Fundamental Study of the Mechanical Strength Degradation Mechanisms of PFSA Membranes and MEAs

Xinyu Huang
Florida Solar Energy Center (FSEC)
and Mechanical, Materials and Aerospace Engineering (MMAE) Department
University of Central Florida

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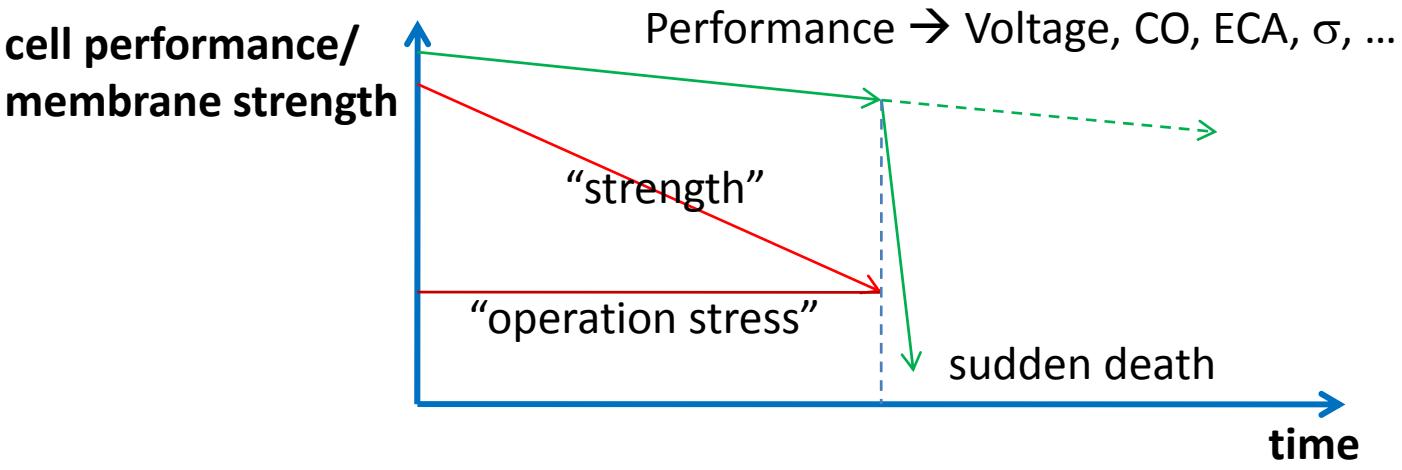
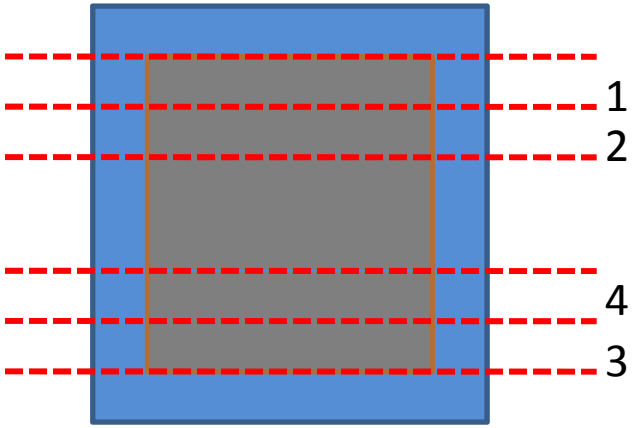
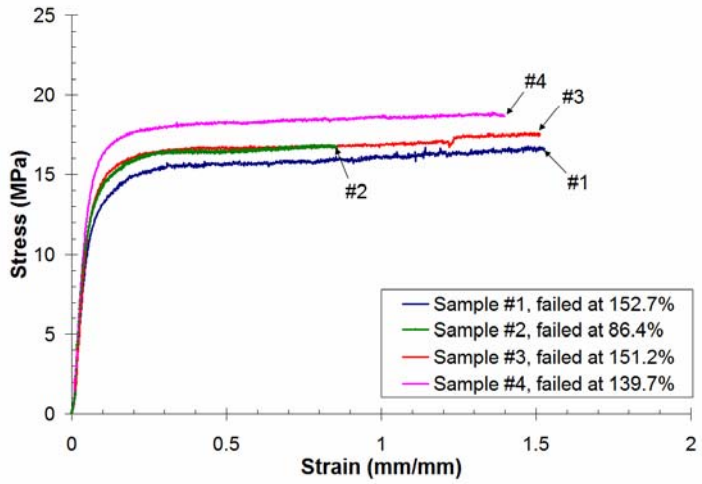
Membrane/MEA mechanical degradation and consequence

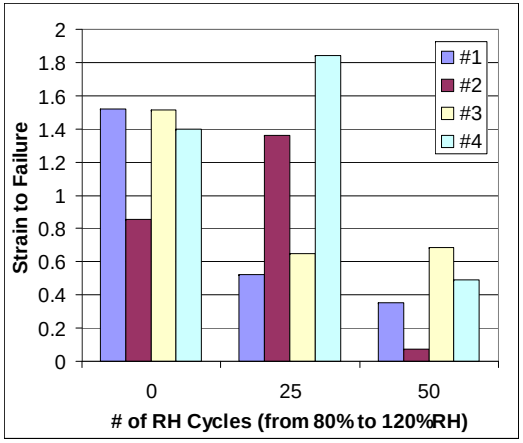
- Membrane/MEA becomes increasingly brittle, can results in catastrophic failure (e.g. rupture) of the membranes/MEAs
- Lack of understanding of the mechanisms and *in situ* methods to detect membrane/MEA mechanical degradation

