

Corrosion Analysis of Mesoporous Carbon Supports for PEM Fuel Cell Applications

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The degradation of electrocatalysts in proton exchange membrane fuel cells (PEMFCs), which arises primarily from the corrosion of the carbon support and the agglomeration of the catalytic nanoparticles, has a deleterious effect on the lifetime and cost of PEMFCs. Therefore, understanding the corrosion behavior of carbon supports through the use of a reliable test method is critical to the development of durable PEMFCs^{1,2}. In this study, a rigorous testing method was developed for the evaluation of the corrosion resistance of conventional microporous Vulcan carbon XC-72R (VC) and two ordered mesoporous carbons (OMCs), formed using aromatic vs. non-aromatic precursors.

The OMCs were synthesized (Fig. 1) by using anthracene and sucrose precursors, denoted as OMC-A and OMC-S, respectively. The synthesis was based on the method reported by Ryoo, et al³, except that an in-house hexagonal mesoporous silica (HMS), having a wormhole structure, was used as the hard template. The preparation of OMC-S and OMC-A has been reported previously^{4,5,6}.

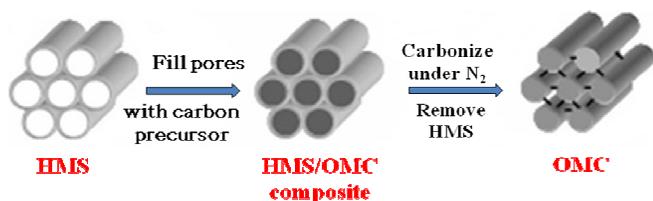


Fig. 1. Schematic of OMC synthesis.

The synthesized OMC supports, as well as VC, were characterized using elemental analysis, N₂ adsorption/desorption isotherms, X-ray diffraction (XRD), and thermogravimetric analysis (TGA) methods. The results indicated that the two OMCs have similar bimodal pore sizes (1.8 and 3.3 nm dia.) and pore volumes (~1.2 mL/g), but that they have a lower degree of graphitization and less resistance to air oxidation at high temperatures than VC.

The corrosion resistance of VC and OMCs was evaluated by cyclic voltammetry (CV) and potential stepping protocols, carried out in a three-electrode cell containing 0.5 M H₂SO₄, a platinumized Pt mesh as the counter electrode, and a reversible hydrogen (RHE) reference electrode. For the working electrode (WE) preparation, 0.01 g of carbon powder was dispersed into 0.4 g of 1 wt % Nafion/isopropanol solution and the mixture was sonicated for at least 30 min to obtain a carbon/Nafion ink. 14 μ L of the ink was deposited onto a glassy carbon (GC) disc electrode (surface area = 0.38 cm²) and then dried at RT conditions to form a carbon film. The OMCs and VC were then subjected to a cleaning step during which the carbon capacitance (both double layer and pseudo-capacitance) was measured. The E/t protocol, shown in Figure 2, involved a potential-step cycling sequence, with an upper potential of 0.8 V for 50 s and a lower potential of 0.2 V for 10 s, for a total of 18 cycles. The corrosion protocol was similar to this, except that the upper and lower potentials were 1.4 V and 0.8 V, respectively. Cyclic voltammetry in N₂-saturated 0.5 M H₂SO₄ (10 mV/s) was carried out both prior to and after the capacitance and corrosion measurements (Fig. 2).

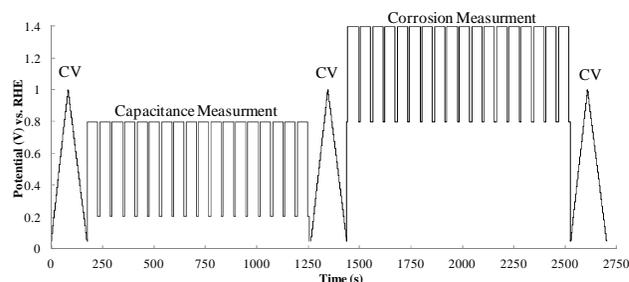


Fig. 2. Potential-time perturbation used during carbon capacitance [0.8 V (50 s)-0.2 V (10 s)] and corrosion [1.4 V (50 s)-0.8 V (10 s)] measurements.

The CV results (Fig. 3) have shown that the increase in pseudo-capacitance and double layer capacitance for carbons with a higher degree of graphitization is smaller than for carbons with a lower degree of graphitization, i.e., VC > OMC-A > OMC-S, which matches well with the XRD and TGA results.

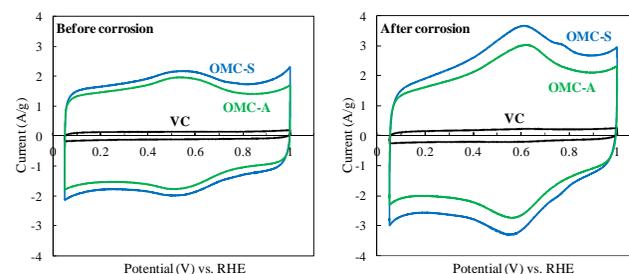


Fig. 3. CVs of carbons before and after corrosion.

Since the CV results do not fully explain the corrosion process, the charge passed during polarization at 1.4 V, as well as the CO₂ produced, were both monitored. The details of these experiments and the results obtained will be addressed in the presentation.

Acknowledgements

We gratefully acknowledge the Natural Sciences and Engineering Research Council of Canada (NSERC) Strategic Research Project Program and Ballard Power Systems for the financial support of this work, as well as Alberta Innovates Technology Futures (AITF) for the scholarship support of FF. We also thank Samuel Aquino and Dr. Hebert Molero for the BET measurements, Hala Handal and Dr. V. Thangadurai for TGA testing, as well as Dr. Scott Paulson and other members of the Birss group for helpful discussions.

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