



# Progress Toward Accurate Through-Plane Membrane Conductivity Measurement

## MOTIVATION

- There is a need for rapid, accurate measurement of the through-thickness resistance and conductivity ( $\sigma_{\perp}$ ) as a function of T and RH
- Traditional approach using catalyzed membrane (MEA) is time-consuming, costly and labor intensive

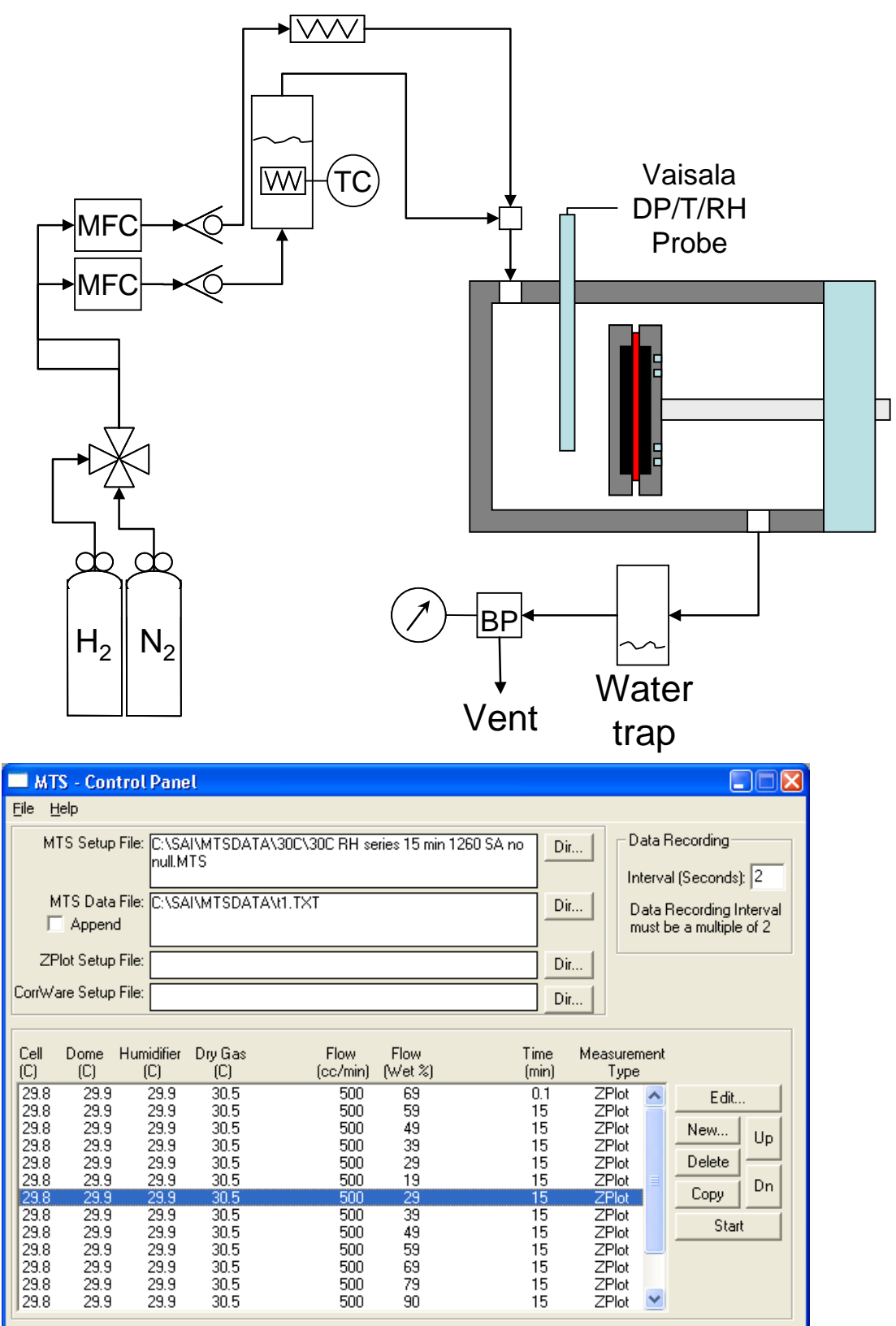
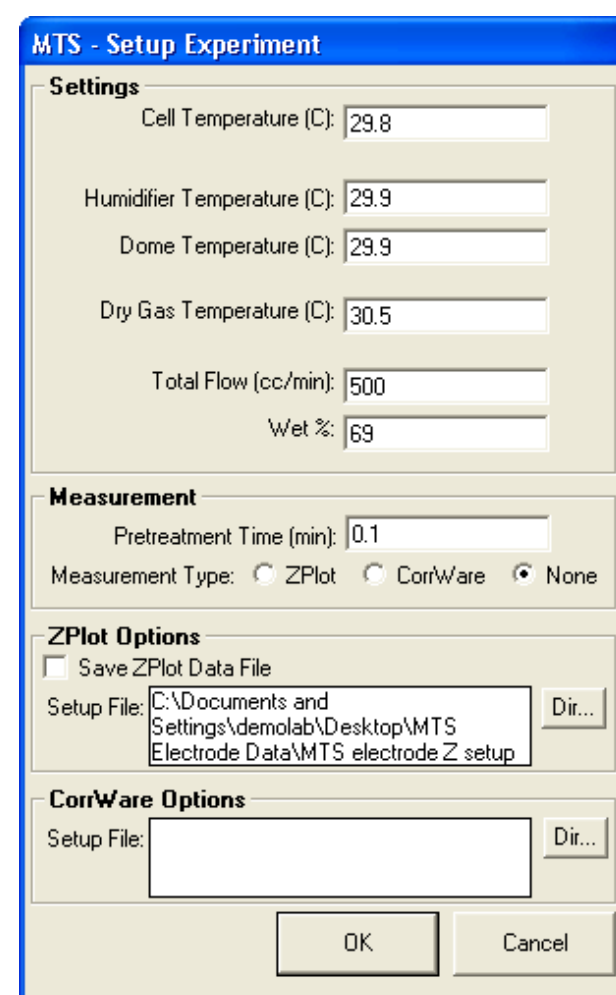
## OBJECTIVE *A versatile tool to support membrane R&D*