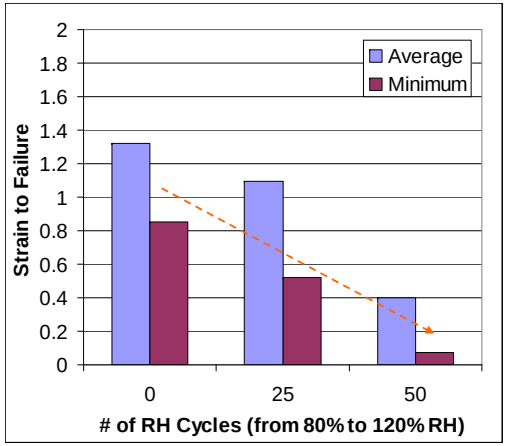


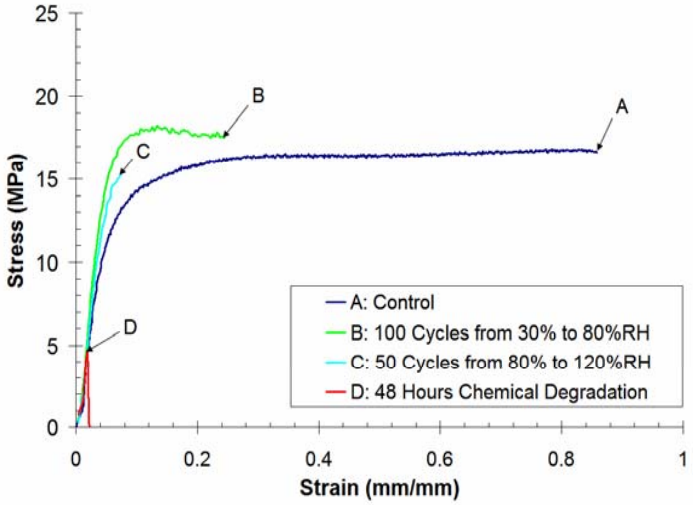
Characterization of membrane strength/toughness





