U.S. Department of Energy • Office of Energy Efficiency and Renewable Energy
Oak Ridge National Laboratory

Fuel Cell Stack Subsystem and Components

Surface Modification to Enable Metallic Bipolar Plates

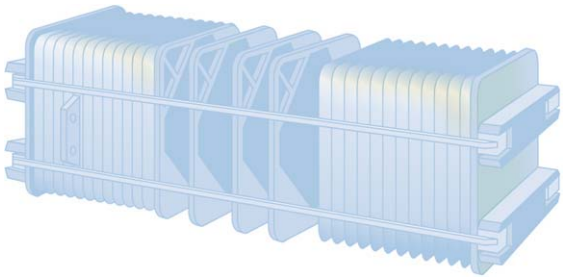
Background

Proton exchange membrane fuel cells (PEMFCs) are of interest for power generation due to their high efficiency and near-zero emissions. Cost remains a key barrier to their widespread commercialization. One of the most expensive components in PEMFCs are the bipolar plates, which serve to electrically connect the anode of one cell to the cathode of the next into a stack to achieve a useful voltage. Thin metallic bipolar plates offer the potential for significantly lower cost than currently used machined graphite bipolar plates and reduced weight/volume and better performance than developmental polymer/carbon fiber and graphite composite bipolar plates. However, inadequate corrosion resistance can lead to high electrical resistance and/or contaminate the polymer membrane, both of which can significantly degrade performance.

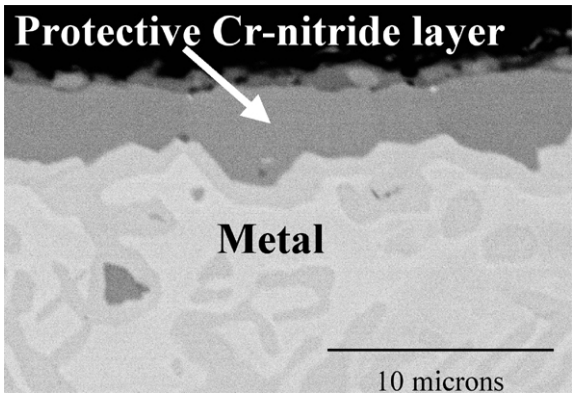
Efforts at Oak Ridge National Laboratory (ORNL) are directed at developing a Cr-bearing alloy that upon thermally nitriding will form an electrically conductive and corrosion-resistant Cr-nitride surface layer to protect the material for use as PEMFC bipolar plates. The main advantage of this approach is the potential to form continuous, defect-free surface layers on complex shaped components. Conventional coating methods typically leave pin-hole through-thickness defects that are not sufficiently protective in corrosive environments, like fuel cells.

The Technology

Proof of principle experimentation has focused on nitridation of a model Ni-50Cr wt.% alloy. Ni is an ideal alloy base to start with because its low reactivity with nitrogen minimizes the potential for interfering with the formation of the desired protective Cr-nitride surface layer. It is also widely available, relatively inexpensive, and exhibits excellent ductility and manufacturability. Evaluation of nitrided Ni-50Cr in fuel cell environments was conducted in collaboration with Los Alamos National Laboratory and the National Renewable Energy Laboratory. Nitridation of Ni-50Cr resulted in a significant decrease in



Paving the way toward a hydrogen economy and net-zero carbon energy future



Cross-section showing thermally nitrided surface of Ni-50Cr

contact resistance, to a value less than 20 mΩ-cm^2 at loads of 100-150 N/cm^2, which is an order of magnitude lower than that of candidate stainless steel bipolar plate alloys such as type 316. The nitrided Ni-50Cr exhibited excellent corrosion resistance, little metal ion dissolution, and negligible contact resistance increase over the course of a 4100 h exposure in 80°C sulfuric acid environments designed to simulate anodic and cathodic bipolar plate operating conditions. 50 cm^2 active area anode and cathode plates were manufactured from nitrided Ni-50Cr and successfully completed 1000 hours of fuel cell operation at 0.7V, with stable (low) interfacial contact resistance and levels of metallic ion contamination in the range of only 0.01 to 0.3 x 10^{-6} g/cm^2. This level of contamination is comparable to that achieved with nonmetal bipolar plates, and indicates inert and protective behavior by the Cr-nitride surface with complete protection of the flow-field features. Collectively, these results establish the viability of thermal nitridation/thermally grown Cr-nitrides to protect metallic bipolar plates.

Commercialization

The nitridation approach is inexpensive and can be readily implemented with existing industrial equipment. The model Ni-50Cr model alloy is, however, too expensive for many PEMFC applications. Work is therefore focused on developing less expensive, lower Cr-containing alloys with Fe/Ni bases (or identifying suitable commercially available alloys) that can form a similar protective Cr-nitride surface on thermal nitridation. Test coupons and plates of nitrided alloys are being supplied to a number of fuel cell manufacturers and end-users for evaluation.

Benefits

Pin-hole defect free coating

Amenable to high-volume manufacturing techniques

Thin metallic bipolar plates translate into higher power density fuel cell stacks

Where Can I Find More Information?

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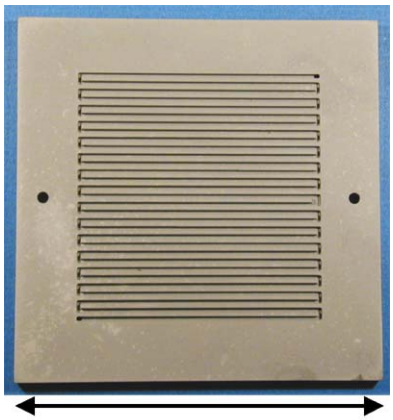

4”

Nitrided Ni-50Cr plate

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