Templated Anode Pt-Ru Electrocatalyst for Direct Methanol Fuel Cells

Elise Switzer, Abhaya Datye and Plamen Atanassov
Chemical & Nuclear Engineering Department
University of New Mexico, Albuquerque, NM 87131 (USA), plamen@unm.edu

Introduction

Pt-Ru blacks are commonly used as methanol oxidation electrocatalysts in Direct Methanol Fuel Cells (DMFCs). Noble metal utilization in these catalysts has been traditionally low in comparison to anode catalysts used in hydrogen/air fuel cells. One of the reasons is inefficient mass transport within the fuel cell catalytic layer. Mass transport within this layer can be improved with a new synthetic method to produce nanostructured Pt-Ru catalysts.

One approach to improve noble metal utilization is the synthesis of nanostructured materials via replication of nanostructured silica templates followed by template removal [1-3]. One example of such an approach is the impregnation synthesis of a Pt-Ru bimetallic nanowire network templated by mesoporous silica, specifically SBA-15 [4]. The pore infiltration procedure is extremely labor-intensive and can lead to an inhomogenous distribution of the alloy components in the pores. Therefore, while impregnation synthesis of bimetallic networks represents an interesting material design approach, it is limited in application due to its complexity, parameter variability and time-consuming steps.

We propose an alternative aerosol-based approach wherein mono-disperse silica particles are used to template a Pt-Ru network. Spray pyrolysis is an aerosol synthesis technique and has been extensively applied to the formation of mesoporous silica particles [5-6]. Our approach allows for the synthesis of a material with a pore structure that is pre-determined by the size of the silica template. Thus, by using the process of spray pyrolysis, the templating of Pt-Ru networks can be achieved in less time and with greater control.

Materials and Methods

Mono-disperse silica nanoparticles were used to template the metallic precursors. A metallic precursor solution, which included the silica template, was ultrasonically atomized and underwent spray pyrolysis. As shown in Figure 1a, the aerosolized solution of precursors was transported through a temperature controlled furnace by means of an inert carrier gas. Upon powder collection, the material was reduced in flowing hydrogen. This step was followed by silica template removal by dissolution in a strong base. The resulting nanostructured Pt-Ru network was characterized by Transmission Electron Microscopy (TEM), X-Ray Diffraction (XRD), X-Ray Photoelectron Spectroscopy (XPS), electrochemical and BET surface area measurements.

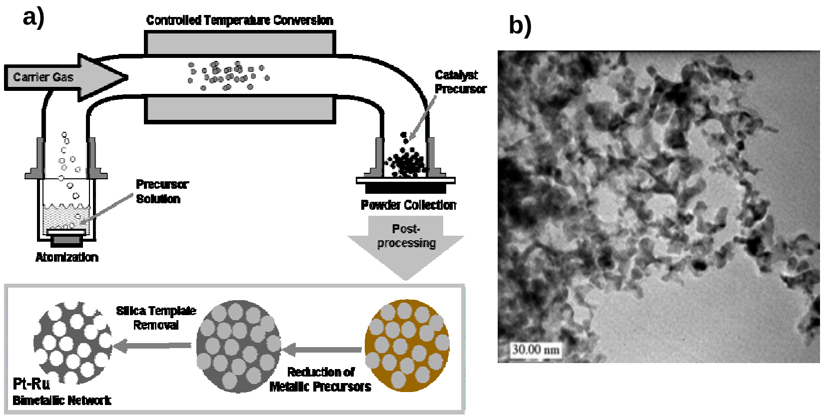

Figure 1. a) Illustration of steps in the synthesis of an aerosol-derived Pt-Ru bimetallic network. b) TEM micrograph showing a templated Pt-Ru network.

Results and Discussion

Figure 1b reveals a highly porous and interconnected Pt-Ru network obtained after silica template removal. The catalysts are composed of face-centered cubic (fcc) Pt-Ru alloy particles as evidenced by XRD. In addition, XPS measurements show that the material has a higher metallic content than commercial Pt-Ru catalysts. Electrochemical data will be presented to show that this network exhibits a high electrocatalytic activity.

Significance

We demonstrate here an aerosol synthesis process to produce nanostructured bimetallic electrocatalysts that are templated by silica nanoparticles. In comparison to previous methods of templating bimetallic networks which are laborious and inefficient, our approach is simple and easily scaled up. Not only is the synthesis process streamlined, but by aerosolizing a solution of the silica along with the Pt and Ru precursors in one step, all phases are in intimate contact during synthesis. This method ensures atomic mixing of Pt and Ru which is crucial for effective electrochemical methanol oxidation.

References

1. Bore, M. ,T.L. Ward, A. Fukuoka, Catalysis Letters 98 (2004) 167.
2. Egan, G.L., J. Yu, C.H. Kim, S.J. Lee, R.E. Schaak, T.E. Mallouk, Advanced Materials 2 (2001) 1040.
3. H.J. Shin, C.H. Ko, R. Ryoo, Journal of Materials Chemistry 11 (2001) 260.
4. Choi, W.C. and S.I. Woo, Journal of Power Sources 124 (2003) 420.
5. Y.Lu, H. Fan, A. Stump, T.L. Ward, T. Reiker, C.J. Brinker, Nature 398 (1999)223.
6. M. T. Bore, S.B. Rathod, T.L. Ward, A.K. Datye, Langmuir 19 (2003) 256.