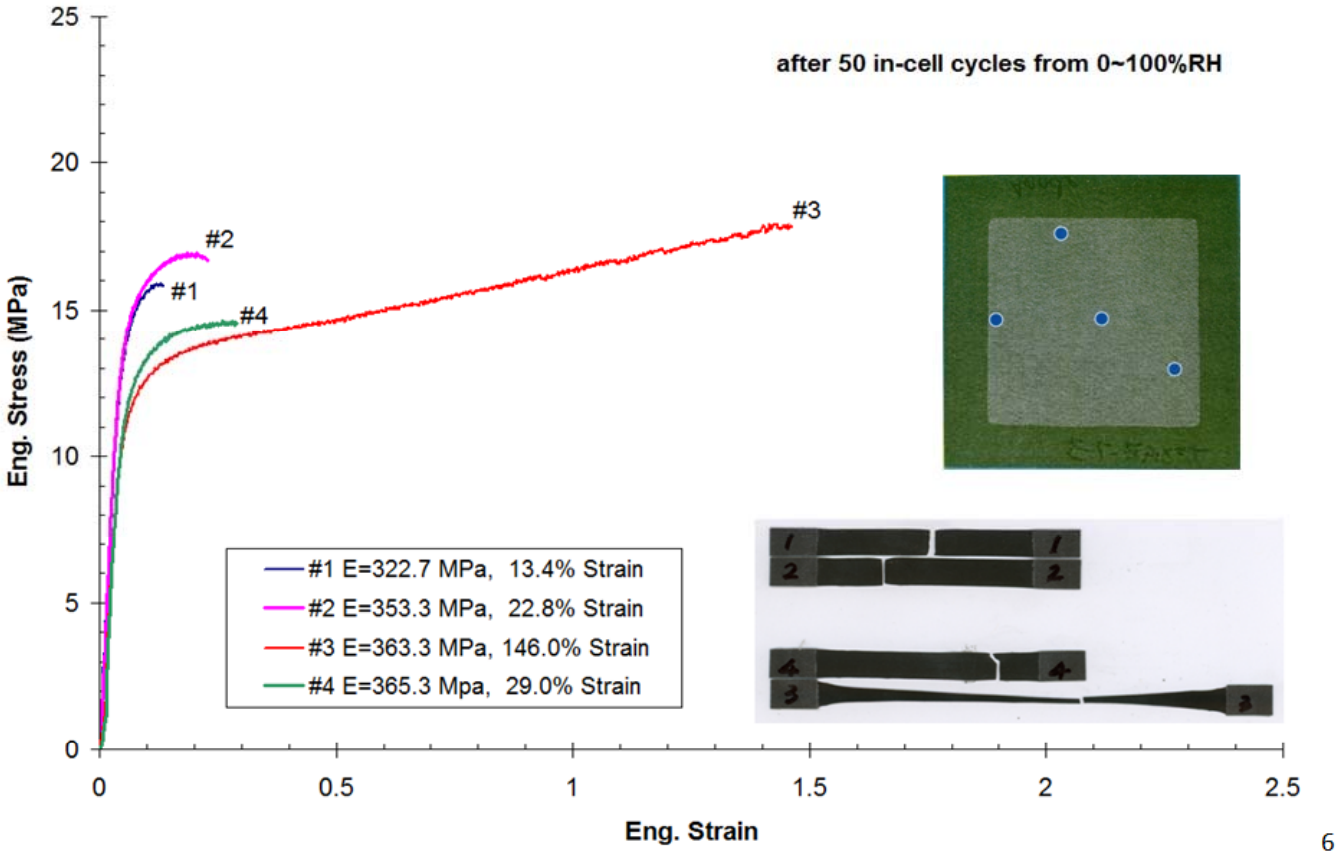






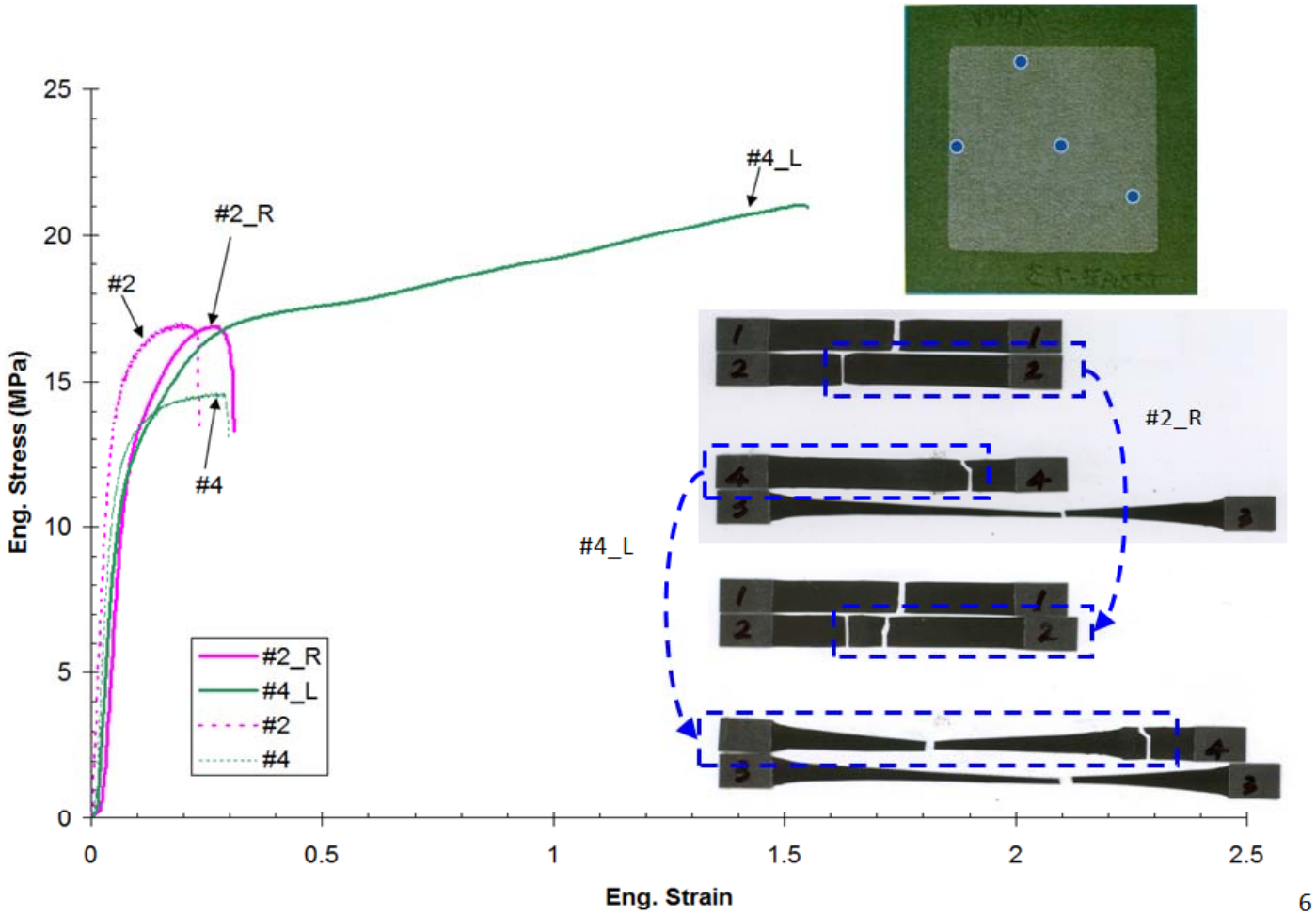
Membrane Mechanical Degradation under RH Cycling Conditions

RH Cycling →discrete / localized defects → strength degradation & pin-holes



X. Huang, C. Russo, Y. Zou, R. Solasi, K. Reifsnider, S. Burlatsky, D. Condit, M. Gummalla, "Degradation and Failure of PEMFC Membrane Electrode Assembly under RH Cycling Conditions," 211th ECS Meeting, Chicago, Illinois, May 6~10, 2007

