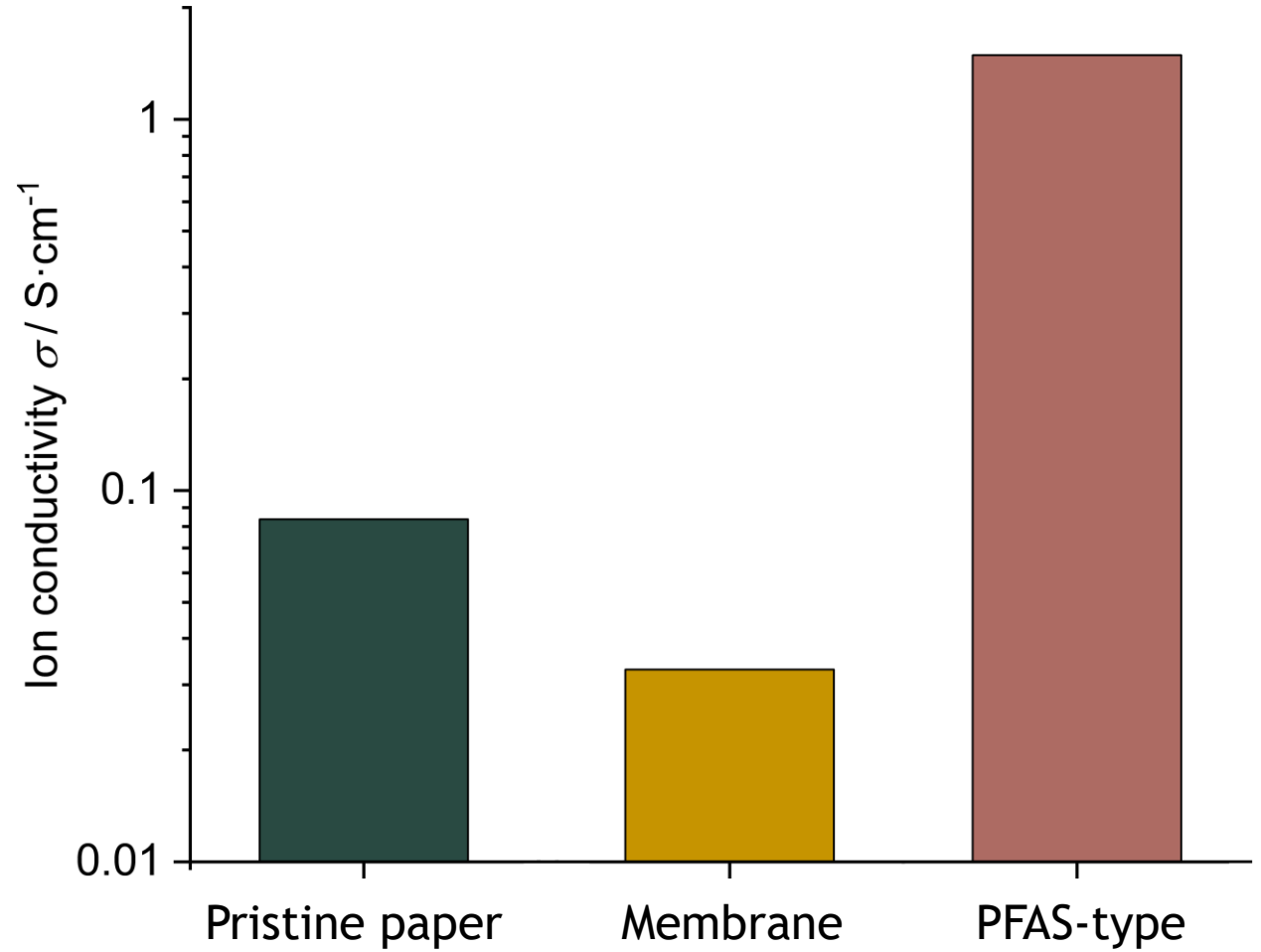
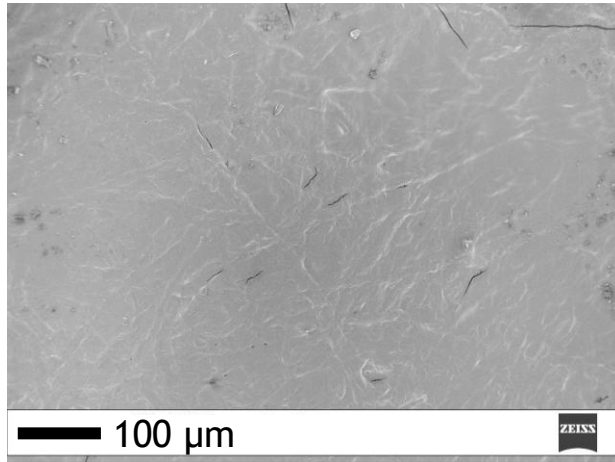
- **Phase A:** Run-in of the battery (swelling of fibers)
 - 0.16 % per cycle
- **Phase B:** Stable operation
 - 0.01 % per cycle
- **Phase C:** Capacity fading
 - 0.08 % per cycle

Electrochemical Impedance Spectroscopy (0.05 M Na₂SO₄)

