Mitigation and Diagnosis of Pin-Hole Formation in Polymer Electrolyte Membrane Fuel Cells

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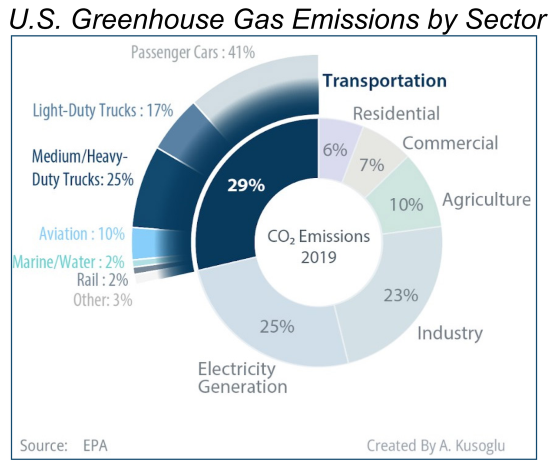
NREL

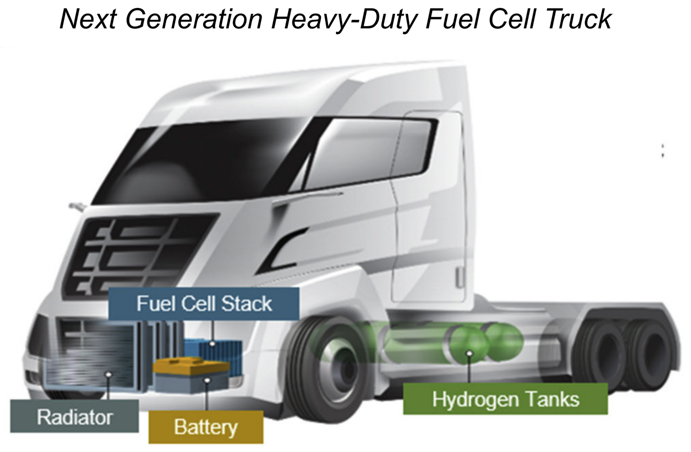
MILLION MILE FUEL CELL TRUCK

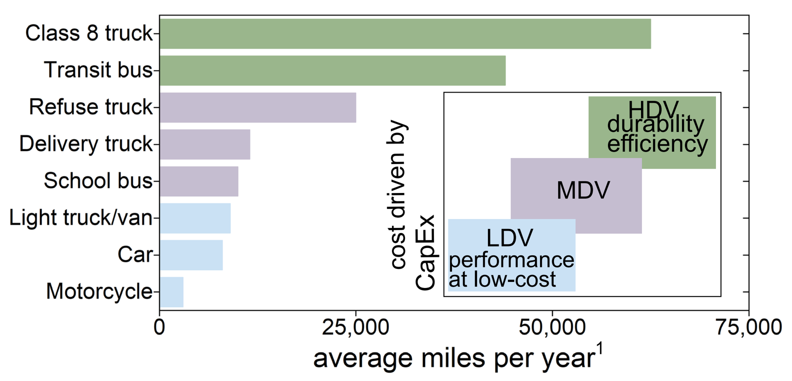
Background and Motivation

U.S. Greenhouse Gas Emissions by Sector

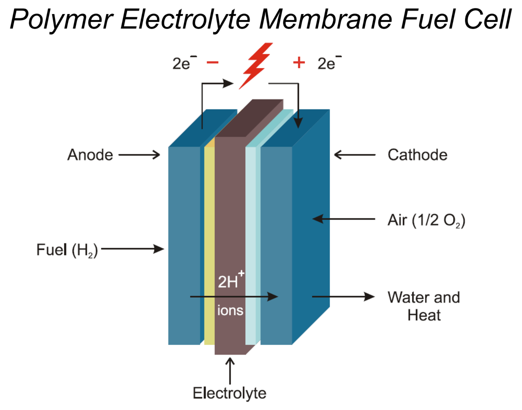