Discrete localized defects & strength



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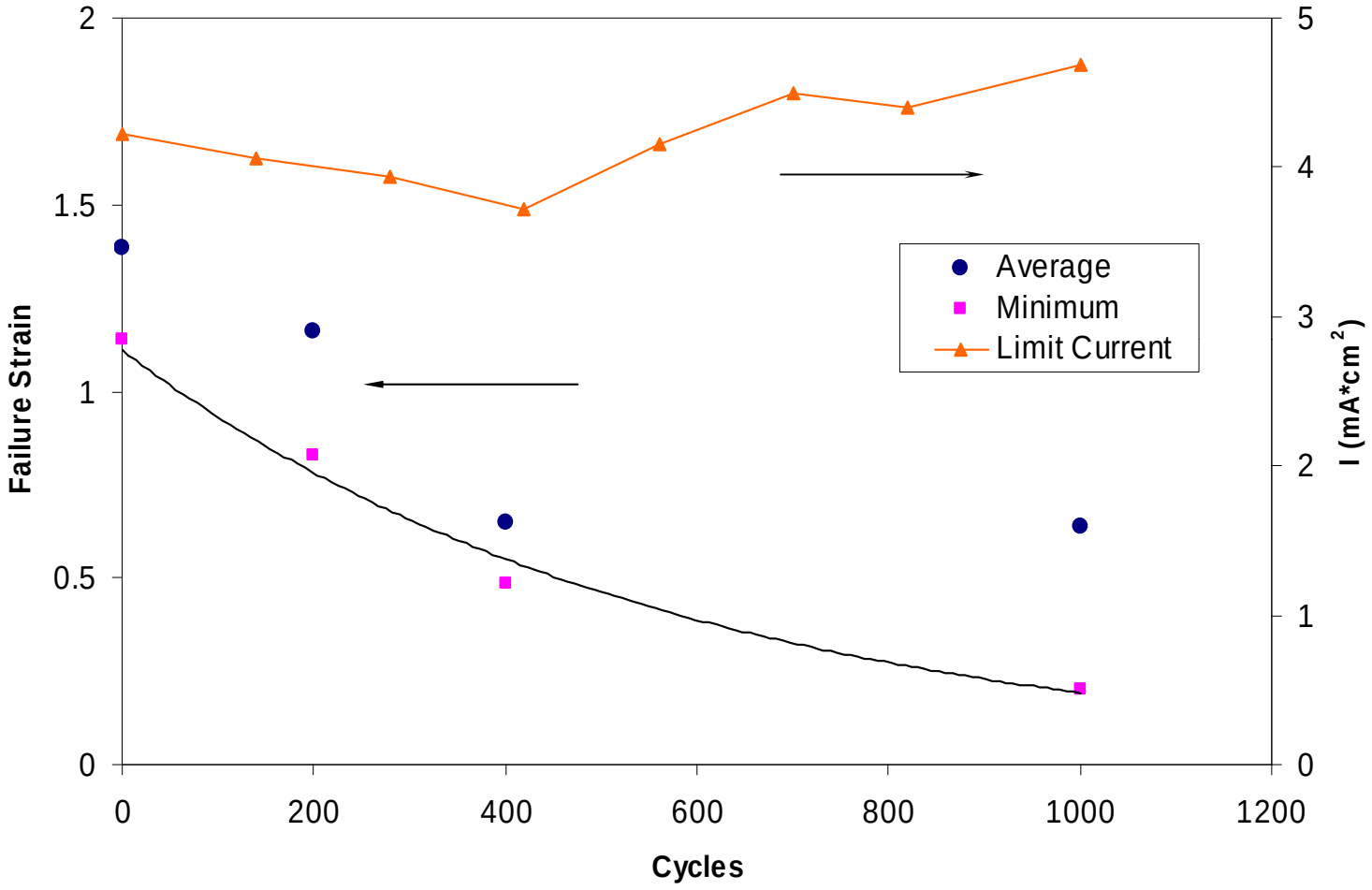
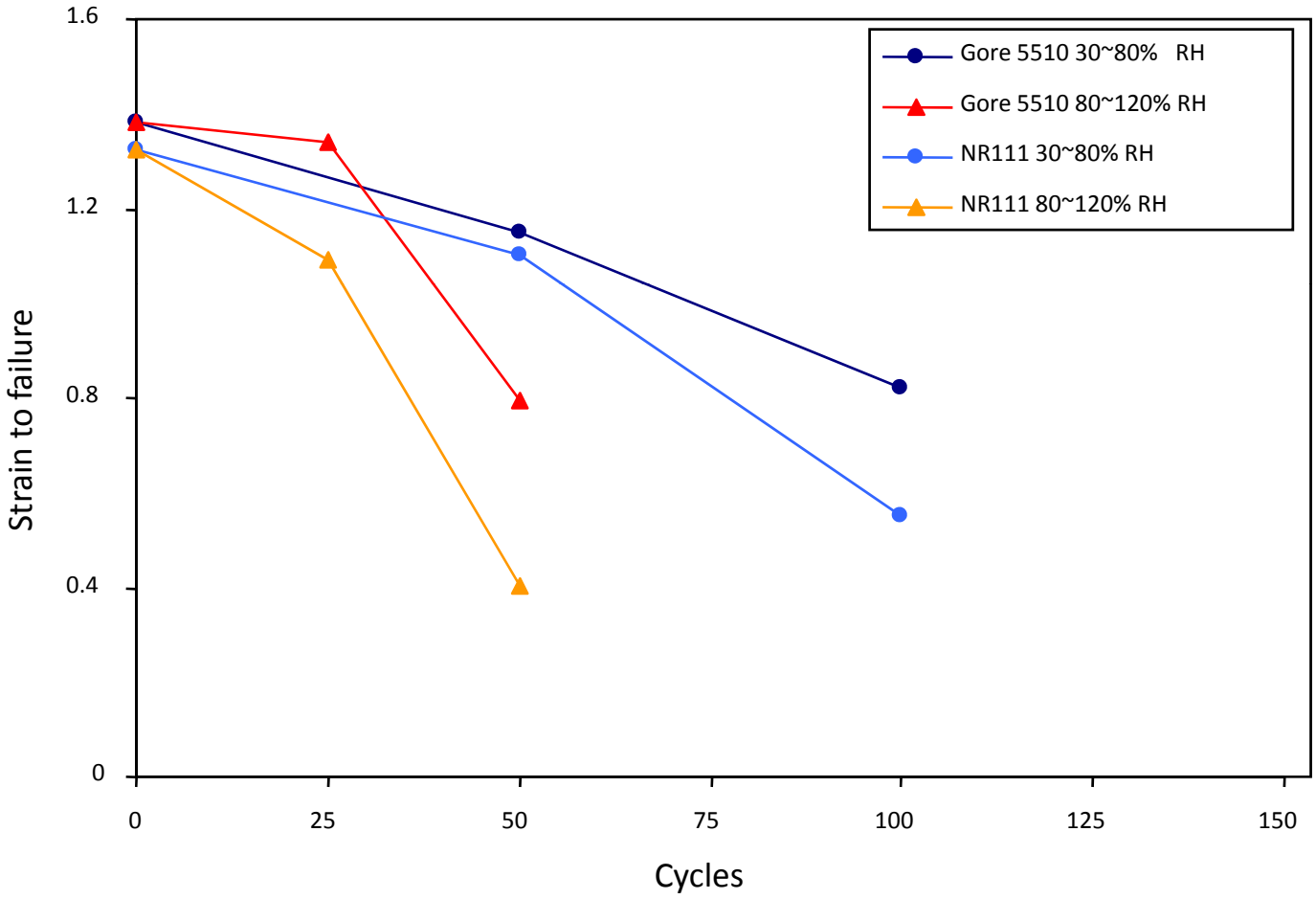
Strain-to-failure and hydrogen crossover versus number of RH cycles



Y. Zou, M.S. Thesis, 2007, Mechanical Engineering Dept., University of Connecticut

Gore 5520 MEA
In-cell test @ 80 ˚C from 0~100% RH

Defect growth rate depends on RH swing amplitudes and # of cycles



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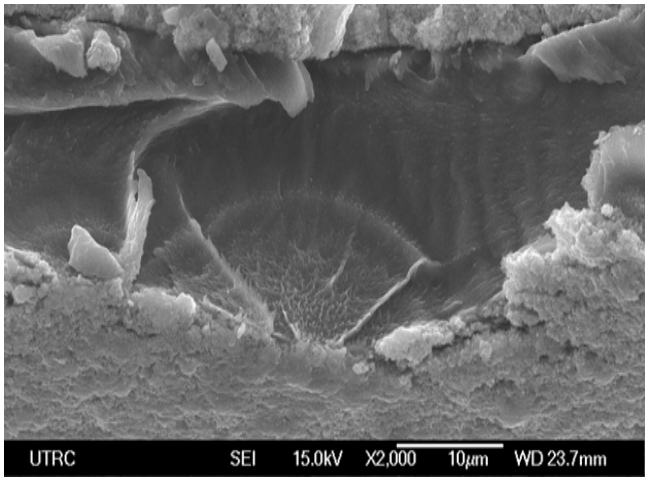
Origin of defects

Mechanical Degradation	Membrane	MEA	5-layer cell	5-layer cell
No-pinch	NO	NO	N/A	N/A
Pinch	Yes	Yes	Yes (hot-pressed once)	Yes

RH cycling induced mechanical degradation is closely related to certain damage caused by pressing GDL against the membrane or MEA