Raw Paper



Membrane before use

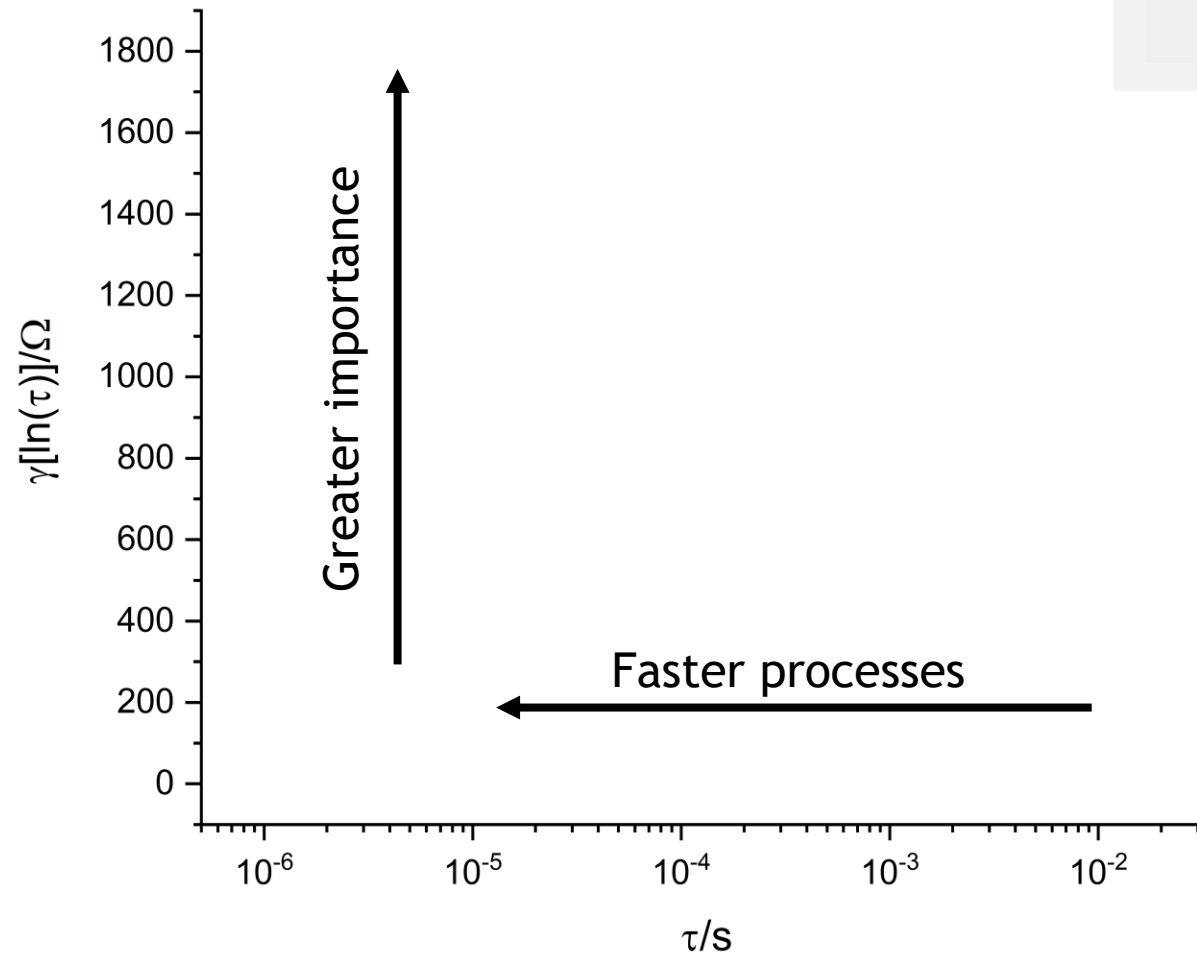


Distribution of Relaxation Time

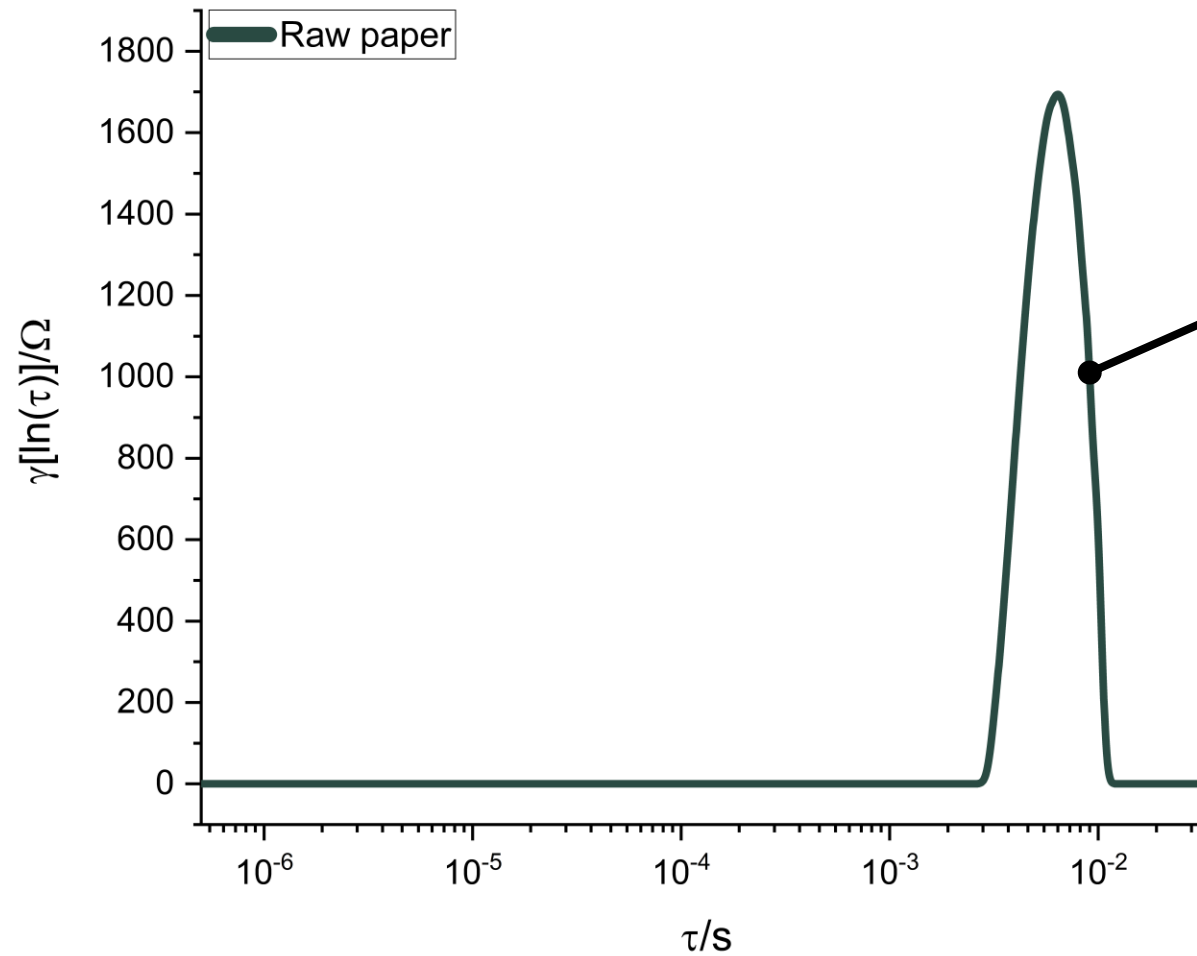


Distribution of Relaxation Time

$$R_{DRT}(f) = R_{\infty} + \int_0^{\infty} \frac{g(\tau)}{1 + i 2 \pi f \tau} d\tau$$