Next Generation Heavy-Duty Fuel Cell Truck

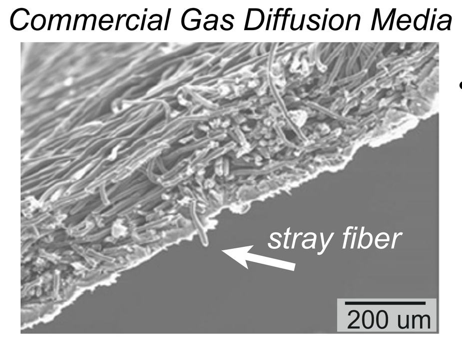




Polymer Electrolyte Membrane Fuel Cell

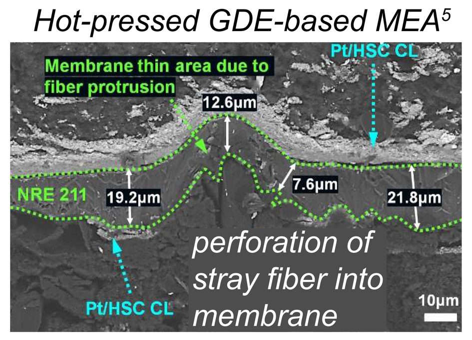


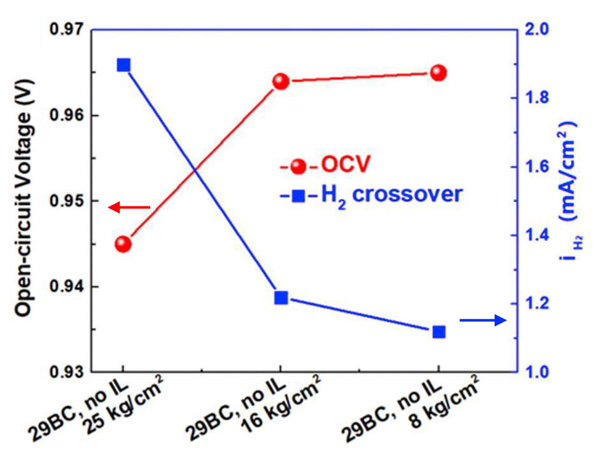
Commercial Gas Diffusion Media

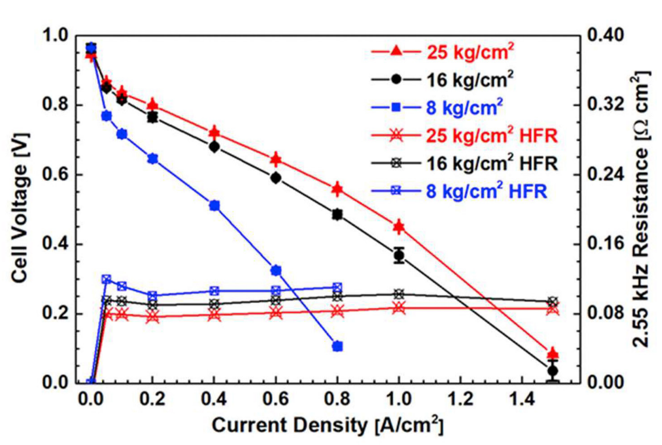


- *Enhanced durability can be achieve through improved manufacturing of membrane electrode assemblies (MEAs)*

Hot-pressed GDE-based MEA[5]

