Roll-to-Roll Direct Coating of Catalyst Inks on Membrane Films: Progress and Challenges

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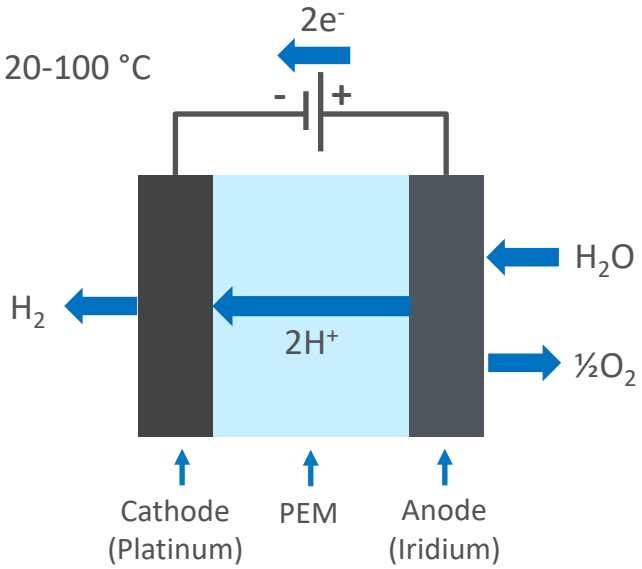
Polymer Electrolyte Membrane (PEM) Electrolyzer