- Develop test system & protocol for *through-plane resistance and conductivity* measurement
  - Uses bare (non-catalyzed) membranes: 10 to 200  $\mu\text{m}$
  - Operates over a wide range of conditions:  $>120\text{ }^{\circ}\text{C}$ , dry to 100% RH, up to 3 atm
  - Rapid  $\sim 15$  min per test condition
  - Robust - accurate, repeatable and reliable

## RESULTS

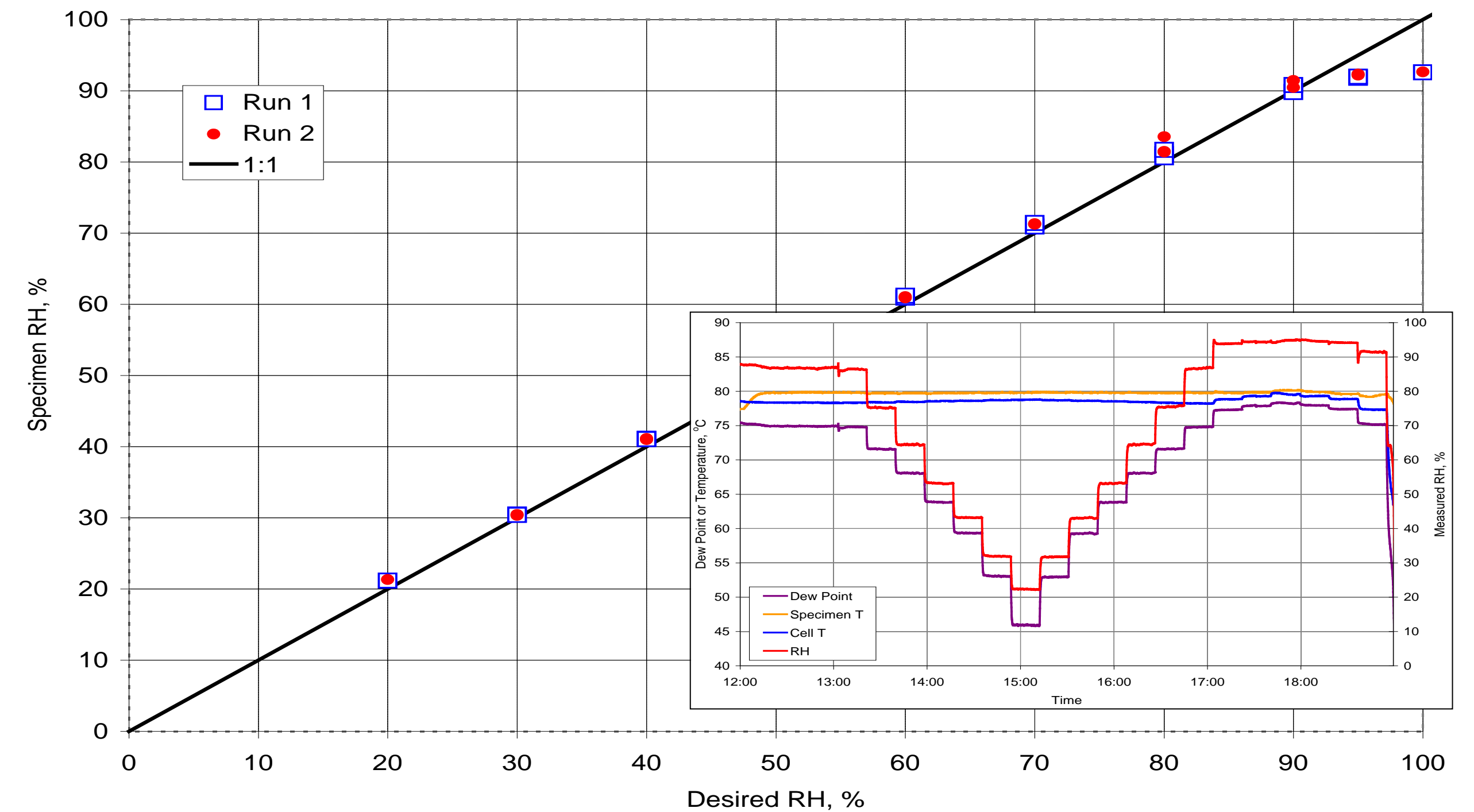
### Commercial Membrane Test System - MTS 740