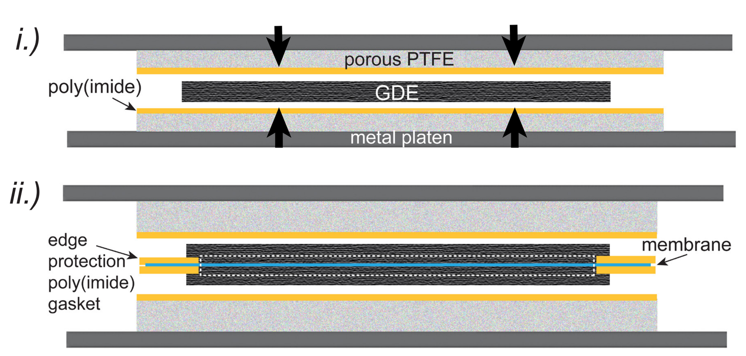






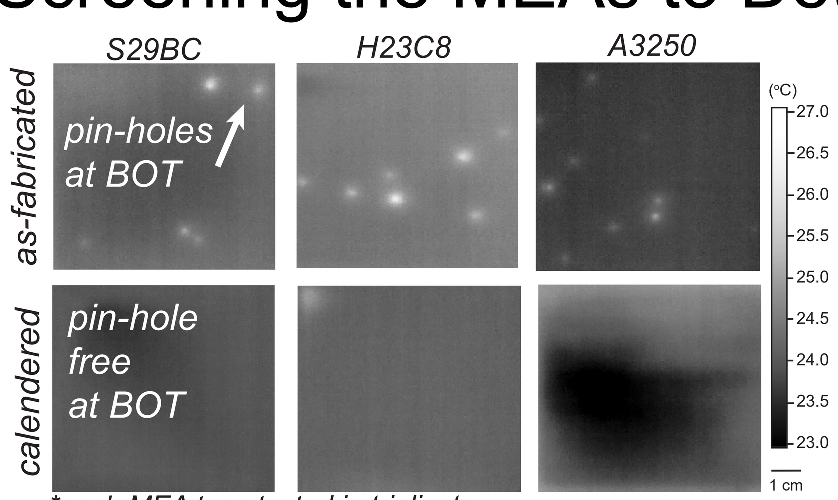
- *Fabrication artifacts can go undetected during initial performance assessments and can obscure a true durability assessment of material properties*

Fabrication of Pin-hole Free MEAs



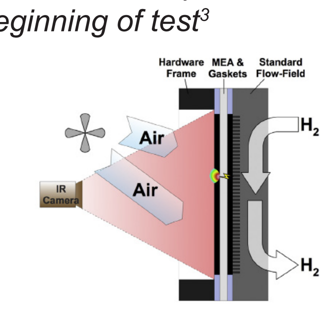
- *Gas diffusion electrodes (GDEs) were calendered at 25 kg/cm² to remove stray fibers and irregularites*
- *The calendered GDEs were subsequently hot-pressed at 25 kg/cm², 125 °C to fabricate the membrane electrode assemblies (MEAs)*

Screening the MEAs to Detect Pin-holes

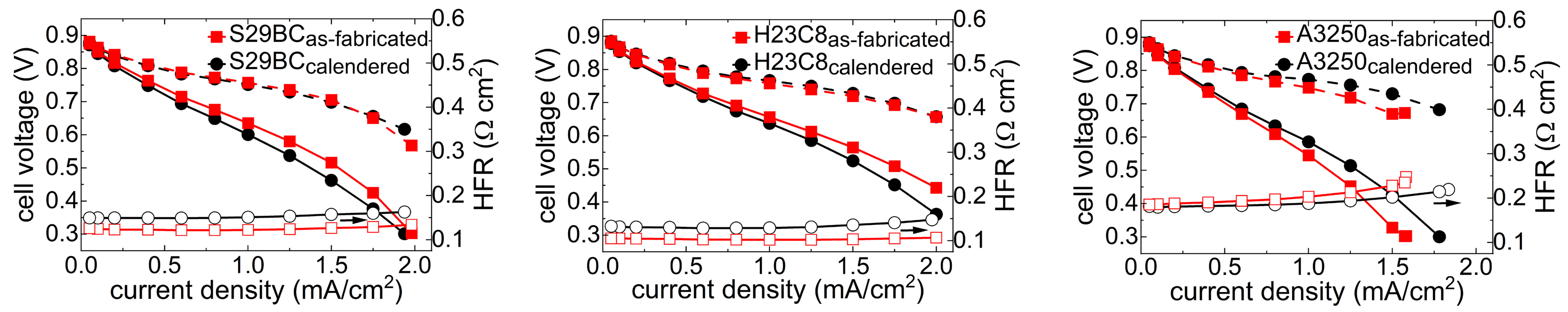


*each MEA type tested in triplicate

- *in-line infrared thermography screening enables a spatial visualization of pin-holes at beginning of test*[3]

