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/cm²). 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.

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References