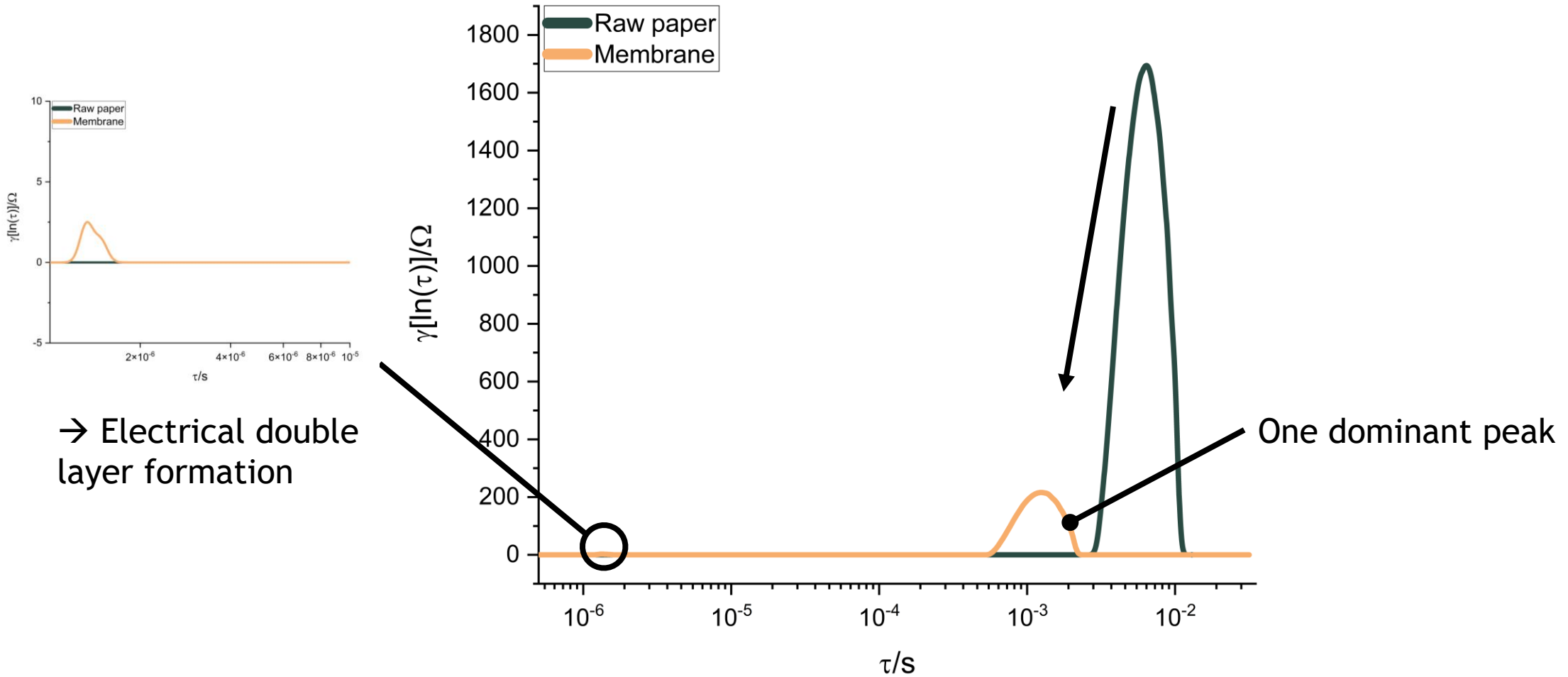
Distribution of Relaxation Time



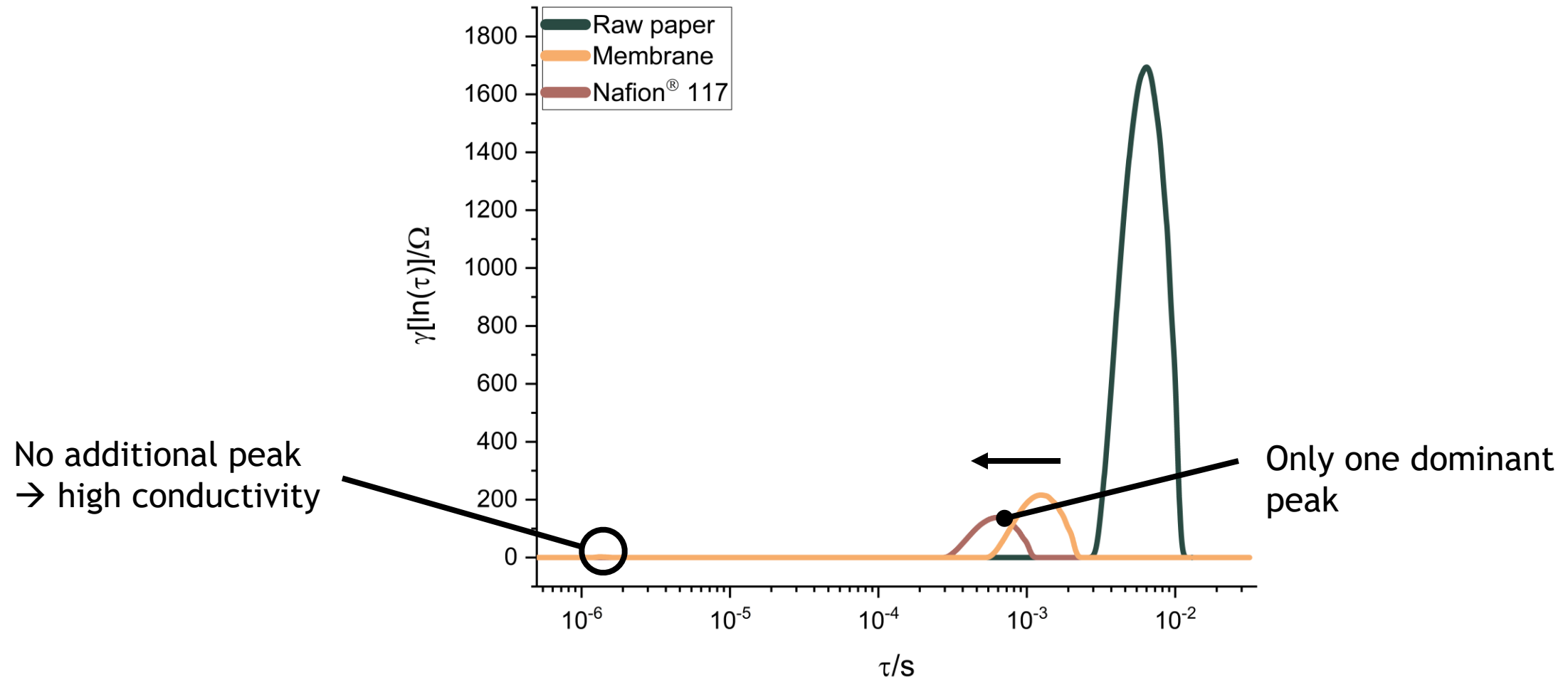
One single dominant peak
at slow time scales

