Fabrication and Evaluation of Platinum/Diamond Composite Electrodes for Electrocatalysis - J. Wang, J. Bennett, and G. Swain (Michigan State University)

No other material shows as much versatility as an electrode as does electrically conducting diamond. The material can be used in electroanalysis to provide sensitive detection of analytes with superb precision and stability; high current density electrolysis (1-10 A/cm^2) in aggressive solution environments without any microstructural or morphological degradation; and spectroelectrochemistry as an optically transparent electrode.

There is a technological need to develop new support materials for electrocatalytic metal particles. Currently, electrocatalysts are often supported on high surface area, sp^2-bonded carbonaceous supports. These support materials tend to undergo morphological and microstructural alterations over a wide range of anodic potentials, changes which lead to increased electrical resistivity and lost catalytic activity. For example, support degradation can occur at the cathode (oxygen reduction electrode) in the acidic environment of polymer electrolyte membrane fuel cells. New support materials that offer excellent electrical conductivity and dimensional stability are required.

Our group has been investigating the utility of electrically conducting diamond thin films as a new support material (1-3). Specifically, a metal/diamond composite electrode has been prepared using electrically conducting and corrosion resistant boron-doped diamond. Fabrication of the composite electrode involves a three-step process, as shown in Figure 1: (i) continuous diamond thin film deposition on a substrate, (ii) electrodeposition of Pt catalyst particles on the diamond surface, and (iii) short-term diamond deposition to entrap the metal particles into the surface microstructure. The process results in a conductive, morphologically, and microstructurally stable composite electrode containing metal particles of controlled composition, size, and catalytic activity. The catalyst particle size ranges from 10 to 350 nm, with a distribution of ca. 10^9 cm^{-2}. The estimated loading is 100 $\mu g/cm^2$. Figure 2 shows an SEM image of highly dispersed Pt particles on the diamond surface, ca. 50 nm, deposited from a solution of 1 mM K_2PtCl_6 + 0.1 M $HClO_4$. Pulsed galvanostatic deposition was employed for 25 pulses, 1 s duration at 0.5 mA/cm^2. The composite electrode is extremely stable, both structurally and catalytically, during a 2 h polarization in 85% H_3PO_4 at 170^0C and 0.1 A/cm^2.

The electrode's catalytic activity was evaluated using the O_2 reduction reaction at room temperature in 0.1 M solutions of H_3PO_4, H_2SO_4, and $HClO_4$. Tafel slopes of -63 to -80 mV/dec were observed at low overpotentials, with the lowest slope in $HClO_4$ and highest in H_3PO_4. The exchange current density ranged from 10^{-12} to 10^{-10} A/cm^2, and increased in the order of $H_3PO_4 < H_2SO_4 < HClO_4$.

The presentation will discuss (i) the fabrication of the composite electrodes, (ii) the stability of the electrodes during exposure to harsh chemical conditions, and (iii) the electrocatalytic activity of the electrodes for the oxygen reduction reaction.

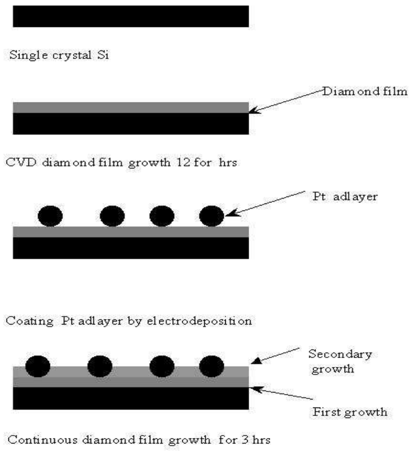

Figure 1. Schematic for the preparation of the platinum/diamond composite electrodes.

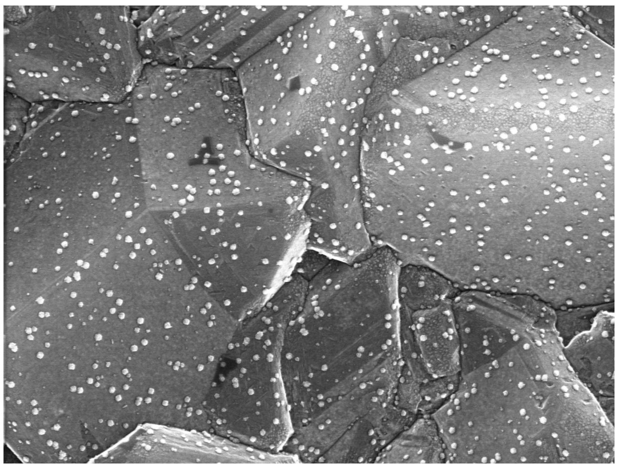

Figure 2. SEM images of Pt electrochemically dispersed on the diamond surface.

References

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