Spring-loaded compression  
 → easy, accurate, repeatable  
 sample loading

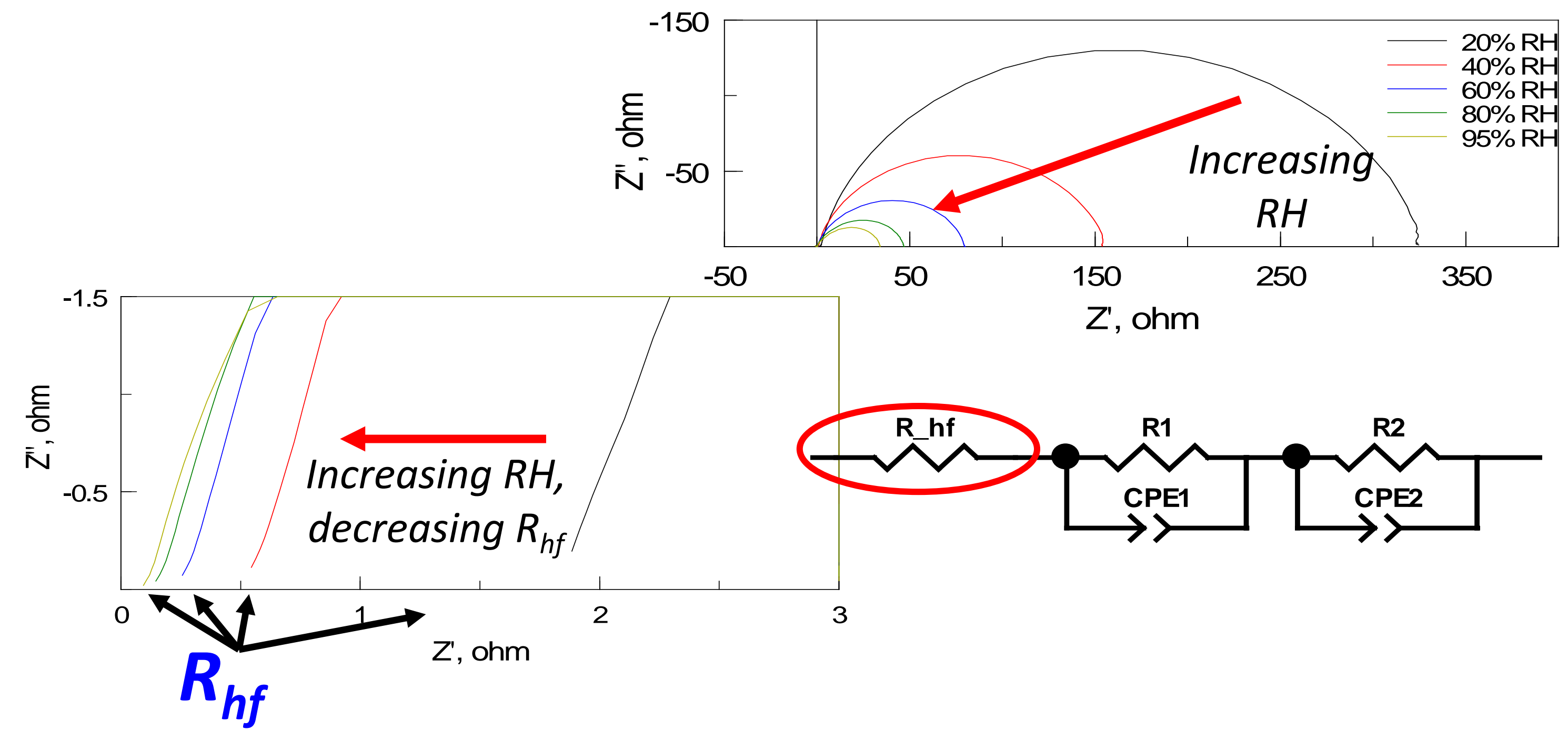


### Wet-dry gas mixing for controlled, rapid RH cycling

- Repeatable, reproducible and stable T/RH control  $\rightarrow \pm 2\%$  from 20% to 95% RH
- Rapid RH cycling for time-efficient testing over wide RH range



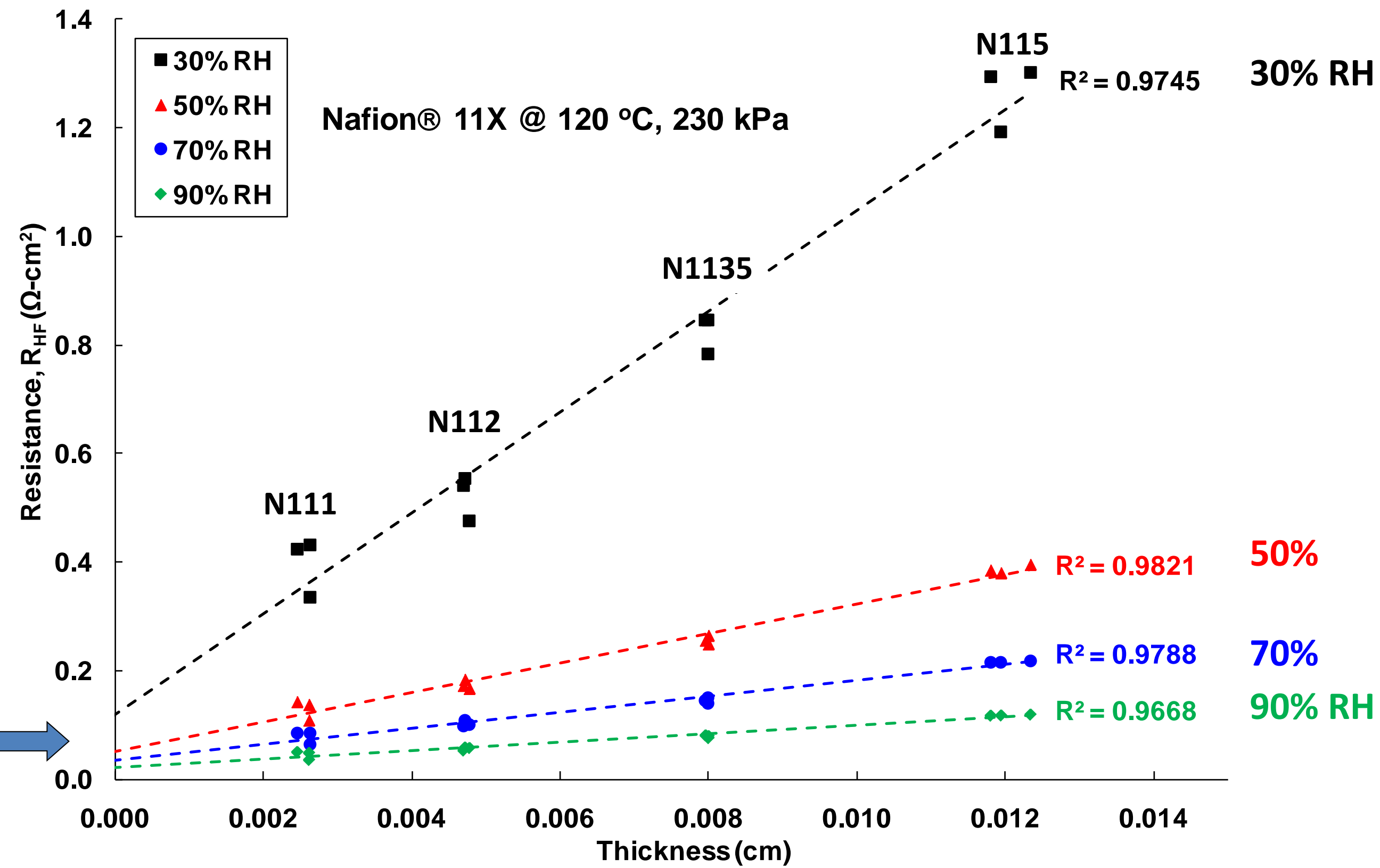
### Equivalent circuit modeling of EIS spectra for high frequency intercept, $R_{hf}$



