

Vertically-Oriented Polymer Electrolyte Nanofiber Catalyst Support for Polymer Electrolyte Fuel Cells

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High Pt loading and degradation of conventional carbon-supported Pt electrodes still remain as challenges for the mass-production and commercialization of polymer electrolyte fuel cells (PEFCs). In addition, the oxygen reduction reaction (ORR) in the cathode is sluggish and results in large over-potential. One way to improve the ORR is to reduce the oxygen transport resistance by fabricating thin-film electrodes with extended surface catalyst and having no polymer electrolyte binder [1]. Thus, yielding high specific activity and low mass transport resistance. However, such electrodes can suffer from flooding due to low pore volume and high ionic resistances at lower relative humidity [2].

In this paper we present the fabrication and characterization of a novel extended surface electrode with a high surface area catalyst support consisting of vertically-oriented polymer electrolyte composite nanofibers. Pt is conformally deposited onto the nanofibers forming a high roughness factor electrode.

Nanofibers of 200nm diameter and 10 μm height were fabricated by casting a $\text{SiO}_2/\text{Nafion}$ composite solution onto a track-etched polycarbonate template (PCT) with 200 nm nominally straight pores to simultaneously form nanofibers and the solid membrane. The 10-20 nm SiO_2 particles are used to increase the rigidity of the nanofibers. After etching away the template, a thin film of Pt was vacuum deposited directly onto the nanofiber side of the membrane. In another variation, we sputtered Pt onto the PCT prior to casting the membrane, which leaves Pt on the surface of inner Nafion after etching away the PCT and the Pt was later also sputtered onto the nanofibers.

Figure 1 shows a scanning electron microscope (SEM) image of the $\text{SiO}_2/\text{Nafion}$ nanofibers. The surface roughness of the 200nm diameter nanofibers, determined from the PCT manufacturer's specification and SEM is 19 assuming the tortuosity of the PCT pores is 1. Since the nanofibers are not perfectly vertical and are inclined at an angle, sputtering does not uniformly distribute Pt on the bottom surface of the nanofibers. Also sputtering on the template does not deposit Pt throughout the pores. By combing the both sputtering on template and sputtering on nanofibers a better distribution of the Pt on the nanofibers was achieved. This is the major difference between the two variations. However, sputtering on the templates results in higher overall Pt loading.

The ECSAs were obtained for the two electrodes using N_2/H_2 cyclic voltammetry (CV) measurements as shown by Figure 2. The surface roughness of the electrode with the sputter template is significantly higher than that with just sputtering on the nanofibers. Figure 3 shows the polarization curves for the two nanofiber electrodes. From the polarization curves we observe that the activation over-potential is large. One of the reasons for the sputtered template electrode to perform better is the higher loading and Pt surface area. However, when comparing the two electrodes on the basis of Pt surface

area from the ECSAs, the electrode with the sputtered template still performs better than the electrode without template sputtering. These initial results show that the pre-sputtered nanofiber electrode is a viable electrode. The next challenge to address is achieving the desired area-specific activity for the Pt catalyst with a robust nanofiber support.

References

- [1] M. K. Debe, Nature, 486, 43–51 (2012).
- [2] P. K. Sinha, W. Gu, A. Kongkanand, and E. Thompson, J. Electrochem. Soc., 158, B831 (2011).

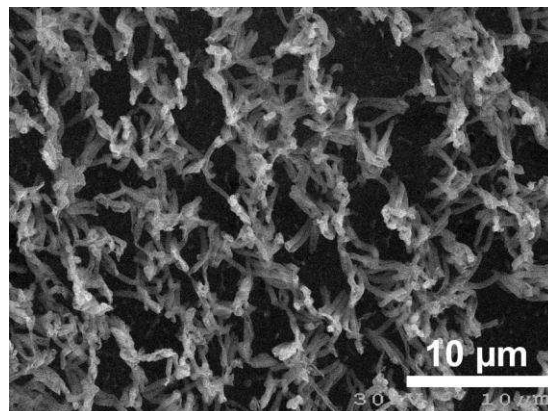


Figure 1: SEM image of the 200nm diameter $\text{SiO}_2/\text{Nafion}$ nanofibers prior to Pt sputtering.

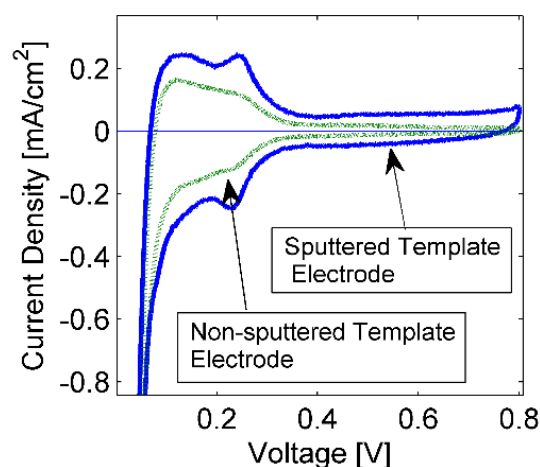


Figure 2: N_2/H_2 CV of the 200nm nanofiber electrodes with hydrogen crossover correction.

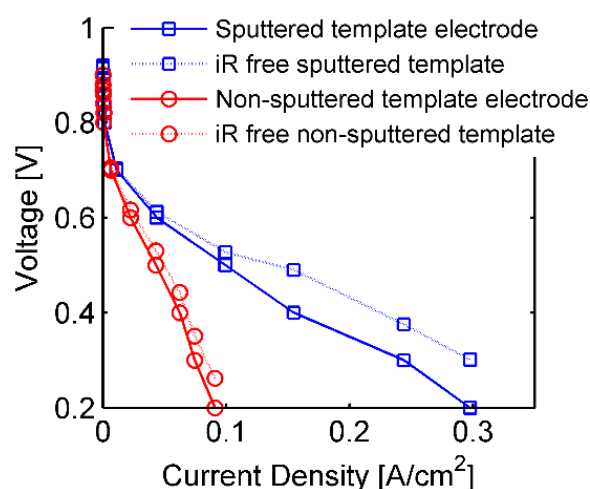


Figure 3: Polarization curve for the pre-sputtered electrode at 80°C, 100%RH and back pressure of 150kPa only on cathode.