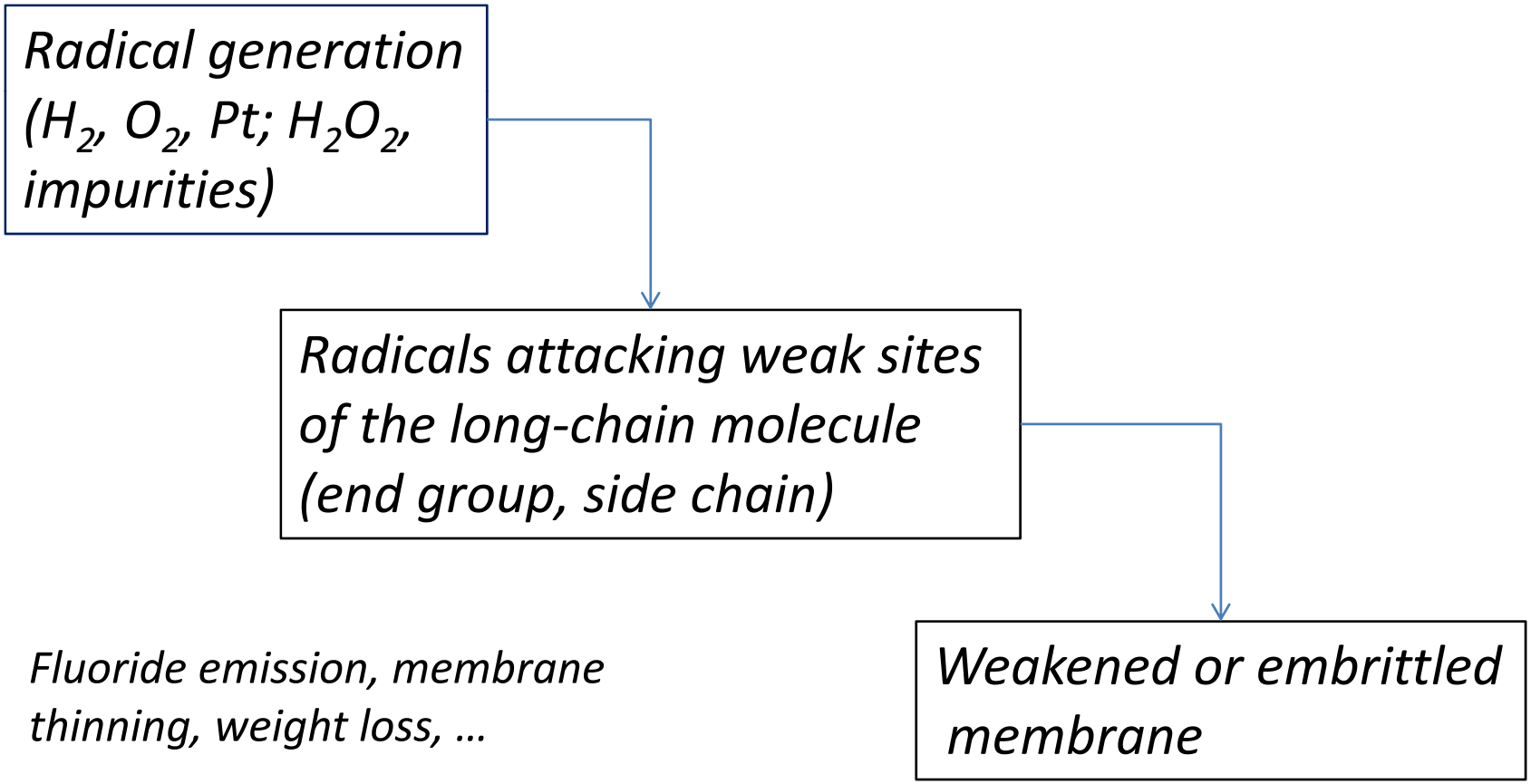


[Ref] Huang, X., Solasi, R., Zou, Z., Reifsnider, K., Condit, D., Burlatsky, K., and Madden, T., "Mechanical endurance polymer electrolyte membrane and PEM fuel cell durability," Journal of Polymer Science, Part B: Polymer Physics, 2006, Vol 44, Issue 16, pp 2346-2357.

