

## **The Corrosion of Metallic Components in Fuel Cells**

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When one is considering the mass production of fuel cells, the manufacturability of each component is very important. To obtain the economy of mass production, approximately one million fuel cell systems need to be manufactured each year, that is almost 100,000 per month. Assuming 120 bipolar plates per stack, that is 12 million bipolar plates per month or 400,000 per day! That means these plates must be injection molded or stamped from metal stock. Injection molding requires a cycle time of less than 10 seconds and conductivity similar to POCO graphite. Because of the need for rapid production, and high conductivity, metal stock is a good possibility. However when considering metal stock, a number of problem arise from the possibility of corrosion leading to failure of the stack. Because of the unique and complex environment in a fuel cell stack, the importance of corrosion testing cannot be understated. A fuel cell stack has a humid environment that includes both oxidizing and reducing atmospheres, small amounts of fluoride leach from the membrane, and other halides, as well as SO<sub>x</sub>, and NO<sub>x</sub> are available from the atmosphere. These conditions can interact in a complex way to attack the metal plates leading to corrosion. Additionally, if the metal plates contain iron, it can leach out into the membrane blocking the sulfonic acid sites, thereby reducing the conductivity of the membrane. Iron can also act as a catalytic poison to degrade the membrane. The goal of this research is to determine corrosion mechanisms for various metal alloy compositions, and to develop techniques for long term corrosion protection for thin metal foils.

The usual way in which stainless steels and titanium are protected is from an inert oxide coat that naturally forms on the surface. Unfortunately, these oxides are typically insulating, leading to ohmic losses within the cell. Additionally, the surface resistance also affects the force needed to hold the cell plates together. Higher resistivity requires a higher force and corresponding thicker and more massive endplates. If these oxides could be made conducting, then perhaps they would not only protect the underlying metal plates from corrosion, but also provide a conducting pathway for the flow of current. This would also reduce the size of the endplates, increasing the energy density of the fuel cell.

Various groups have looked at the corrosion resistance of a number of stainless steel formulations. Hornung and Kappelt (from Siemens) studied Fe-based alloys for construction of bipolar plates (1). Their goal was to replace gold-coated nickel bipolar plates with low cost Fe-based alloys. They concluded, with regards to corrosion resistance, that Fe-based alloys have similar characteristics as the nickel-based alloys, However, only the gold-coated plates gave contact resistances that were low enough for fuel cell performance. Davies, et.al., looked at electrical resistance of the surface oxide films for three stainless steel alloys, 310, 316, and 904L (2). All these films were shown to be resistive and the resistive losses could be correlated with the thickness of the film. The performance increased (due to a lower surface film resistance) in the order  $316 < 310 < 904L$ . They concluded that the thickness of the film was thinner in alloys containing higher concentrations of nickel and chromium. They also mention a proprietary low surface resistant coating for 316 stainless steel that increased cell performance. As expected they determined that the bulk resistivity is insignificant as compared to the resistivity of the passivating film.

Most of the testing of these plates has been in the 1000-3000 hour range, and for automotive use the lifetime needs to be at least 5000 operational hours and for stationary systems greater than 50,000 hours. Cleghorn et. al., commented that while stainless steel systems showed no apparent effects from corrosion after 1000 h of testing, some form of surface treatment may be required to achieve extended long-term stability (3).

Developing a conducting passivating film for metal based bipolar plates would greatly enhance the performance of the fuel cell and address the issue of the bipolar plate manufacturability (4). It may also be possible, with proper choice of conductive coating, to protect the Nafion membrane from transition metal ion poisoning. NREL is unique in having a long experience in conducting

oxides due to their use in various types of solar cells. For example, conductive tin oxide, used as the current collector for solar cells, may offer the appropriate protection and give high conductivity. This includes SnO:F which would likely be stable in the presence of fluoride. Other coatings of interest are ITO (indium tin oxide), ZnO and SnO<sub>2</sub>. Tungsten trioxide, used in electrochromic devices, becomes conducting in the presence of hydrogen and perhaps could be used as a protective coating for the hydrogen side of the plate. In solar cells, these coatings are deposited on glass and on stainless steel in large areas and at high volume. For this work, NREL is combining its expertise in corrosion testing with its unique capability in conducting oxides.

A laboratory has been set-up to test the corrosion resistance of these coating and experiments are underway.

### **References**

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