→ Most likely diffusion

Distribution of Relaxation Time

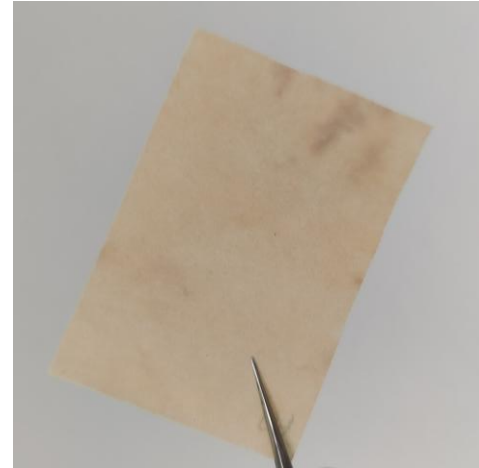


Distribution of Relaxation Time



Conclusion

- Modification of paper with poly(IL) is possible
- Stability of the membranes for >800 cycles
- Cross-diffusion below commercial products
- Conductivity one order of magnitude below PFAS-type



Thanks to colleagues and funding:

- FFG Austria (IonFlow, Grant No. 888427)
- European Union (EIC Vanillaflow Grant No: 101115293)
- Special thanks to Tim Tichter and Jose Diaz for the discussions on DRT and EIS



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THANK YOU!

Contact me:

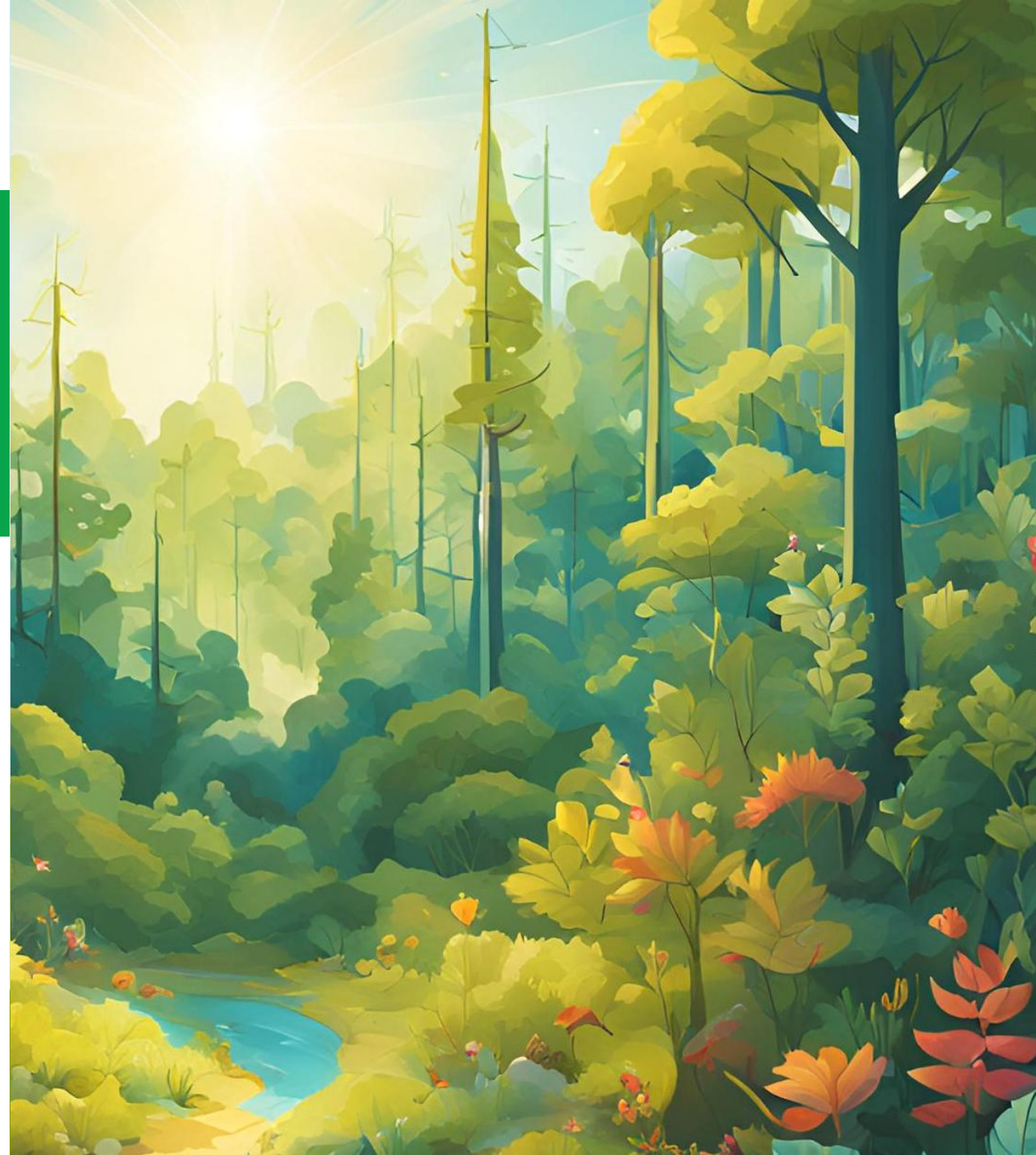
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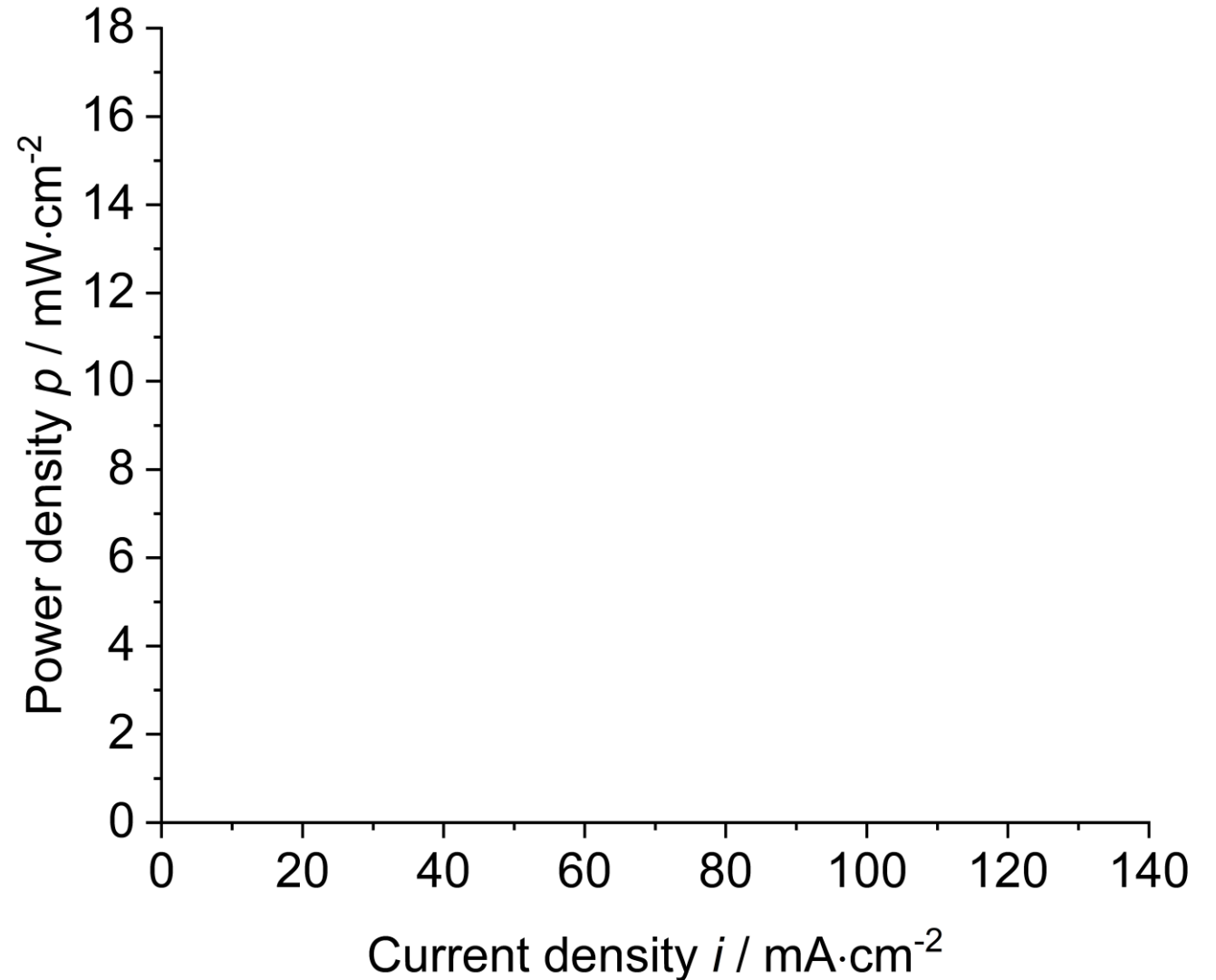
www.ecolyte.at