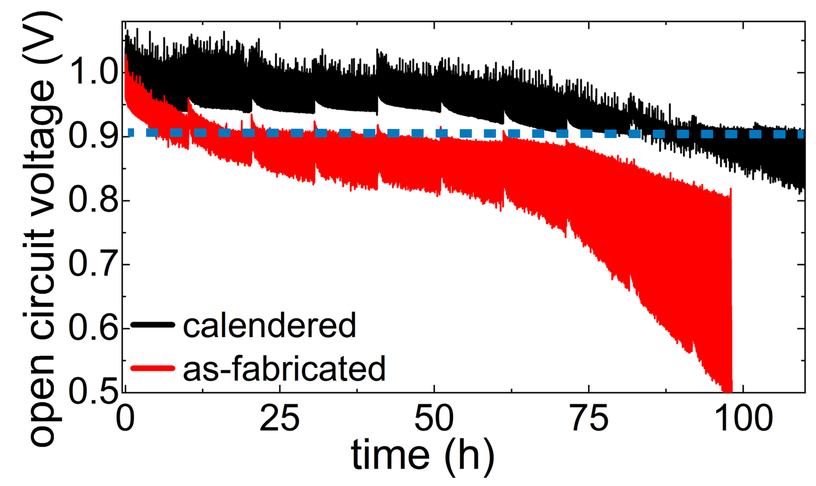


Initial Performance Assessment of the MEAs



- *Polarization measurements performed in H_2/air at 80 °C, 100% RH, and 150/150 kPa after standard break-in*
- *HFR-free cell voltages demonstrate that the influence of calendering on the MEA performance is negligible*

Calendered MEAs Demonstrate Lifetime Improvements During Combined Chemical-Mechanical Accelerated Stress Testing (AST)

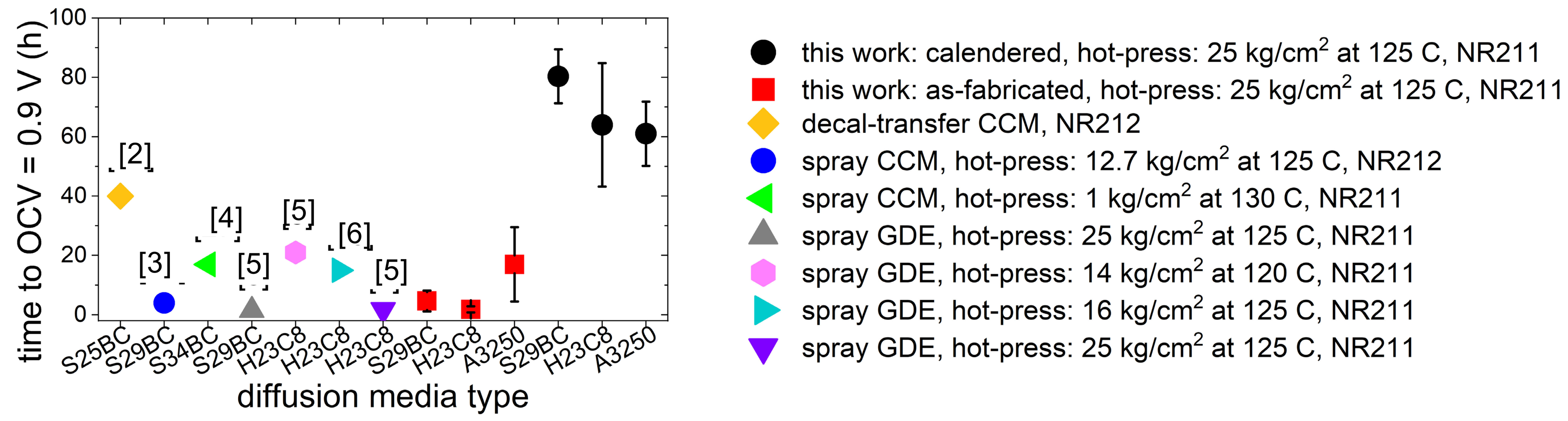


AST Conditions:
- *90 °C, 30/45 s wet/dry, 2/2 slpm, H_2/air, 101/101 kPa, at OCV*