Low temperature electrolysis

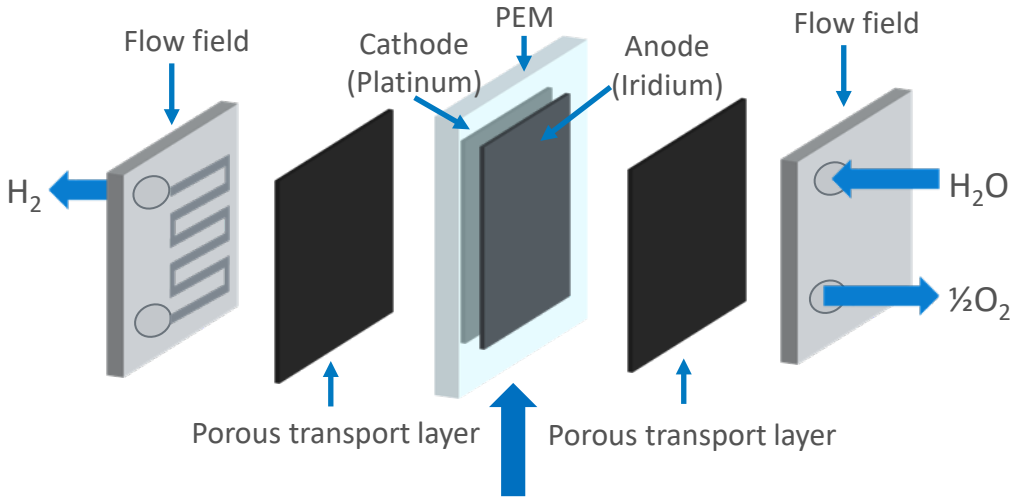


Anode: $H_2O \rightarrow 2H^+ + ½O_2 + 2e^-$

Cathode: $2H^+ + 2e^- \rightarrow H_2$

Overall reaction: $H_2O \rightarrow H_2 + ½O_2$

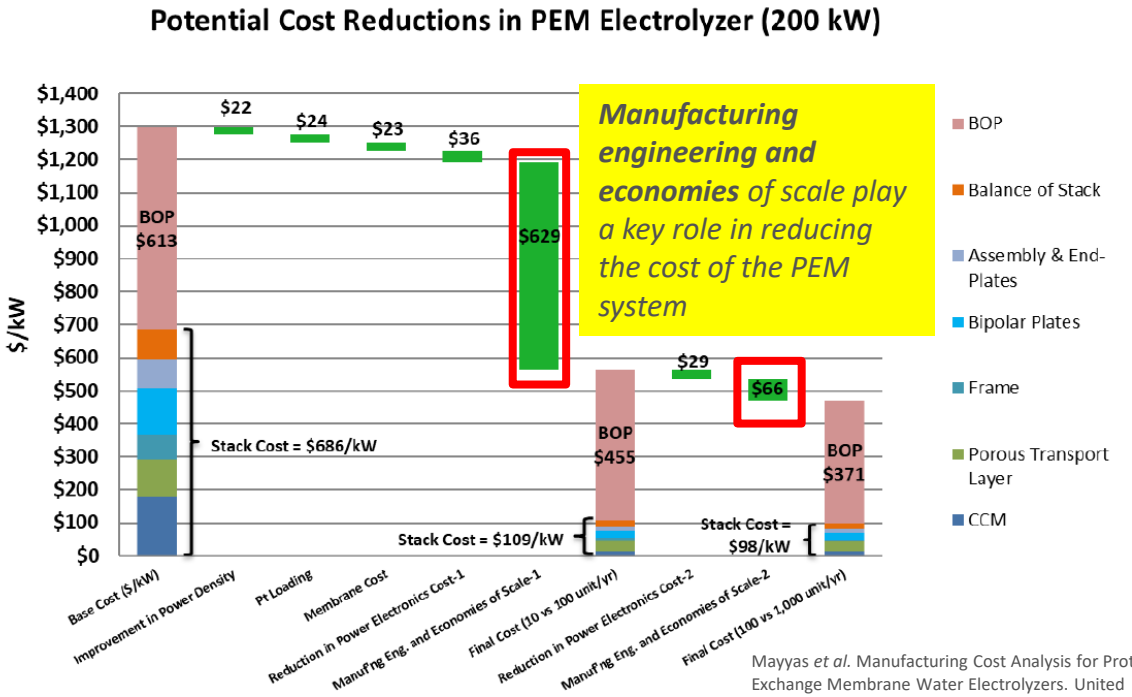
Membrane electrode assembly (MEA)



- Catalyst-coated membranes (CCM) are a key component of water electrolyzers

CCM Production: Decal Transfer Vs. Direct Coating

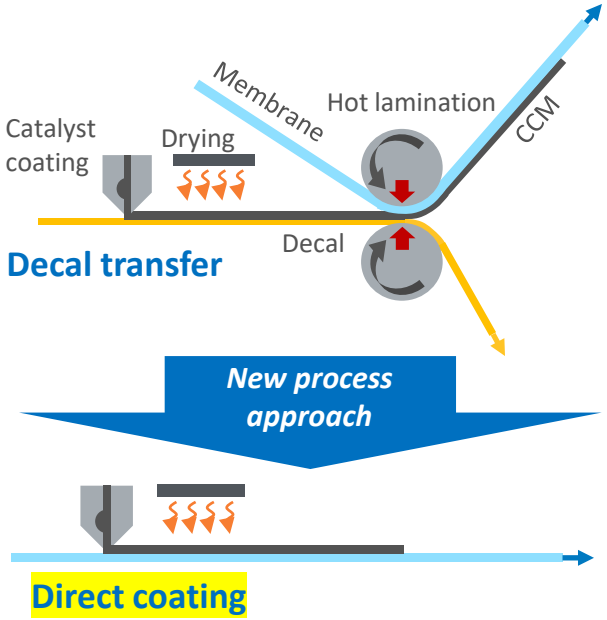
US Department of Energy target of hydrogen production cost of <$2/kg



***Manufacturing engineering and economies** of scale play a key role in reducing the cost of the PEM system*

Mayyas *et al.* Manufacturing Cost Analysis for Proton Exchange Membrane Water Electrolyzers. United States. doi:10.2172/1557965.

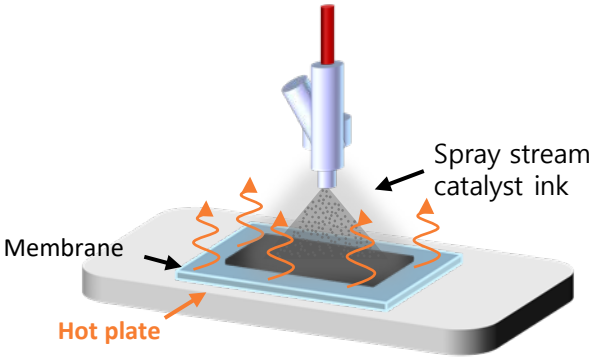
Simplified Manufacturing Process



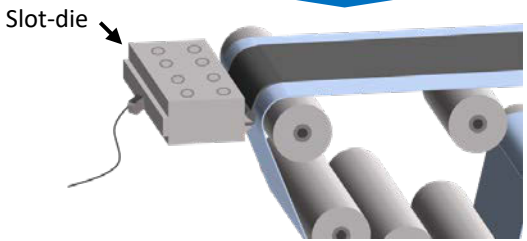
- **Reduction** in (1) process (2) materials costs