Polarization of the Battery

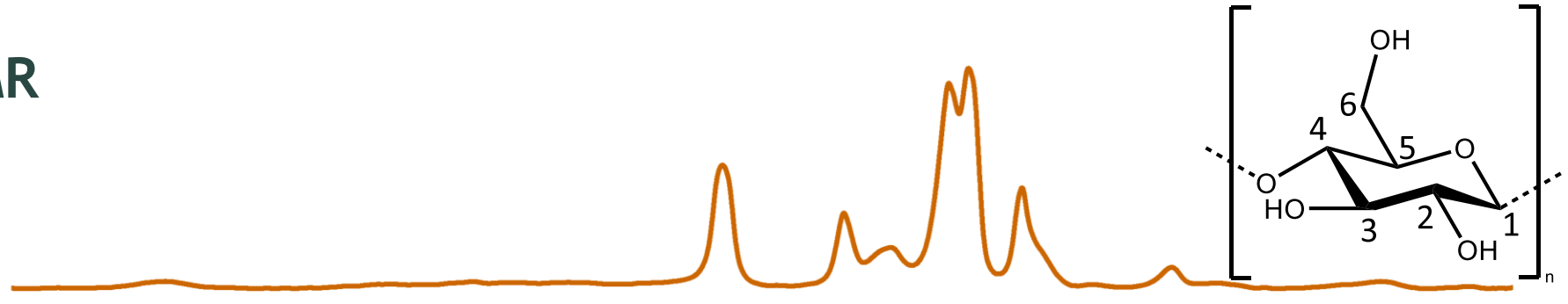
Power density drop through:

- Deposits on the carbon felt
- Degradation of the electrode
- Cross-diffusion of the active species
- ~~Degradation of the membrane~~