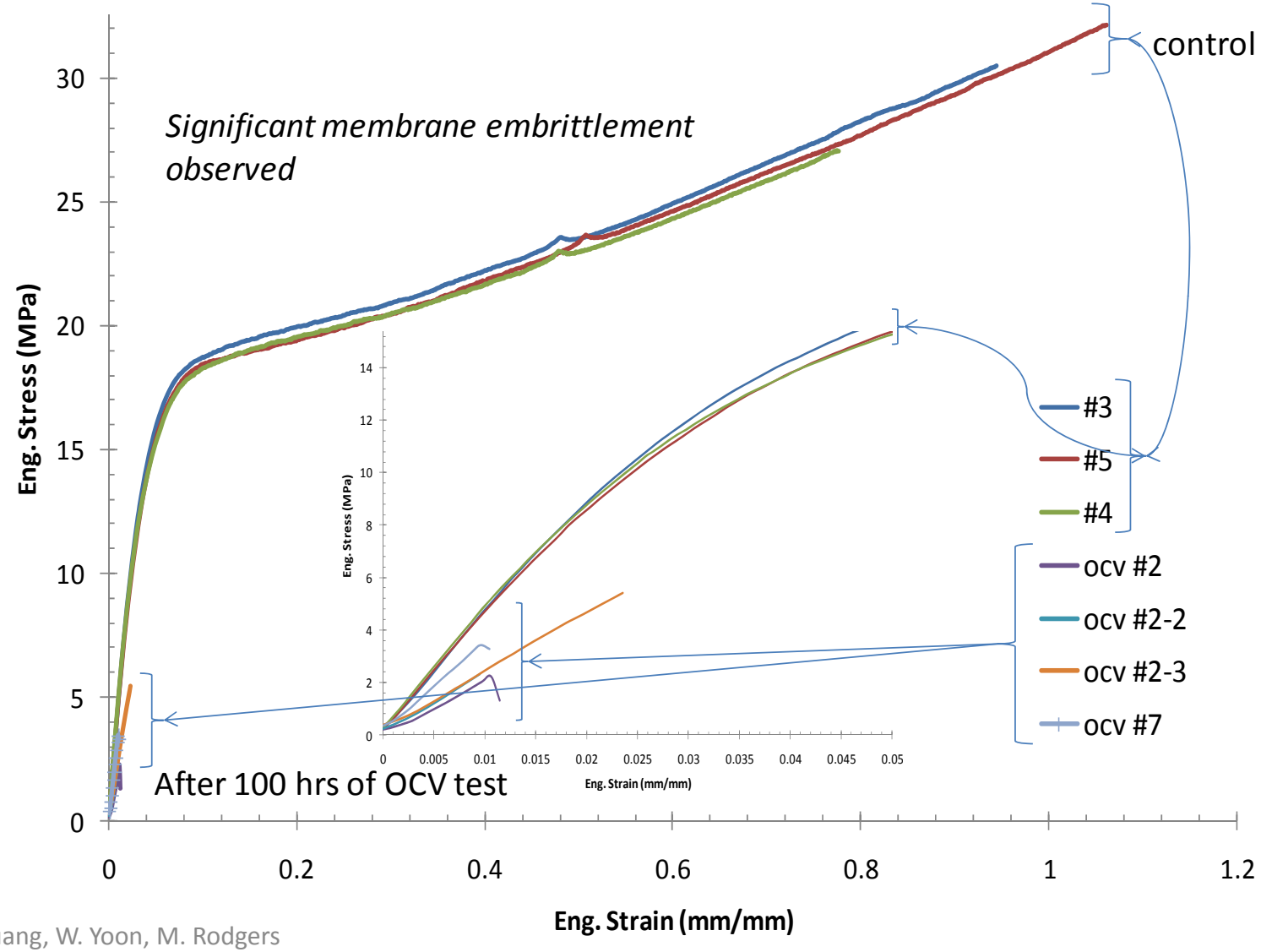
Summary

- Discrete defects formation and growth is likely the cause for mechanical strength decay under RH cycling conditions
- Defect growth shows a cycle-depend and RH swing amplitude dependence, typical of fatigue behavior
- Initial defects are closely related to the mechanical interaction between the GDL and the MEA

Membrane mechanical strength decay after accelerated chemical degradation and endurance test



Mechanical strength of MEA with N112 membrane: before and after OCV test



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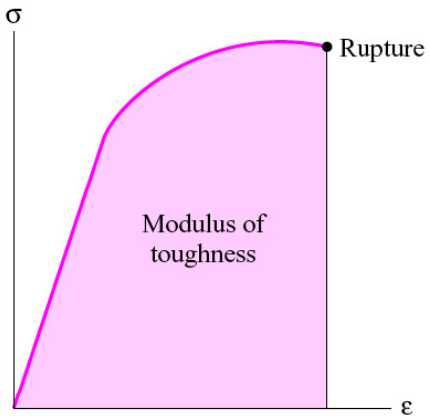
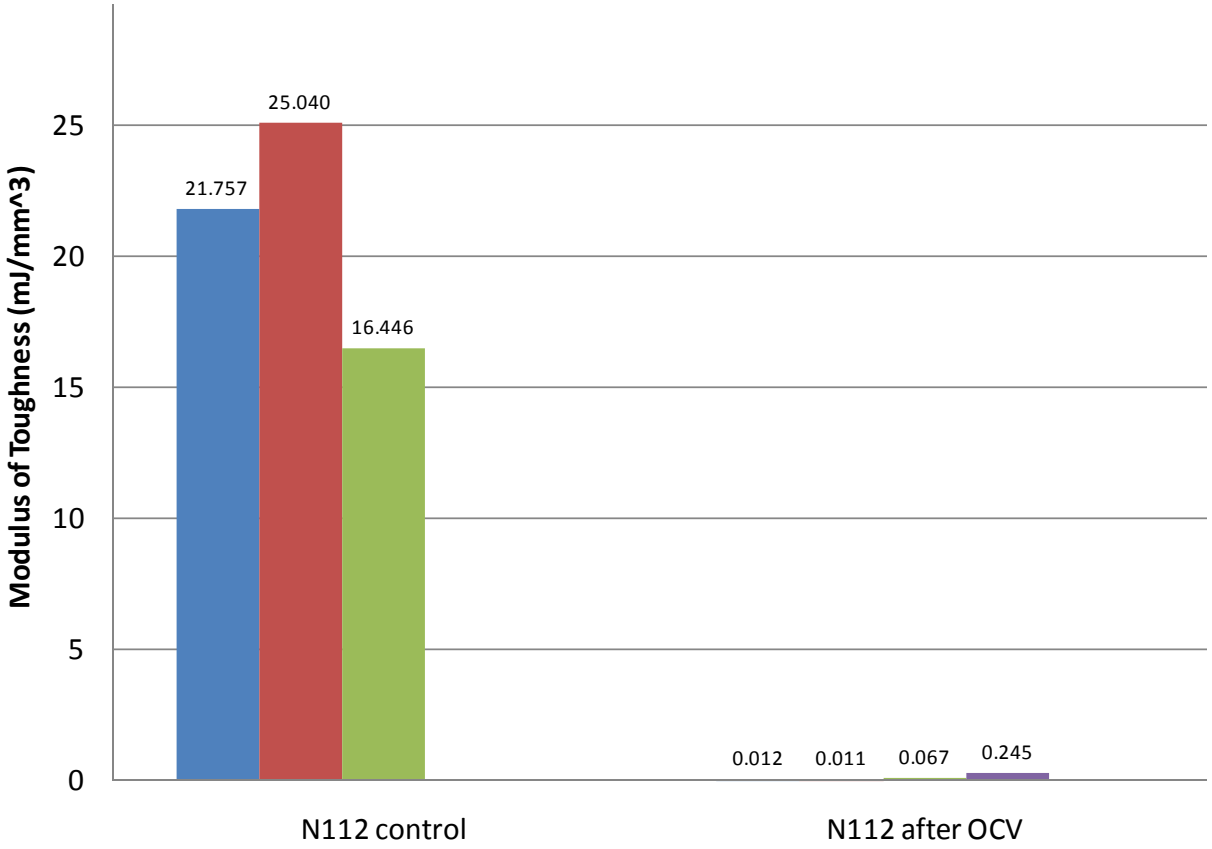
Membrane/MEA mechanical degradation: modulus of toughness



