

PTFE distribution in high temperature PEM electrodes and its effect on the cell performance

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In high temperature polymer electrolyte membrane (HT-PEM) fuel cell research, a great deal of effort has been devoted to the optimization of electrodes. This is because the properties of the electrodes are critical for the stability and performance of the fuel cells.

A conventional PEM electrode primarily consists of carbon-supported platinum catalyst and binder. Because of the elevated operating temperature of HT-PEMs, polytetrafluoroethylene (PTFE) is often used as a binder material. For this purpose Nafion is not practical because under anhydrous conditions it is nonconductive and tends to encapsulate the Pt-nanoparticles, which results in blocking of the catalysts sites for hydrogen oxidation and oxygen reduction.

To visualize the nanoscale structures of HT-PEM electrodes, we carried out experiments using scanning electron microscopy (SEM) and atomic force microscopy (AFM). Besides morphology and topography, the AFM is also capable of measuring the local conductivity (Fig. 1) of the sample.

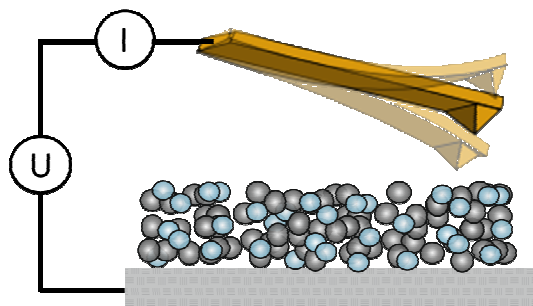


Fig. 1: Schema of AFM current measurement

These techniques were previously used to characterize low temperature Nafion-based electrolyte fuel cell membranes and electrodes [1, 2], and we find they are especially suited for HT-PEM electrodes due to the specific spherical shape of the nonconductive PTFE binder.

Using SEM and AFM, we studied the PTFE particle size distribution on the surfaces of the electrodes prepared with PTFE contents of 10% and 40%.

PTFE and platinum agglomerates in the electrode were imaged by locally resolved current distribution (Fig. 2) with conductive tapping mode AFM, which was able to resolve even single PTFE particles in the catalyst layer. Size distribution of conductive areas in the catalyst layer was analyzed with AFM, and the electrode structure was determined with scanning electron microscopy (SEM). Morphology and topography of the electrodes with various PTFE contents were compared, and their influence on the fuel cell performance was investigated through electrochemical characterization of single cells.

We found that the PTFE content had strong effects on the MEA performance. First, it influences the internal cell resistivity. The internal cell resistance measurements revealed that reducing the PTFE content from 40% to 10% resulted in a decrease of the internal resistance of the MEA by 25%. Similar trends were also observed in the ex-situ AFM resistivity measurements.

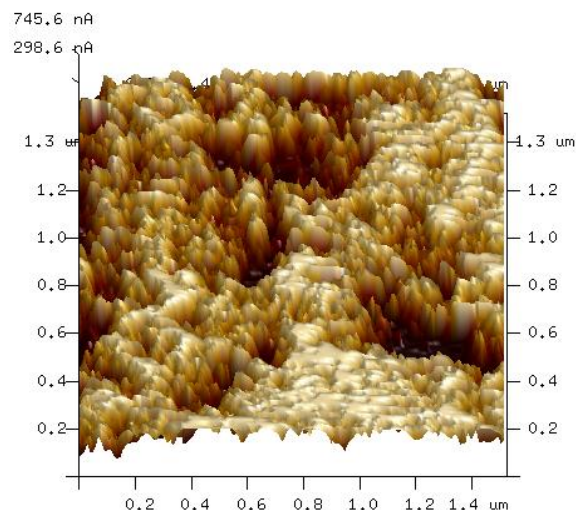


Fig. 2: Locally resolved current distribution

Secondly, and probably even more important for the cell performance, the PTFE content governs the wettability of the electrode. The lower PTFE content leads to a more hydrophilic nature of the surface. In addition, the lower PTFE content tends to create a more porous structure of the electrode. Both properties help enhance the fuel cell performance by improving the phosphoric acid uptake and distribution within the electrode.

References

- [1] Hiesgen, R., Wehl, I., Aleksandrova, E., Roduner, E., Bauder, A. and Friedrich, K. A. (2010), *Nanoscale properties of polymer fuel cell materials - A selected review*. Int. J. Energy Res., 34, 1223-1238.
- [2] Ma, S., Solterbeck, C. H., Odgaard, M., & Skou, E. (2009). *Microscopy studies on proton exchange membrane fuel cell electrodes with different ionomer contents*. Applied Physics A, 96(3), 581-589.