Membrane Swelling Issue

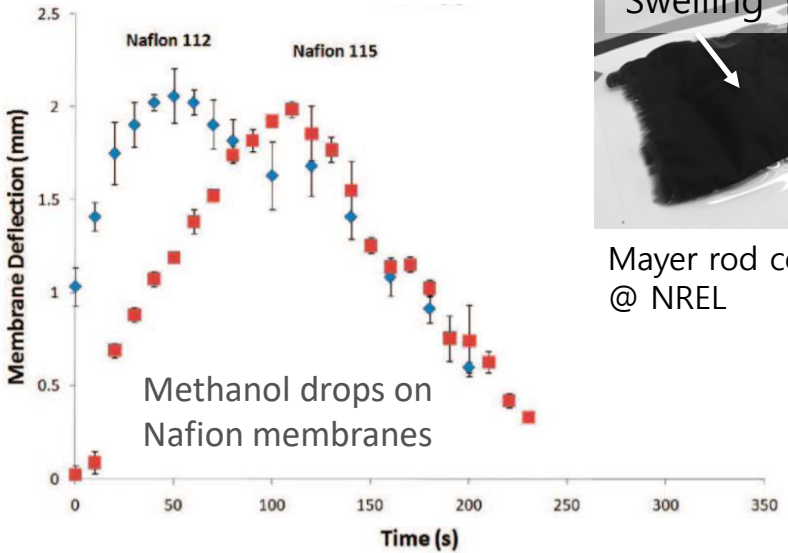
Amount of solvents applied



Solvent-membrane Interaction time gets longer



Membrane deflection



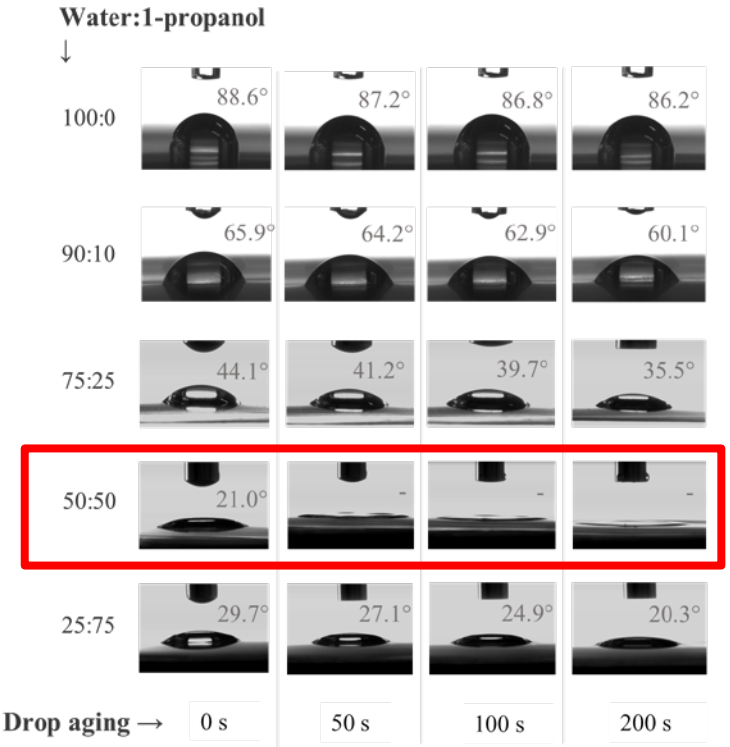
Goswami *et al. Langmuir* 24.16 (2008)

