The Micro Structure of the Cathode Catalyst Layer in Polymer Electrolyte Fuel Cells

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PEM fuel cell electrodes outfitted with thin-film catalyst layers, a technology developed in our Laboratory, [1] have been used to achieve improved cell performances with very low catalyst loadings (as low as 0.1 mg Pt/cm^2). The catalyst layer made by this technique contains three main components— metal catalyst, carbon black (that supports the catalyst and provides paths for electronic conduction), and recast Nafion (that binds the catalyst and the carbon, and also renders the ionic media for H^+ transport). To facilitate the oxygen reduction, the cathode catalyst layer must have (1) high porosity to allow efficient gas transport and water dissipation, (2) good proton conductivity, and (3) good electronic conductivity. An accurate description of the microstructure of this composite and the interaction of its components is critical for improving cathode performance. It can provide answers to fundamental questions such as: what is the coverage of recast Nafion on catalyst particles? (This is directly related to the oxygen permeation and the electronic conductivity) How does the ionomer network inside the catalyst layer form and how does it interact with catalyst particles? Does the ionomer network phase separate from catalyst particles or the catalyst particles intimately interacting with the ionomer network? How effective is proton transfer along the recast Nafion ionomer network relative to that in a Nafion membrane? What is the size of carbon agglomerates and how they are distributed in the catalyst layer? The microstructure of the three components within the catalyst layer still remains unknown.

A systematic approach has been taken to study the structure of the three components of catalyst layers. The components, like carbon, catalyst/carbon, Nafion membrane, and recast Nafion (both in proton and in sodium forms) are studied individually and in combination. Atomic force microscopy (AFM) is used to study the morphology of the catalyst layer in both surface and cross section. Great effort has been dedicated to resolve the structure of the three components with AFM. Scanning electron microscopy (SEM) combined with energy dispersive analysis x-ray (EDAX) also has been used to study the surface and cross-section of the catalyst layer. Transmission electron microscopy (TEM) is used to determine the catalyst cluster size and the carbon particle size in the catalyst layer.

In this thin film electrode, the catalyst ink is first painted onto a Teflon-coated fiberglass decal, baked at 140 °C for 30 minutes and then hot pressed onto a Nafion 112 membrane (sodium form) to make a MEA. After hot pressing, the MEA must be boiled with sulfuric acid to transform the sodium form to the proton form membrane [1]. Preliminary results from AFM indicated that there is a thin film of ionomer on the surface of catalyst layer before reprotonation. The existence of the thin film on the surface of catalyst layer was confirmed by SEM. The SEM results also reveal that this thin film of ionomer on the surface of the catalyst layer is very smooth and dense, but it becomes porous after the catalyst layer is boiled in sulfuric acid and then in deionized water. The presence of this thin film could hinder the transport of oxygen and the water dissipation. The causes of the formation of the thin film and the effect on the performance of the cathode are still under investigation.

Acknowledgments
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References

[1] M.S. Wilson and S. Gottesfeld, *J. Appl. Electrochem.*, **22**, 1 (1992).