Modulus of toughness = Energy per unit volume necessary to rupture the material, Joule/m^3 or milli-Joule/mm^3



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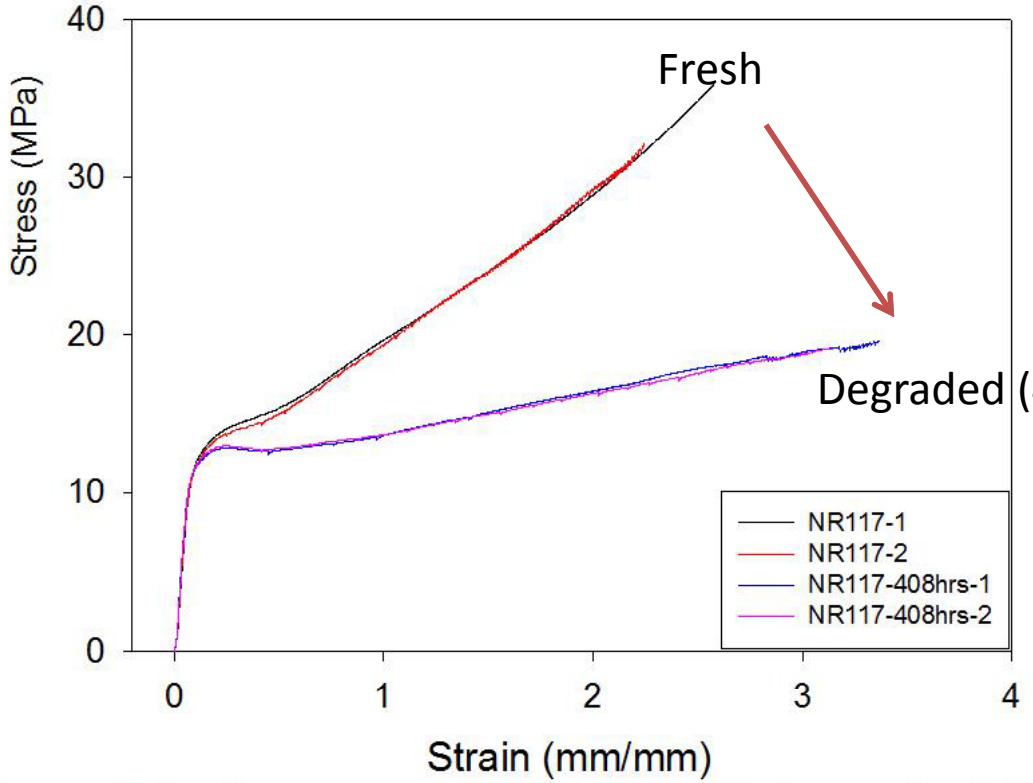
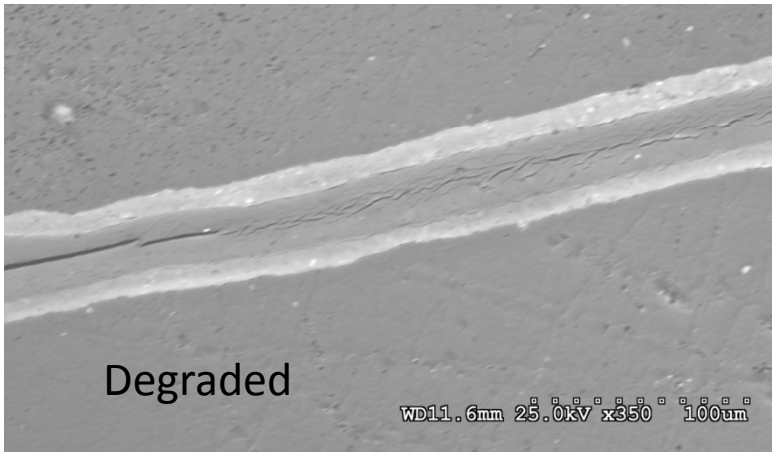
Effect of ex-situ Fenton test on membrane mechanical degradation



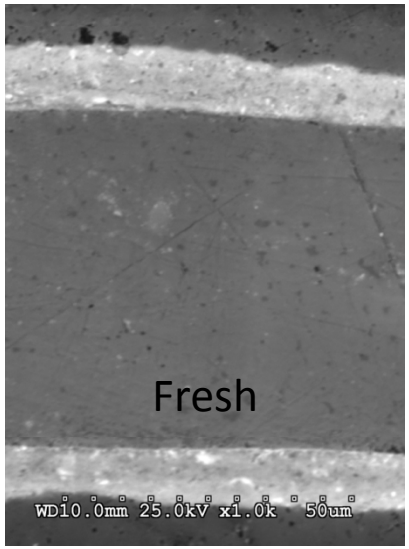
Stress-Strain Curve of Fresh and Degraded N-117

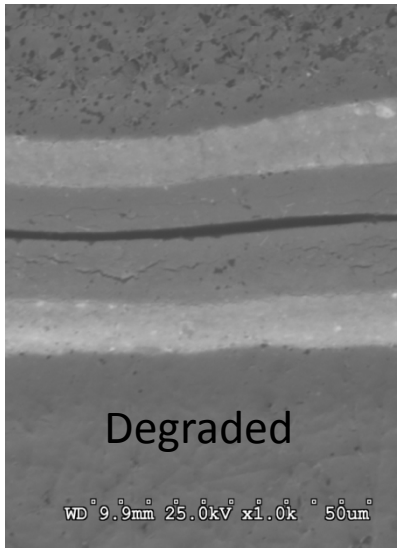
Radical attack ≠ Membrane embrittlement

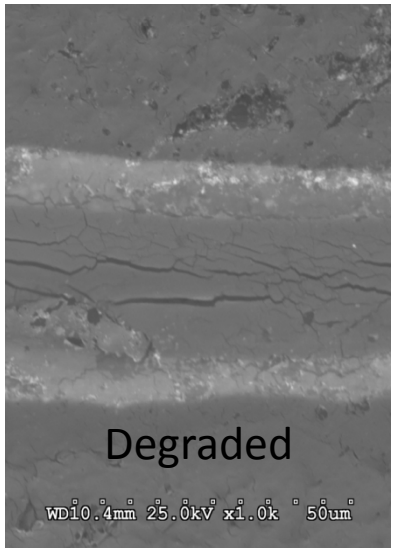
Evidence of localized defects formed inside membrane after OCV test