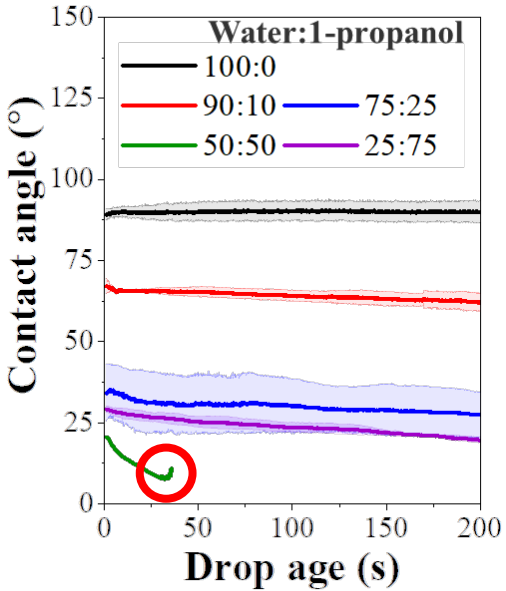
Mayer rod coated CCM @ NREL

- **The catalyst ink design** ➔ minimize swelling and absorption into the membrane

Wetting and Absorption Behaviors of Nafion Membrane

Water/1-propanol mixtures on Nafion 212





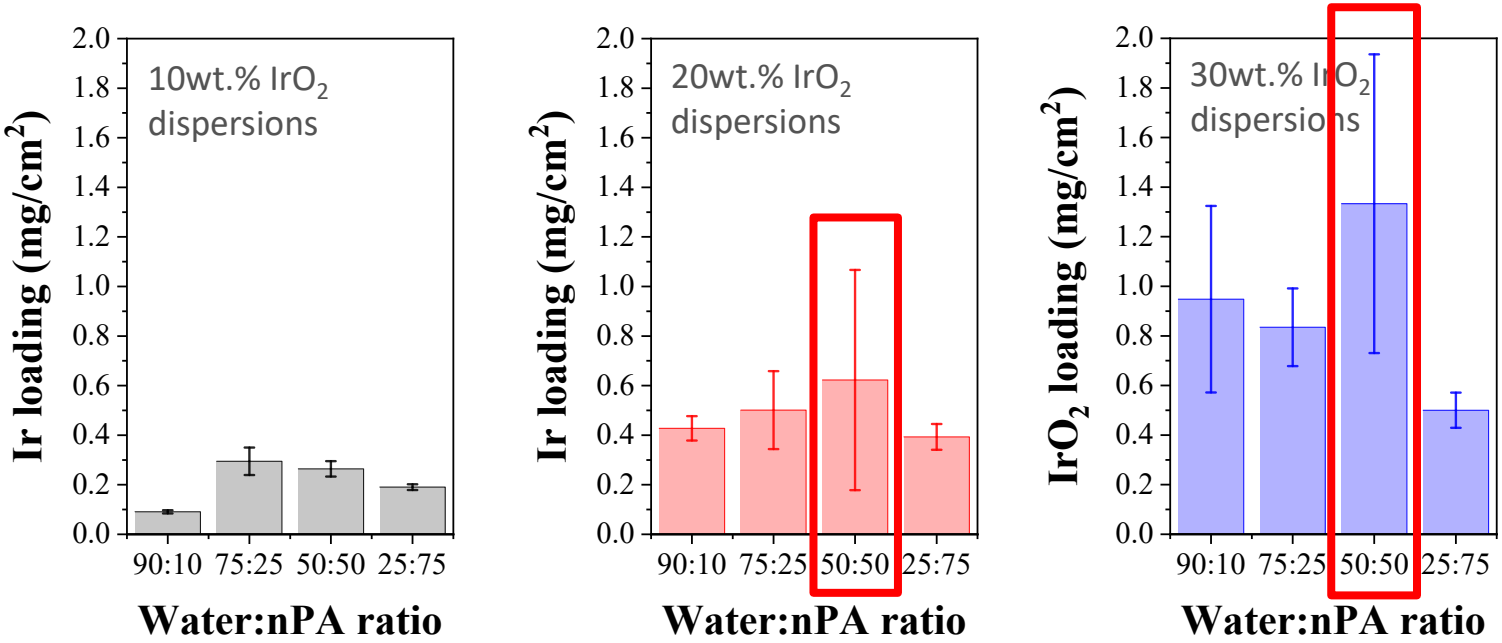
50:50 mixture

➔ Fast penetration into the membrane

➔ High interactions hydrophobic and hydrophilic domains of the membrane and the water/propanol molecules of the mixture