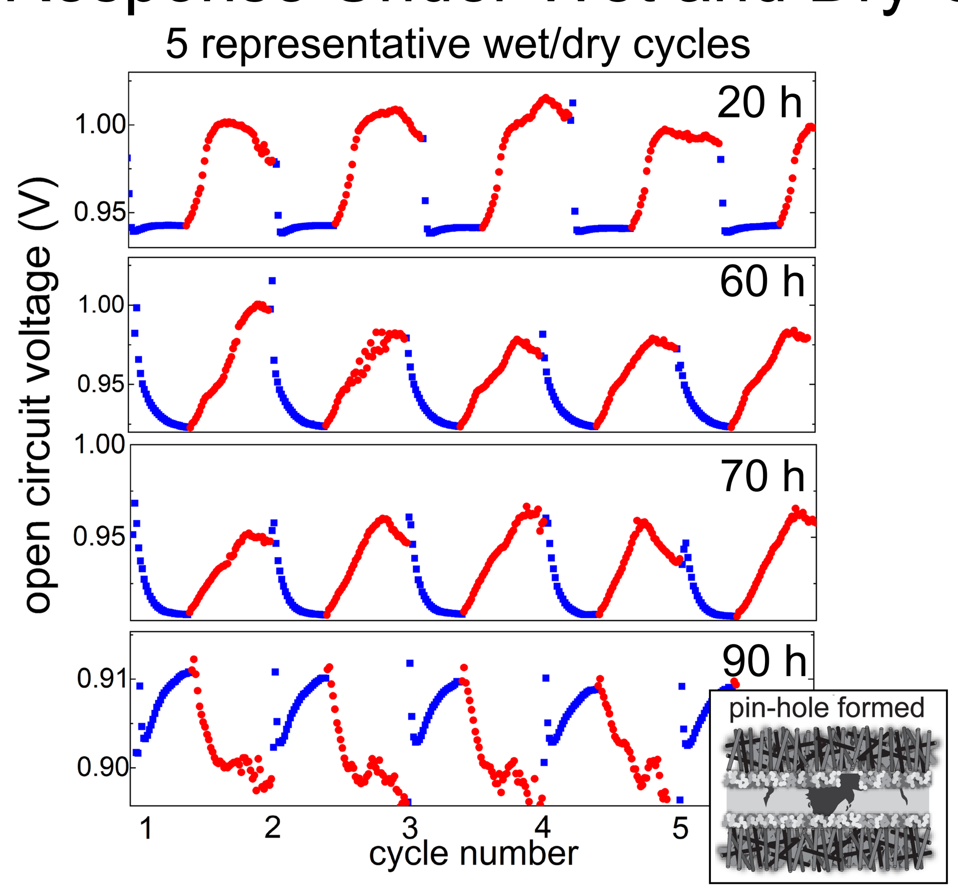
Mechanical Stressors:
- *RH cycling between wet and dry reactant gases*

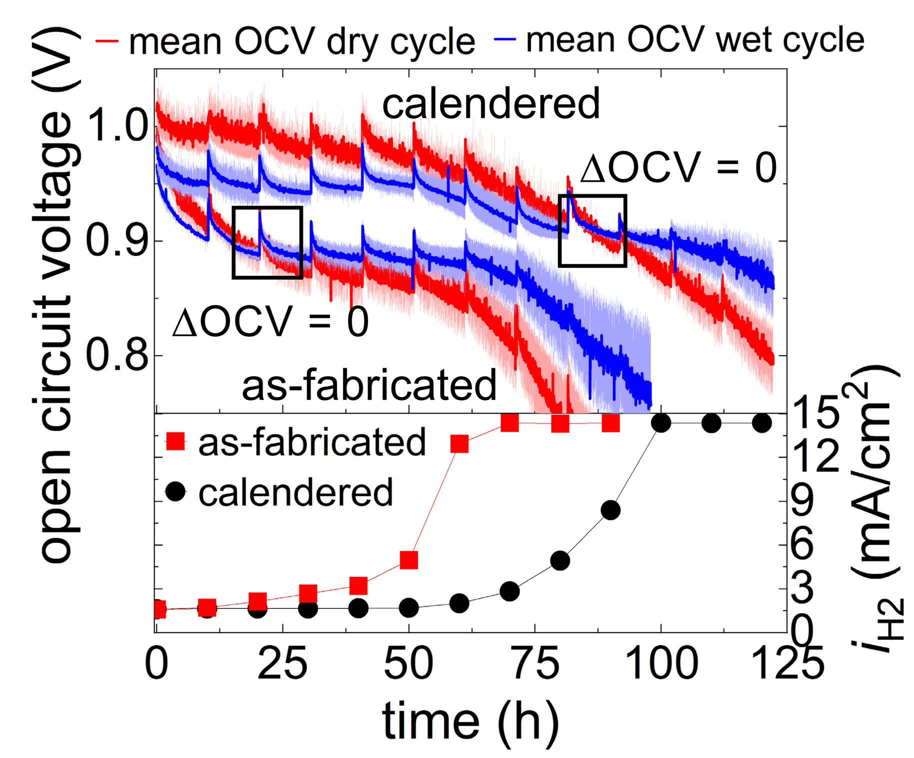
Chemical Degradation:
- *OCV hold at high temp promotes formation of radical species*

