Characterization of PEM-FC materials with scanning transmission X-ray microscopy

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Proton exchange membrane (PEM) fuel cells are of significant interest due to their use as an alternative energy source in both residential and automotive applications. [1,2] PEM fuel cells convert chemical energy stored in hydrogen and oxygen to electrical energy, generating water and heat in the process. For mobile applications, PEM-FC is attractive to the automotive industry because of the cleaner byproducts generated and the zero-carbon emission at the tailpipe. However, challenges remain to be solved before personal automobiles based on PEM fuel cell technologies become commercially successful.

One of the major challenges is to lower the cost of PEM fuel cell technology. The main cost driver is the Pt catalyst, so methods to reduce Pt loading while retaining performance and robustness are of paramount importance. Improving our understanding of Pt interactions with the other components in the catalyst coated membranes (CCMs), the carbon support and ionomer in particular, can help lead to more efficient use of Pt. A major factor is optimization of the ionomer loading of PEM-FC electrodes so that as much of the Pt as possible contributes to power generation.

Soft X-ray scanning transmission microscopy (STXM) is a powerful tool for studying PEM fuel cells as it provides chemical speciation via near edge X-ray absorption fine structure (NEXAFS) spectroscopy and quantitative chemical imaging with spatial resolutions of 30 nm. [3-7] In particular, combined C 1s and F 1s edge studies provide mapping and quantification of Pt, carbon support and ionomer in various membrane electrode assembly (MEA) architectures [8]. Quantitative component maps (nm thickness) are derived by fitting sets of images recorded from ultramicrotomed thin sections (100-300 nm thick) at the C 1s and F 1s edges to quantitative reference spectra (absorbance per nm) of each component. The reference spectra are obtained from the pure materials. This approach allows quantification of the thickness of multiple components over a large spatial range (50 x 50 microns) with fine pixel spacing (50 nm or smaller). This allows for quantification across the whole MEA with fine spatial resolution in a relatively short period of time.

We will present results from STXM studies of various CCMs with different ionomer content, Pt loadings, morphologies and operational characterization. Results for samples prepared using commercially available membranes [2, 9, 10] will be presented. It has been found that the morphology and ionomer to carbon support ratios are highly dependent on the type of sample. The use of STXM as a tool for rational optimization of PEM fuel cell materials and fabrication procedures will be outlined.

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