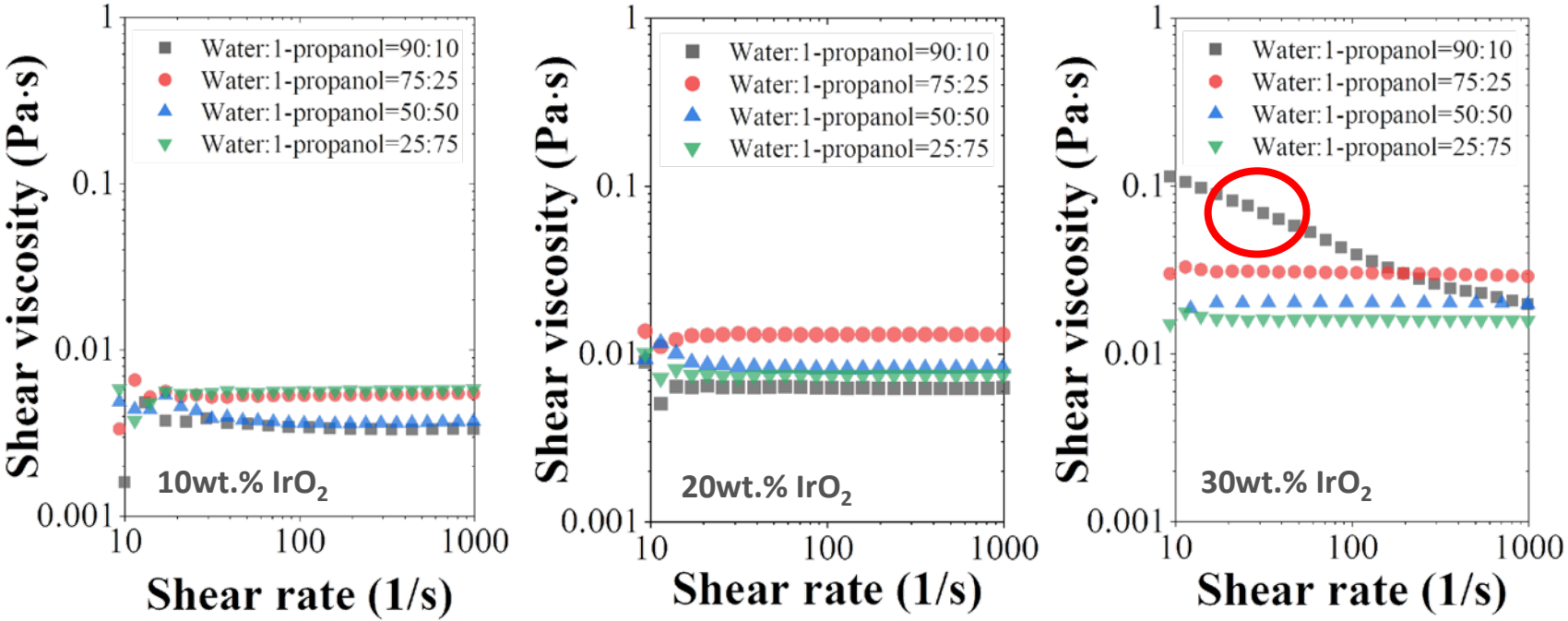
Lab Scale Coating using Mayer Rod Technique

Measured Ir loading by X-ray fluorescence



- **50:50 mixture: high variance in Ir loading**
  - ➔ due to rapid permeation of the mixture into the membrane