- *A mean lifetime improvement of 77% is demonstrated for calendered MEAs*
- *Enhanced process-quality enables pathway toward isolation of true material property failures*



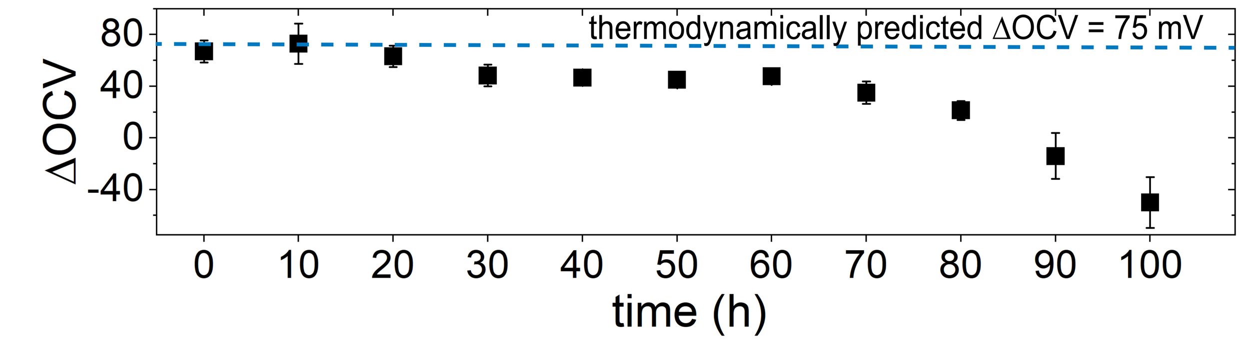
In Situ Tracking of Pin-hole Formation Using Open Circuit Voltage Response Under Wet and Dry Gas Flows