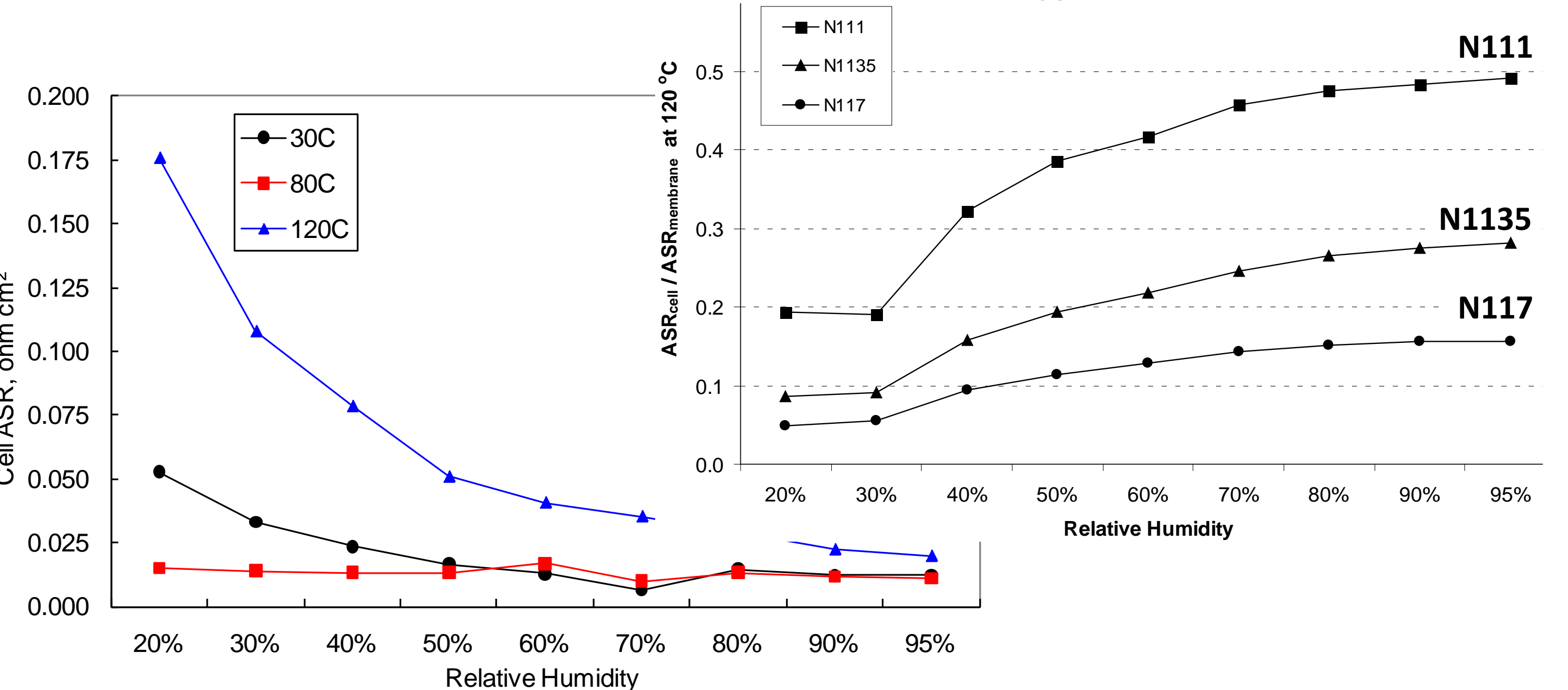


## Correcting $R_{hf}$ for cell resistance, $R_{cell}$

- $R_{hf} = R_{membrane} + R_{cell}$
- All are function of T & RH
- $R_{cell} = R_{interface} + R_{e-} + R_{contact}$
- Assumption:  $\sigma_{\perp} \neq f$  (thickness)

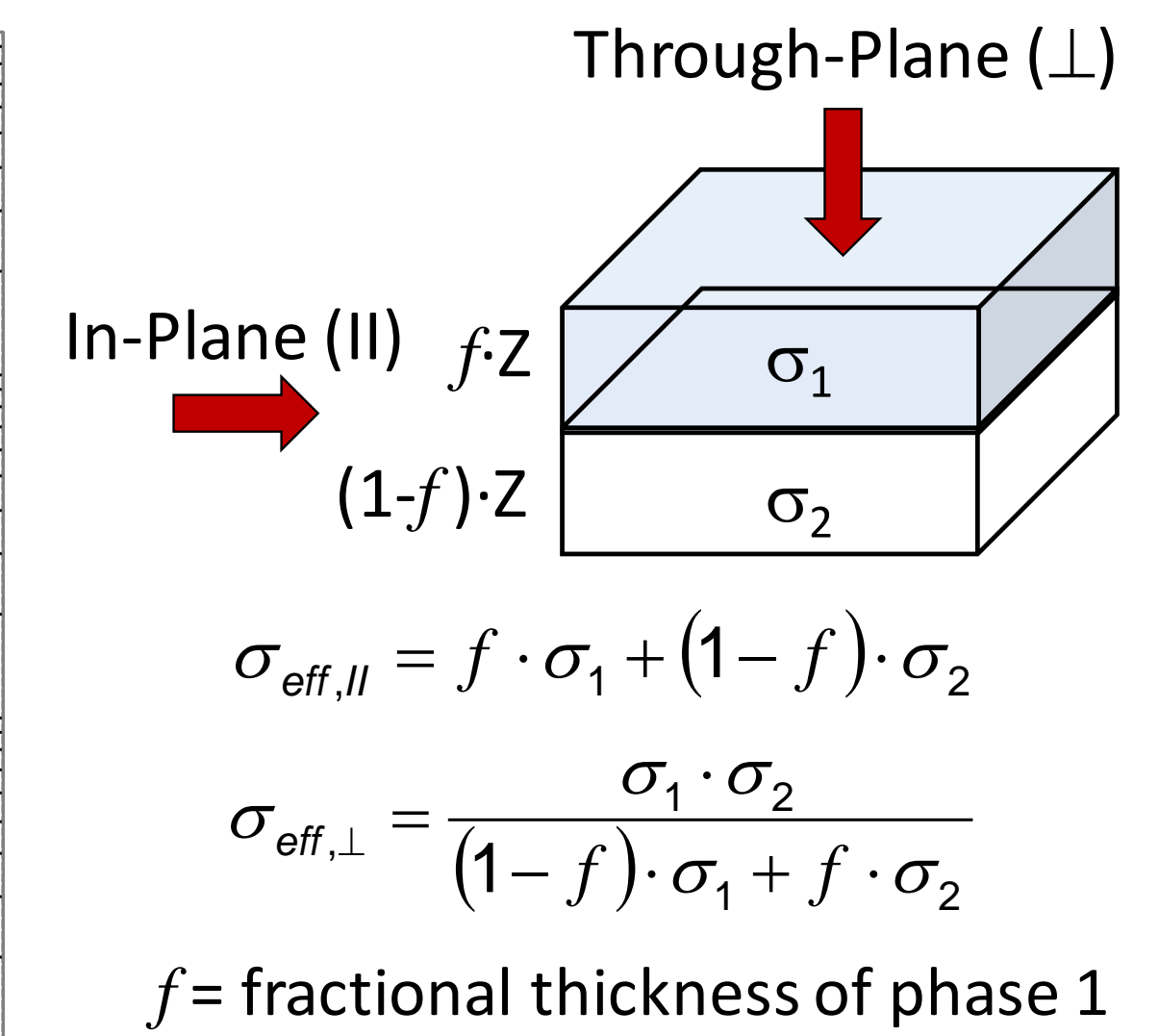
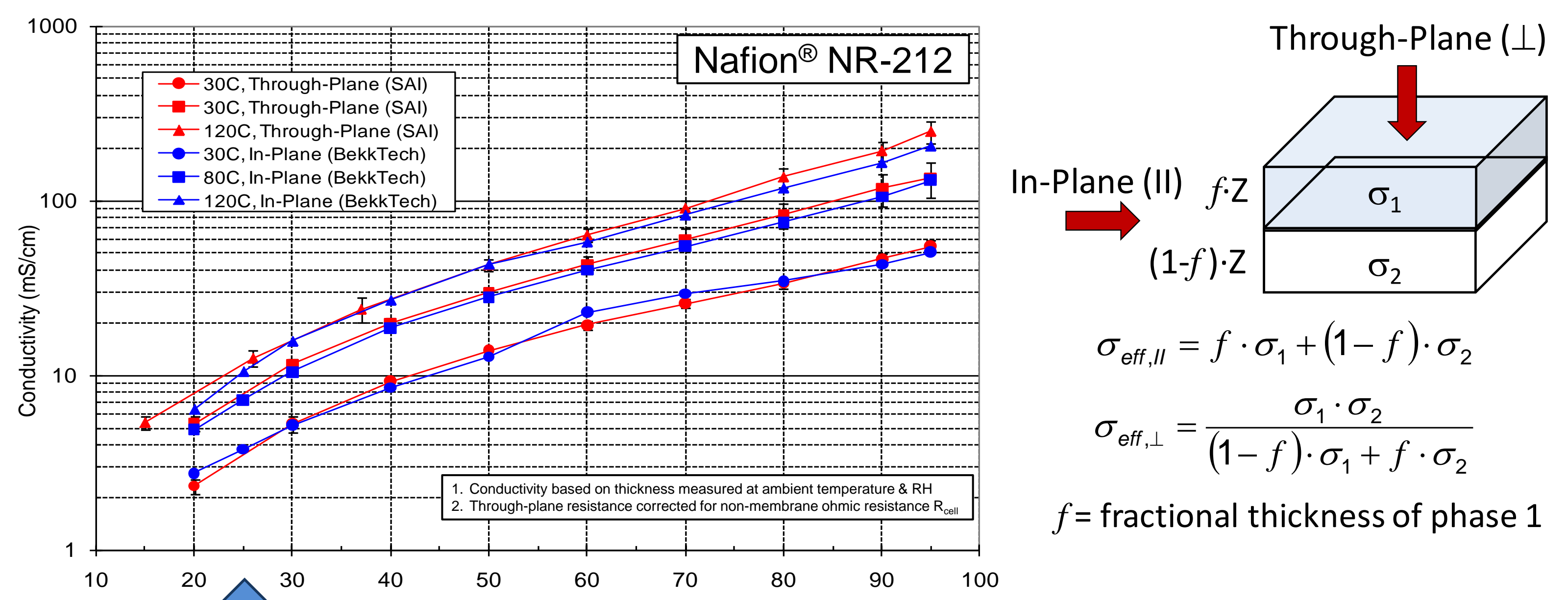