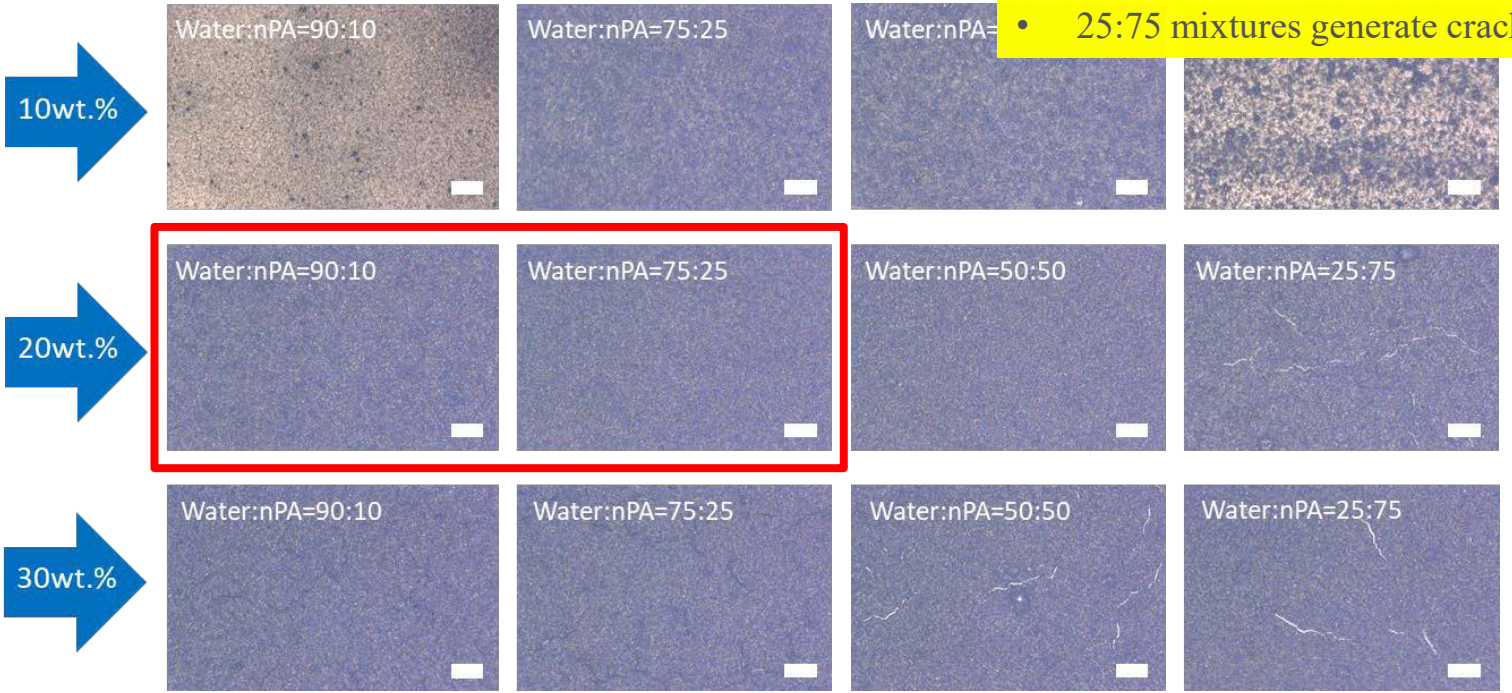
Steady-Shear Viscosity Data for Different Solvent Ratios and Dispersions



- **30wt.% IrO_2 & 90:10 water:nPA mixture** ➔ leads to a destabilization of the dispersion that results in the agglomeration

Microscopic Images Catalyst

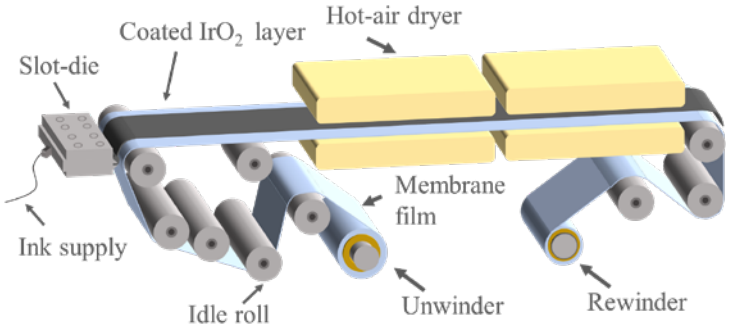
- 10wt% ➔ heterogeneous structure
- 30wt.% & 90:10 mixture ➔ bad rheology
- More solids are better (less solvent)
- 50:50 mixture should be avoided
- 25:75 mixtures generate cracks



- Two inks of 20wt.% dispersions were down selected: **90:10 and 75:25 water/1-propanol**