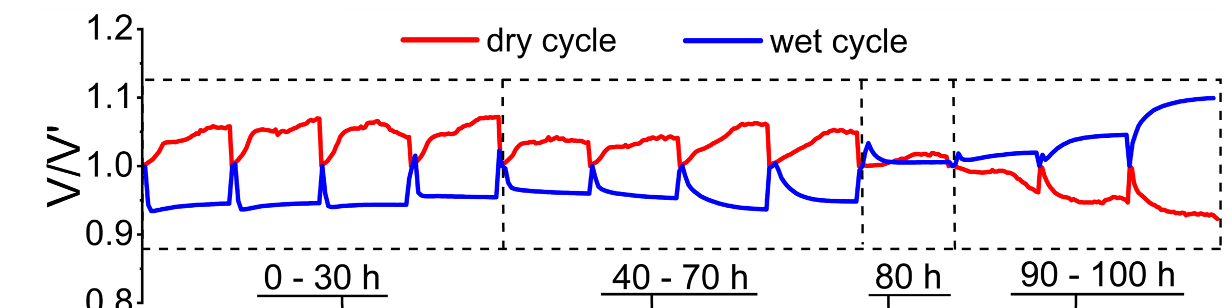


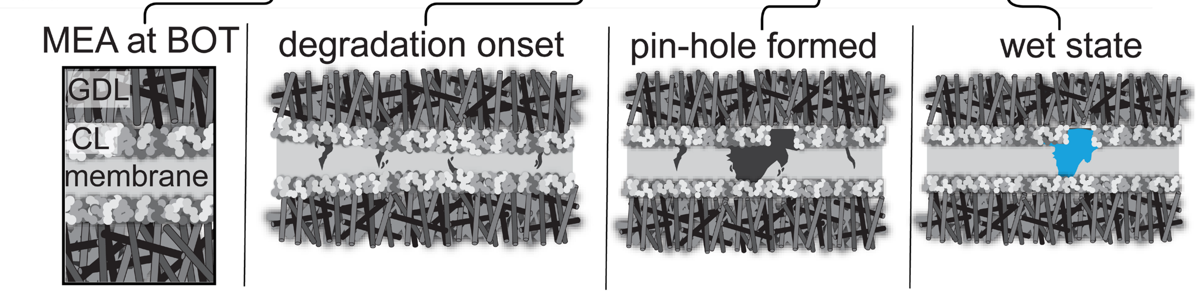


$$\Delta OCV = (E_{rev}^{dry} - \eta_{ORR}^{dry}) - (E_{rev}^{wet} - \eta_{ORR}^{wet})$$

Voltage Transients as a Diagnostic to Inform MEA State of Health

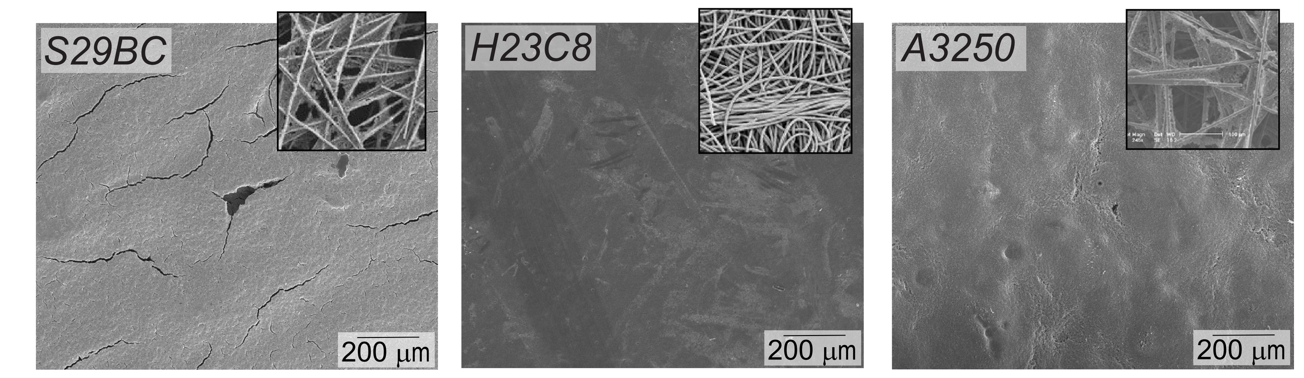






- *Deviation from the thermodynamically predicted ΔOCV indicates MEA degradation events*
- *Voltage transients could be used as a diagnostic to predict maintenance requirements in HDV fuel cell trucks*

Characterization of the Calendered Gas Diffusion Media



GDL type*	as-received thickness‡ (µm)	post-calendering thickness‡ (µm)	compressibility$^{\gamma}$
S29BC	241 ± 4.46	221 ± 3.76	8.75%
H23C8	220 ± 4.3	215 ± 4.81	1.86%
A3250	228 ± 3.42	184 ± 8.07	19.1%

* Abbreviations: S29BC = Sigracet 29BC; H23C8 = Freudenberg ; A3250 = Avcarb GDS 3250.
‡ The reported means were each calculated from nine measurements which included three measurements acquired for three separate pieces of gas diffusion media for each type. The error represents one standard deviation from the mean.
γ The compressibility represented as the percent change calculated from the as-received thickness and the resulting thickness after calendering at 25 kg/cm².

- *Follow-up work to include structure-function correlations in durability assessments with artifact-free baselines using the estabilished methodologies*

References

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[3] Philips, A.; et al. *Int. J. Hydrogen Energy*, **2018**, 43, 6390-6399.
[4] Ngo, P.M.; et al. *J. Power Sources*, **2022**, 542, 231803.
[5] Wang, M.; et al. *Int. J. Hydrogen Energy*, **2021**, 46, 14699-14712.
[6] Wang, M.; et al. (*In progress*).
This work: Taylor, A.K. et al.; *J. Power Sources*, **2023**.

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