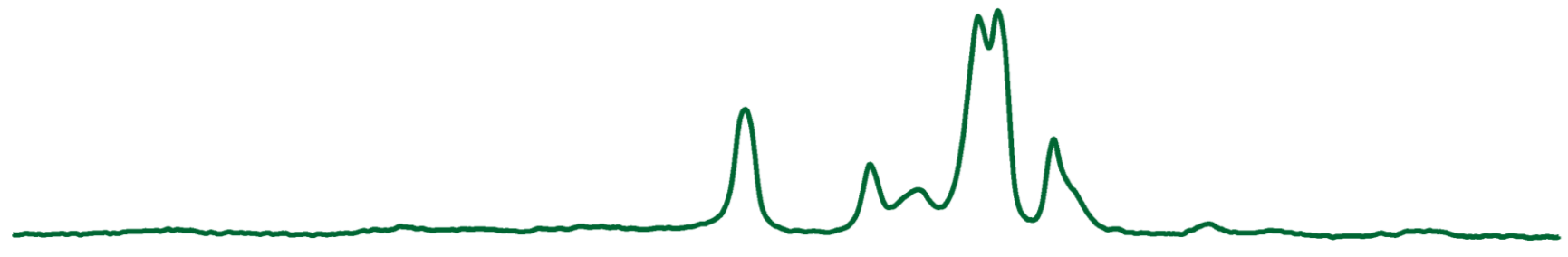


Solid state NMR

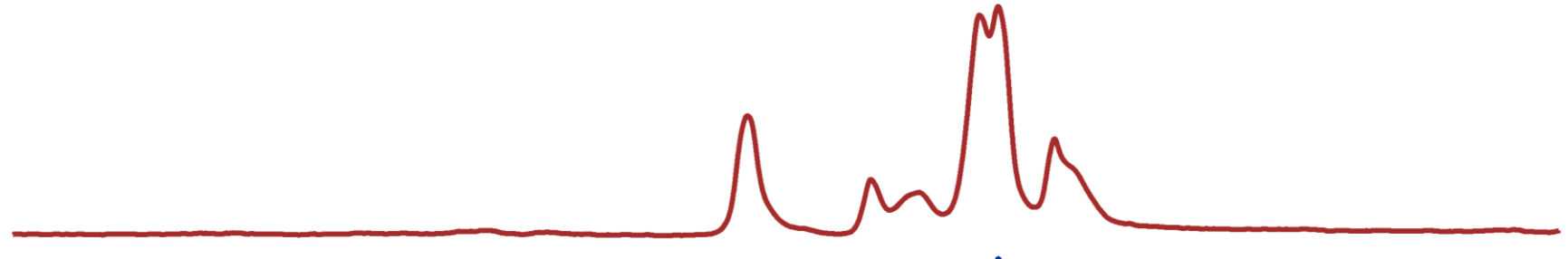
Membrane used



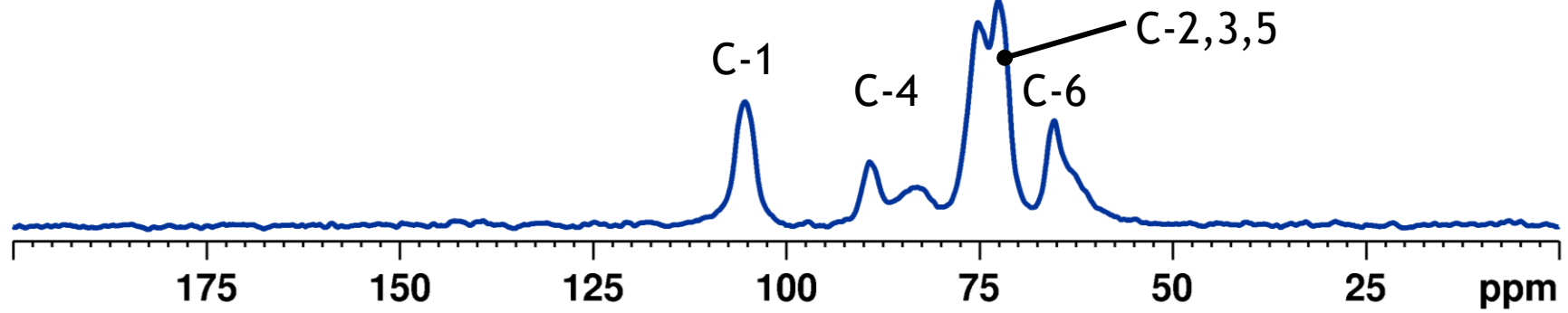
Membrane new



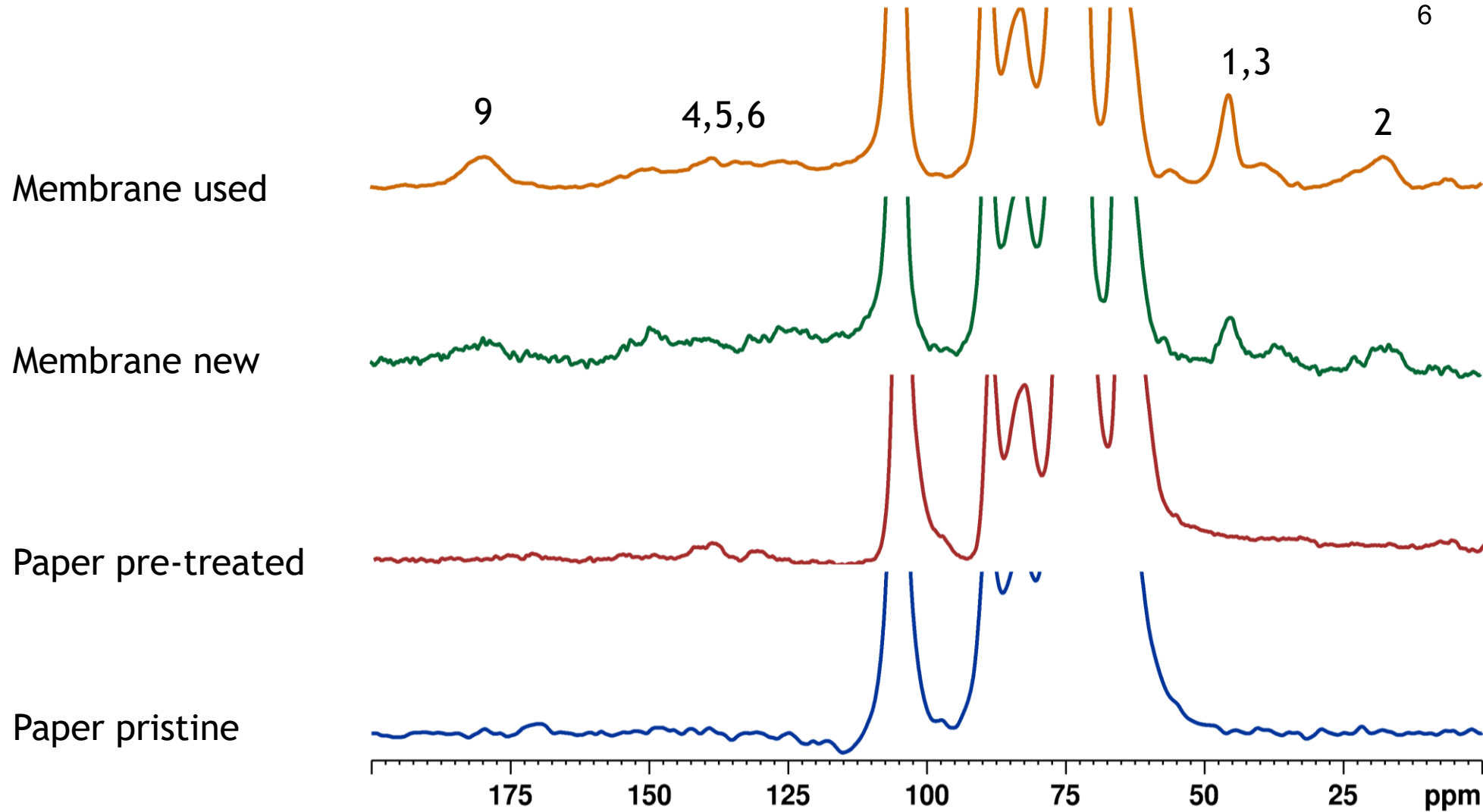
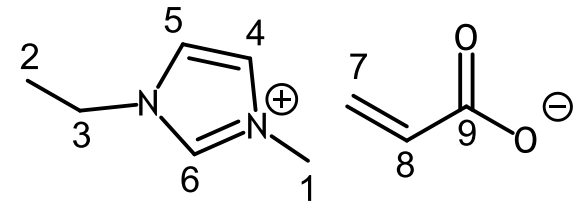
Paper pre-treated



