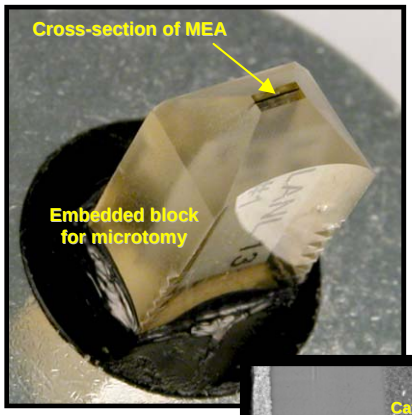
Hydrogen, Fuel Cells & Infrastructure

High Durability Membrane Electrode Assembly Materials to Extend Fuel Cell Life

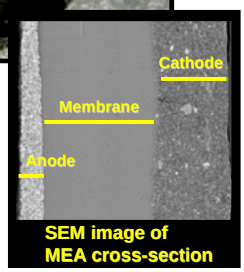
Advanced Microanalysis Techniques Reveal PEM Membrane Electrode Assembly (MEA) Degradation Mechanisms

Background

The MEA is the core of a Polymer Electrolyte Membrane (PEM) fuel cell where the conversion of chemical energy into electricity occurs. Examination of the aging of MEA materials under load for thousands of hours are critical to evaluate the their durability in (1) aggressive reductive and oxidative environments, (2) high electric currents, (3) temperatures ≥80°C, and (4) exposure to liquid water. Understanding MEA structural and chemical degradation mechanisms will be critical for their successful implementation in future power sources. Advanced microstructural and microchemical analysis techniques are being used to characterize as-processed and electrochemically-aged PEM fuel cell MEAs.

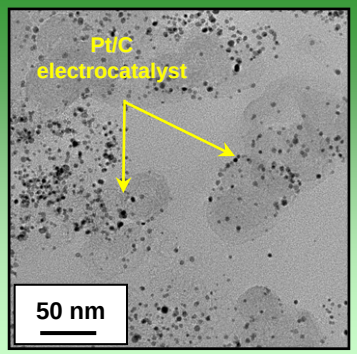


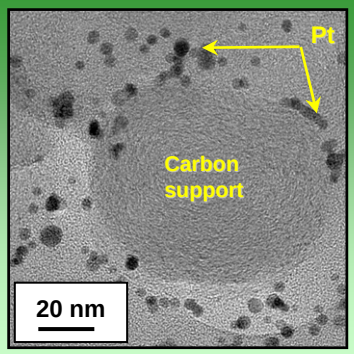
Trimmed block of embedded MEA cross-section is first used initially for SEM imaging, then it is ready for TEM thin-section preparation



Technology

High-resolution scanning, transmission, and analytical electron microscopy (SEM, TEM, and AEM) have been used to evaluate MEA structural change and degradation under load. Use of these advanced characterization techniques is possible due to improvements in specimen preparation. Ultramicrotomy is used to produce large areas of extremely thin (<50 nm), fully intact MEAs for TEM. These specimens allow the quantitative characterization of atomic-scale structural and chemical changes within



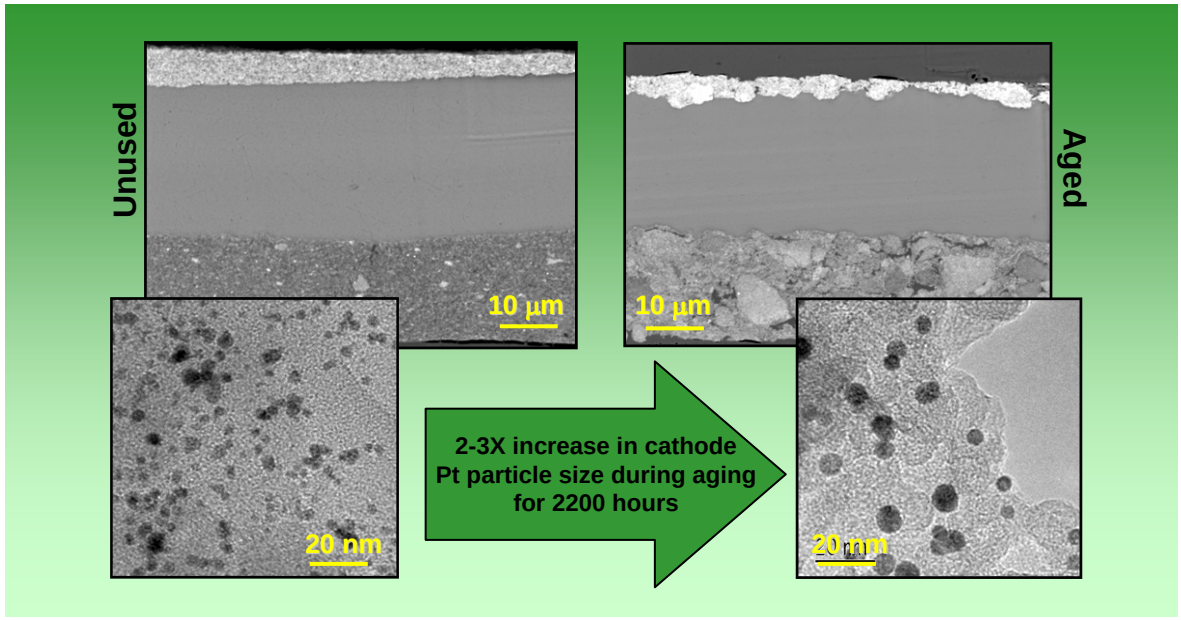


TEM images showing constituent arrangement within electrodes

the polymer electrolyte membrane and electrodes. Individual constituents and their assemblages within the electrodes (carbon support, ionomer, electrocatalyst particles, and interfaces between the electrode and membrane) can be evaluated pre- and post-aging.

Partnerships

Collaborations have been established with industrial and national laboratory partners to conduct long-term MEA durability studies. For each, ORNL characterized MEAs which were fabricated and electrochemically-aged (single-cell or stack) by the external collaborator. Examples of structural changes observed for a Los Alamos National Laboratory (LANL)-prepared, electrochemically aged (2200 hours) MEA are shown below. The SEM and high magnification TEM images show the bulk electrode damage (extensive cracking, material loss, thickness loss, electrode/membrane interface roughening) and Pt-based catalyst particle coarsening that occurred during aging.



Benefits

Microstructural evaluation of pre- and post-aged MEAs improves the ability to:

- develop direct correlations between as-processed MEA microstructure and performance,
- elucidate contributing MEA degradation and/or failure mechanisms, and
- establish long-term collaborations with PEM fuel cell developers, manufacturers and end users to evaluate their MEAs using advanced electron microscopy techniques and provide feedback for MEA optimization.

Future Work

ORNL currently is collaborating with W.L. Gore, Fuel Cell Energy, Battelle Memorial Institute, Arkema Inc.and PlugPower to evaluate the durability of particular MEA structures and compositions. The evaluation of the effects of cycling and temperature on the durability of LANL MEAs, and futher investigation of the structural changes to MEA components under aging will continue. Alternate catalyst compositions will be examined.

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