- Similar  $R_{cell}$  determined for 2 different PFSA-based membranes
- Thin membrane at high RH  $\rightarrow R_{cell} \sim 50\%$  of  $R_{membrane}$
- Accurate results require accounting for  $R_{cell}$

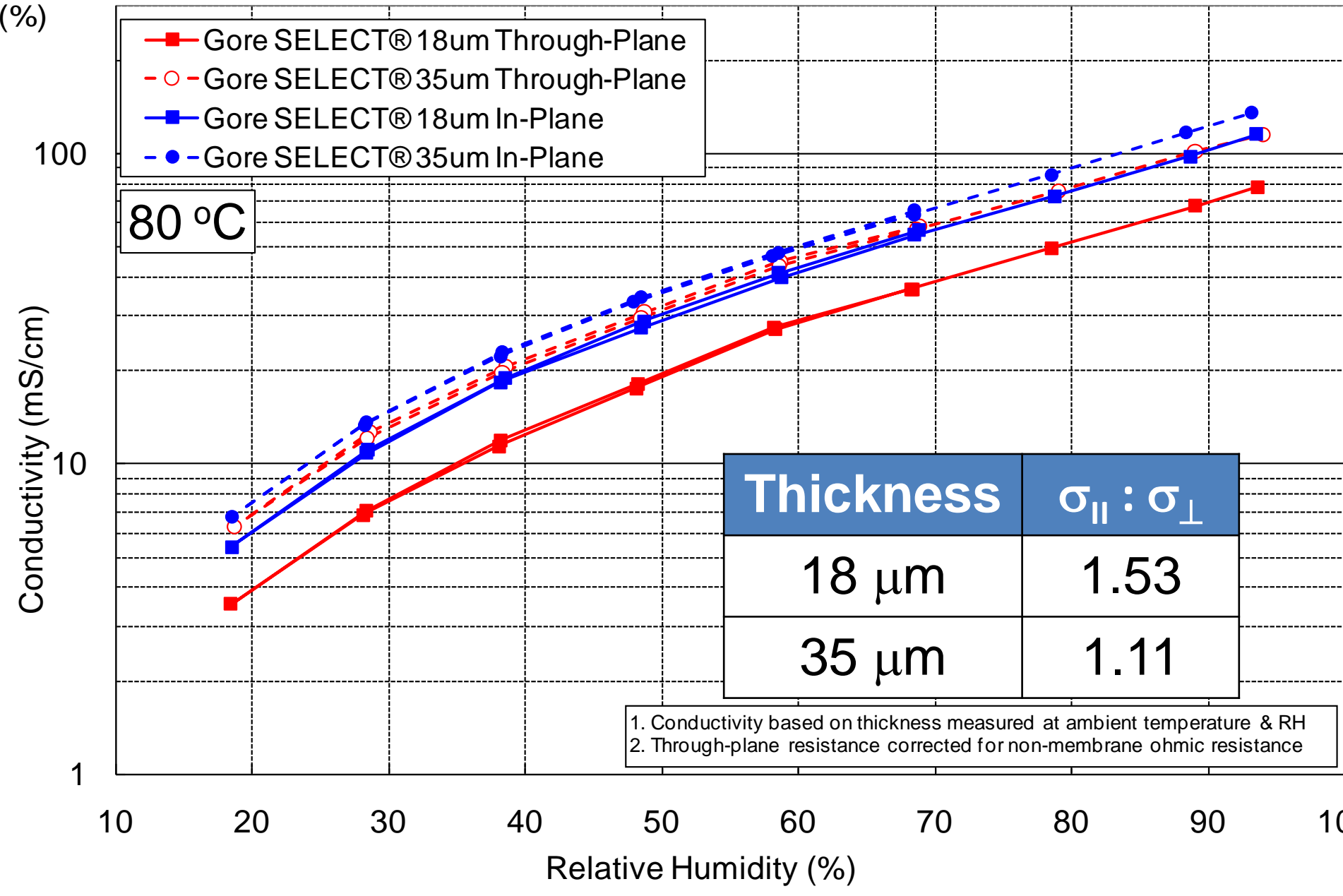


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## Comparing Through-Plane ( $\sigma_{\perp}$ ) & In-Plane ( $\sigma_{\parallel}$ ) Conductivity of Nafion® NR-212 & GORE-SELECT® Supported Membrane



- Dispersion cast NR-212
  - ✓  $\sigma_{\parallel} \cong \sigma_{\perp}$
- GORE-SELECT® membrane
  - ✓ ePTFE support
  - ✓  $\sigma_{\parallel} > \sigma_{\perp}$
  - ✓  $\sigma_{\parallel} : \sigma_{\perp} \rightarrow 1$  as  $f \rightarrow 0$  or  $1$
  - ✓ Ratio is greater for thin membrane (same support thickness)



### CONCLUSIONS

- **Through-plane resistance & conductivity test system developed**
  - Bare membrane – rapid, lower cost vs. MEA/FC testing
  - Repeatable, accurate control of environmental conditions: cell to 150 °C, humidifier to 120 °C, dry to 100% RH, 3 atm
- **Nafion® NR-212 though-plane and in-plane conductivity are equal**
- **Differentiate in-plane and through-plane conductivity for anisotropic material, e.g., GORE-SELECT® membrane with ePTFE support**