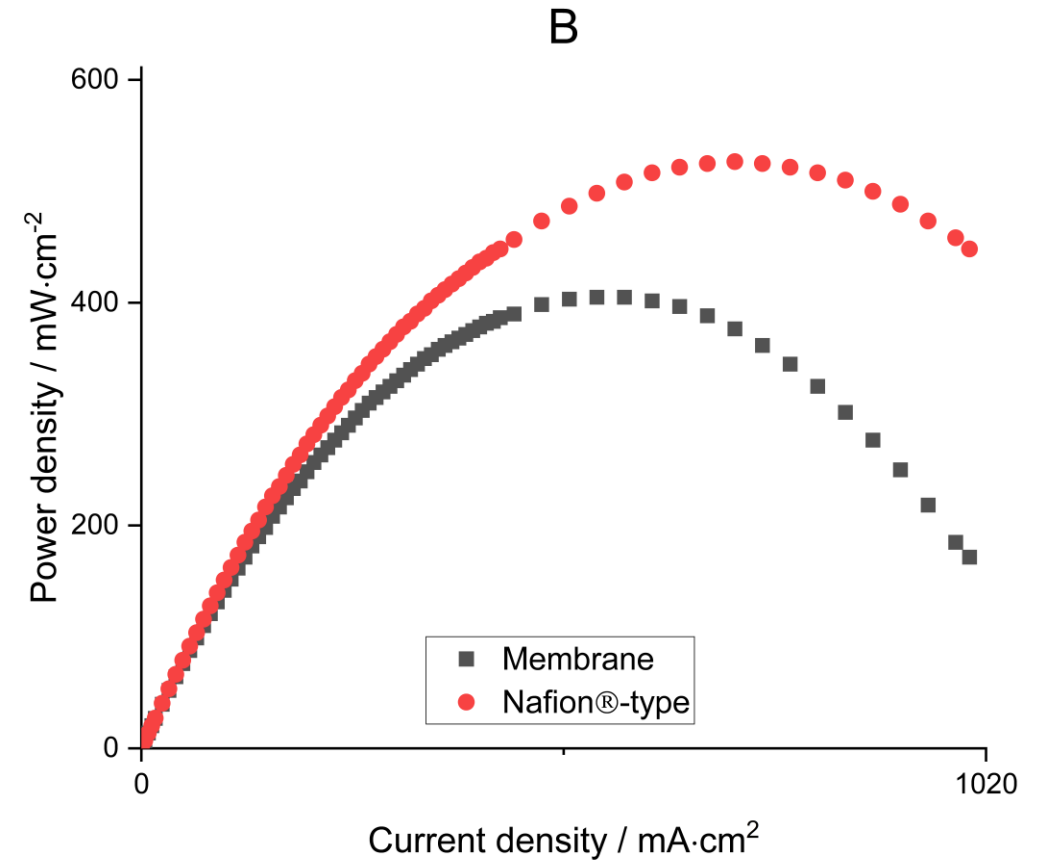
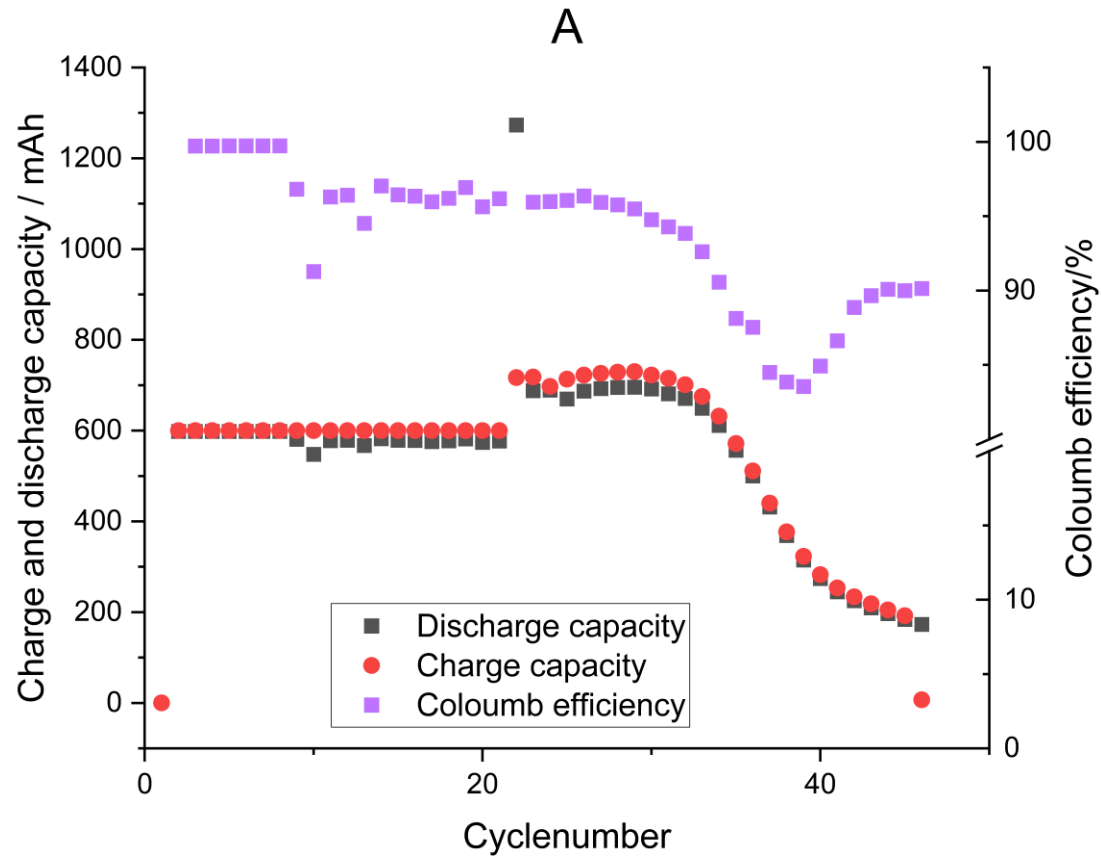
Paper pristine