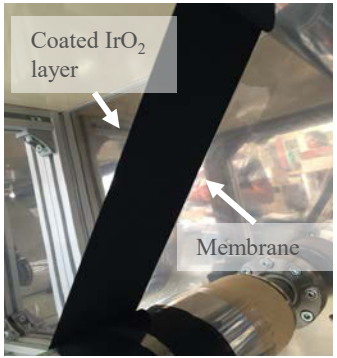
R2R Direct Coating onto Nafion Membrane

Schematic of the process



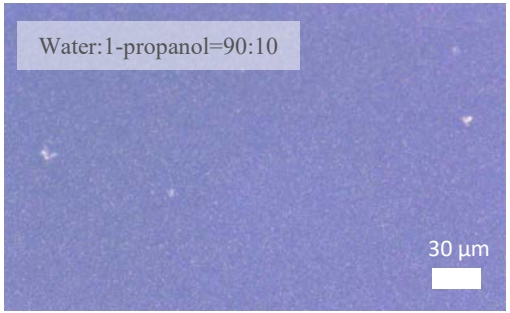
Coating photos

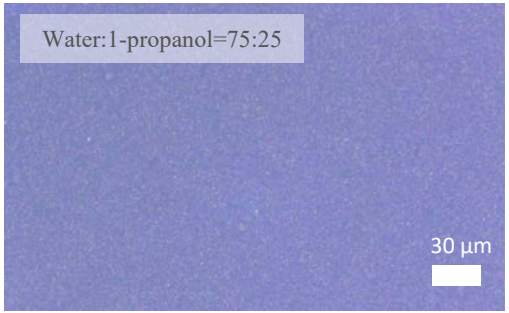
Before drying



After drying

Microscopic Images of the CCMs – 20wt.% IrO_2

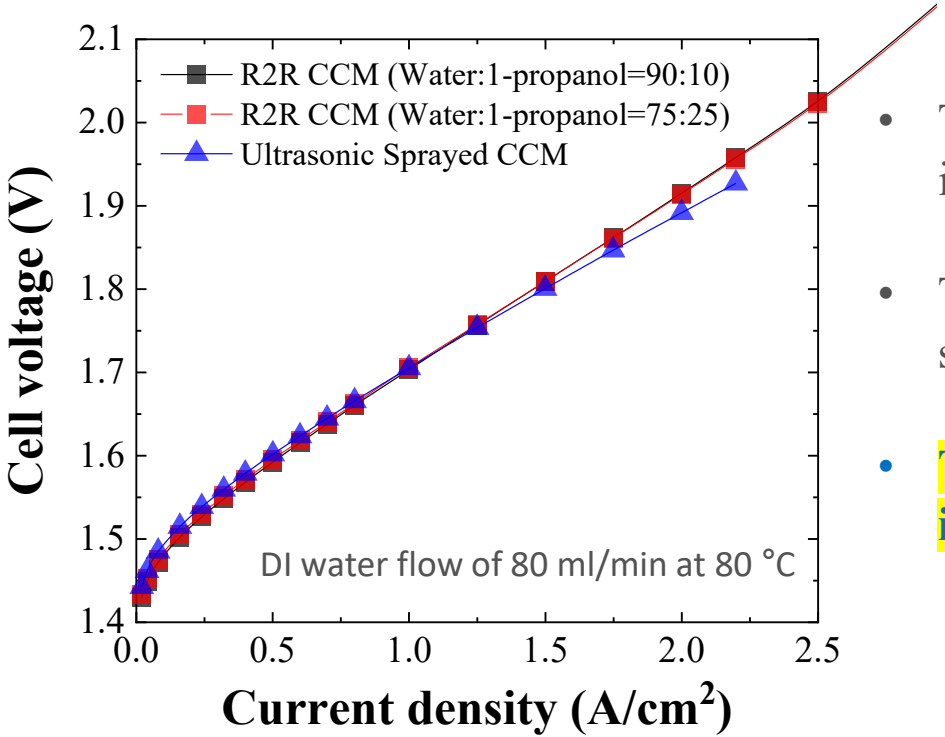




- Heat and web tension
  ➔ remove some of the swelling-induced wrinkling of the membrane

Electrochemical Test Results: R2R Vs. Lab Scale Spray

Ambient-pressure polarization curves for MEAs



- The two R2R-coated CCMs perform identically
- The R2R CCMs perform very similar to the spray coated MEA
- **The R2R-processed CCMs have increased throughput by more than 500x**

Conclusion and Future Work

- We have demonstrated a roll-to-roll (R2R) process for direct coating of anode catalyst layers on a polymer electrolyte membrane for low-temperature water electrolysis.
- Determined that high water content in catalyst ink results in better coatings because of low absorption
- This work shows that it should be possible to **eliminate the decal transfer processes** that is commonly used today. Both of these factors will lead to **reduced catalyst layer production costs** in water electrolyzers manufacturing.
- **Investigating the correlation between solvent absorption and membrane web elongation/tension variation during direct coating**

Thank You

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