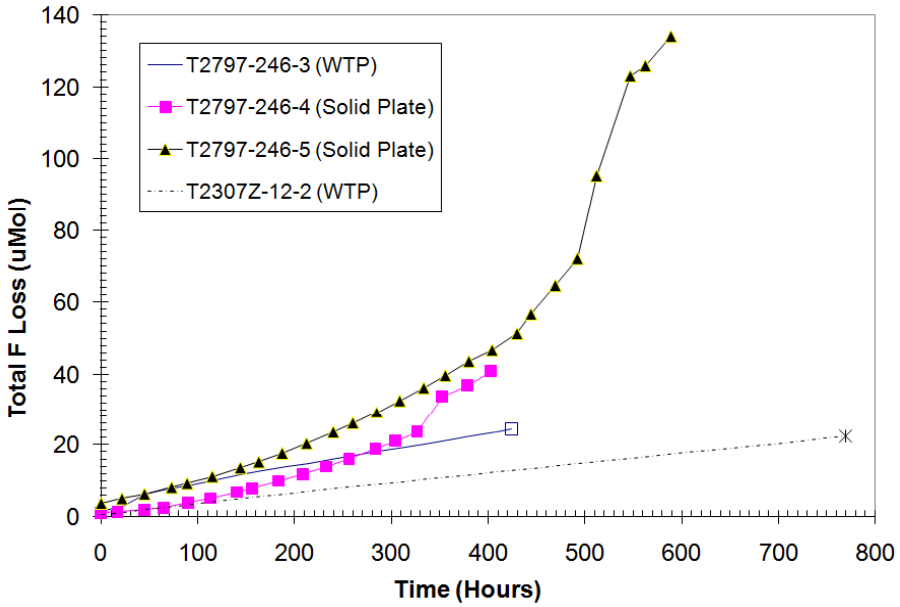
Nafion N-112 after 100hrs of OCV hold test with H2, air at 30% RH

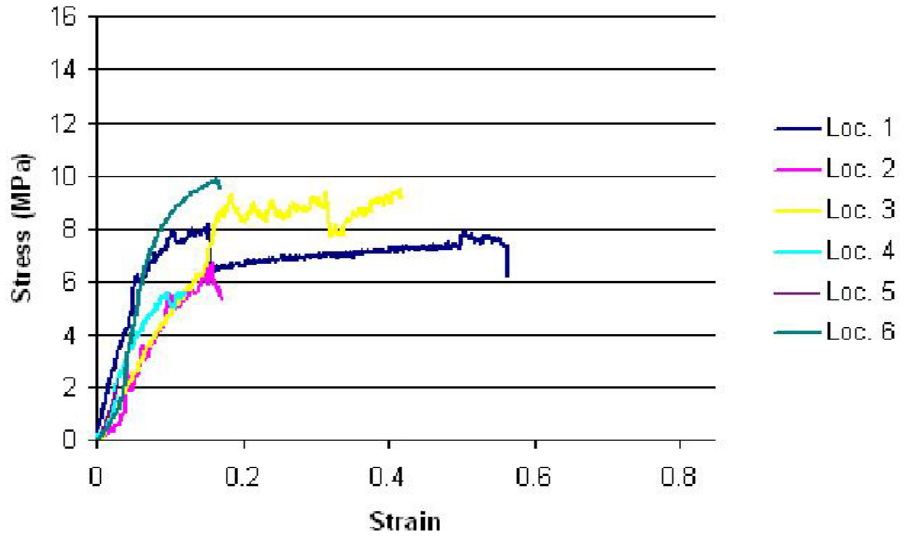


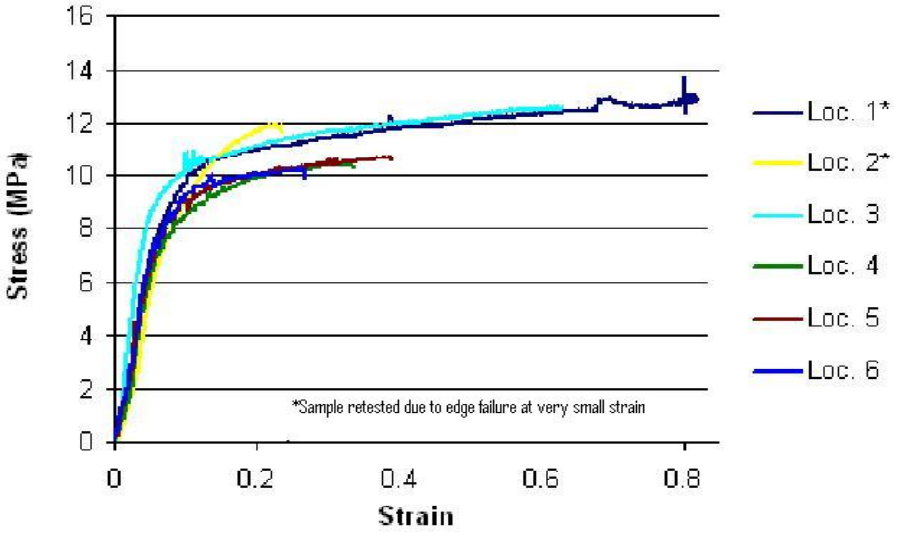




Water management schemes significantly affect membrane mechanical degradation







[Ref] X. Huang, X. Wang, J. Preston, L Bonville R. Kunz, M. Perry, D. Condit, "Effect of Water Management Schemes on the Membrane Durability In PEMFCs," submitted to ECS Fall Meeting 2008

Summary

Radical generation (H_2, O_2, Pt; H_2O_2, impurities)

??? Mechanisms of localization of chemical degradation due to local geometrical conditions (e.g. edge, land/channel boundaries) and local operation conditions (e.g. potential, current density, temperature, RH, liquid water, impurity accumulation) …

Radicals attacking weak sites of the long-chain molecule (end group, side chain)

Defects formation due to inhomogeneous / localized chemical attack

Fluoride emission, membrane thinning, weight loss, …

Weakened or embrittled membrane

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- Yue Zou (Areva)
- Roham Solasi (Sensata)
- Hongying Zhao (UConn)
- Xiaofeng Wang (UConn)
- Josh Preston (UConn)