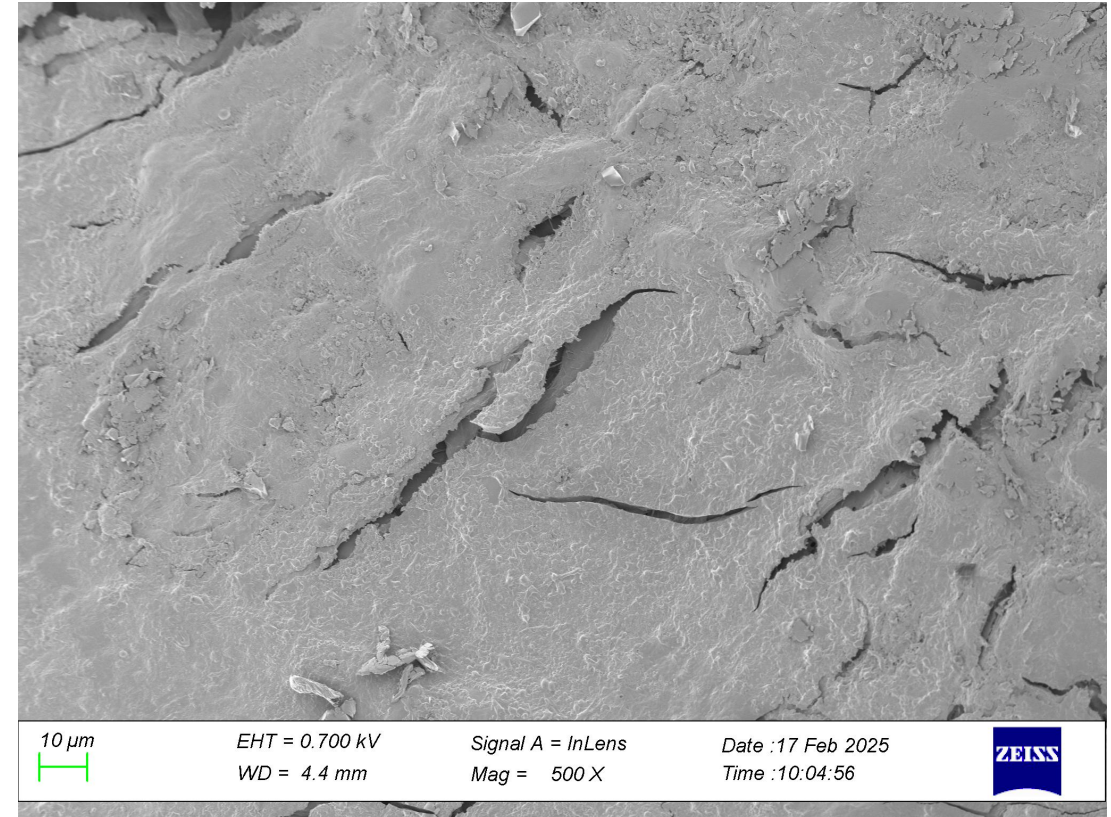
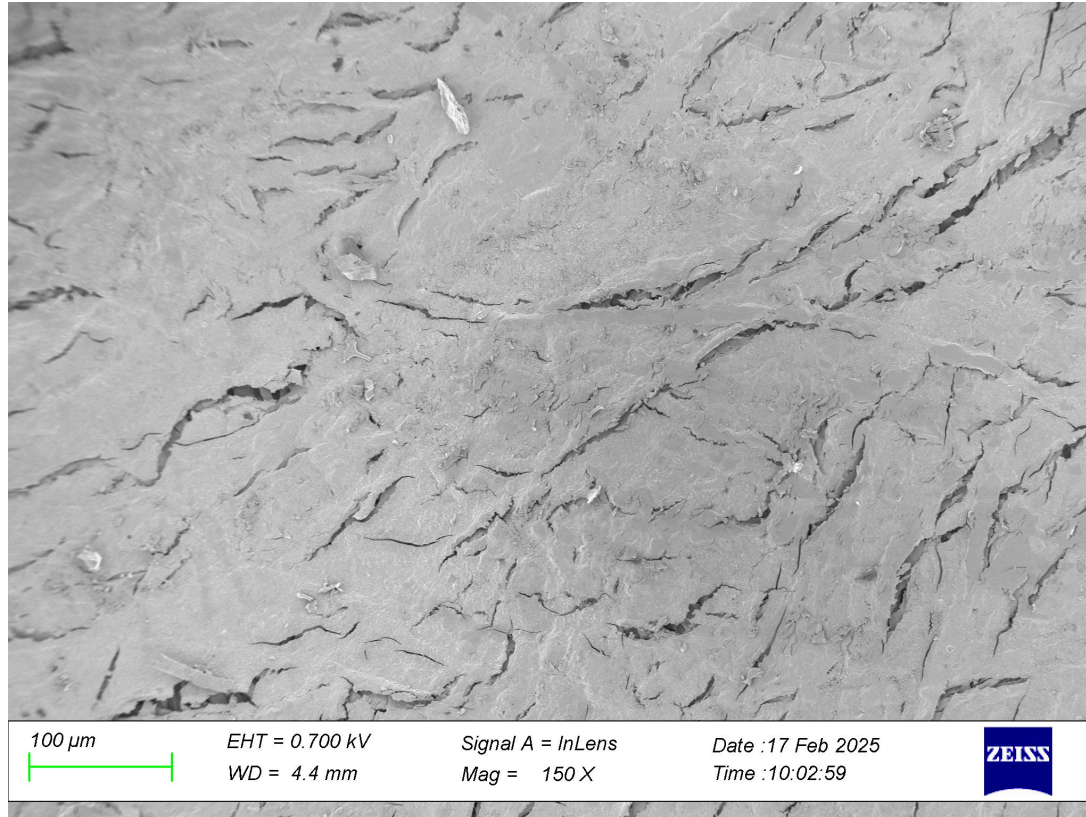
Solid state NMR



Vanadium RFB



Stability



Used Membrane after 800 cycles