

A LOW CTE INTERMETALLIC BIPOLAR PLATE

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Fabrication of a structurally stable, high-temperature solid oxide fuel cell is hindered by the mismatch in material properties between component materials (1,2,3). Specifically, the mismatch in thermal expansion between the bipolar plate and ceramic electrode/electrolyte materials promotes fracture and delamination. This problem is exacerbated by the requirements of maintaining a conductive path through the electrodes and bipolar plate at high operating temperatures.

A solution to these material problems is the development of a lightweight, low coefficient of thermal expansion (CTE) bipolar plate that serves as the structural substrate and electrical interconnect to the relatively thin ceramic SOFC coatings. Intermetallic materials satisfy the electrical, structural and thermal stability requirements for operating temperatures in the 900 – 1000 °C range but the CTE remains high and there are fabrication problems.

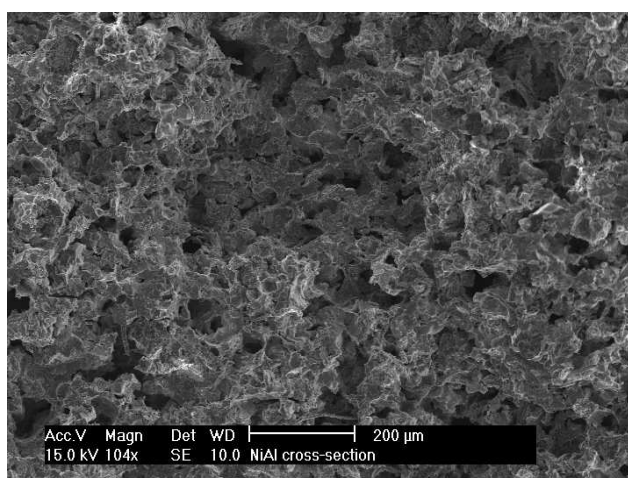


Figure 1. Micrograph of NiAl microstructure showing large pores in microstructure.

The INEEL has been developing a nickel-aluminide (NiAl) intermetallic system as a bipolar plate. A nickel-based intermetallic was chosen since it is catalytic for reforming hydrocarbon fuels. By using inert, ceramic filler materials the formation reaction of the intermetallic NiAl system is controlled resulting in net-shape formed plates (final dimensions are the same as the original green-formed piece). The ceramic material exhibited high thermal stability and its added volume was low enough to allow the intermetallic constituents to form a strong, conductive, net-shape plate. A final volume of 35 vol% - 40 vol% ceramic filler powder was adequate for lowering the plate CTE to $\sim 12 \times 10^{-6}$ cm/cm-°C (similar to the zirconia electrolyte used in our SOFC design) at planned cell operating temperature.

One of the main benefits of the relatively high filler volume was that the oxide powder physically diluted the nickel-aluminide combustion synthesis reaction. By preventing development of a high speed reaction front, the incipient melting of the Ni during the reaction does not occur and dimensional stability of the part is maintained. In addition, the volume reduction involved in the reaction $\text{Al} + \text{Ni} \rightarrow \text{NiAl}$ causes the formation of

voids resulting in an extremely porous microstructure, Fig. 1.

Dilution has the effect of slowing the reaction front as it sweeps through the powders and reducing the overall temperature of the component resulting in significantly less warping and physical contraction of the intermetallic material. This produces a net-shaped component with overall dimensional changes less than 0.10-mm after reaction. Components with complex geometry, tight tolerances, and no warping are easily produced.

The porous microstructure makes the plate stable to thermal shock. Since the ceramic electrolyte and electrode coatings are deposited by plasma techniques, the ability of the NiAl substrate to withstand extreme thermal shock is critical for producing a stable cell.

To protect the NiAl intermetallic from oxidation at the high operating temperature a protective ceramic oxide coating is plasma deposited on the cathode side of the cell. The Lanthanum-Strontium-Chromate (LSC) coating is deposited as a dense, relatively thick coating ($\sim 200 - 300 \mu\text{m}$) which protects the NiAl from oxygen in the cathode. The NiAl structural plate has demonstrated that it is capable of withstanding the extremely high temperatures reached during deposition of LSC (~ 1200 °C) without cracking, breaking apart, or any apparent damage to the coating.

The relatively coarse, porous microstructure of the NiAl provides an extremely rough interface for deposition of the LSC layer. This results in significant mechanical interlocking between the two disparate materials creating a very strong bond, Fig. 2. This strong bond between the LSC layer and NiAl plate provides a solid substrate foundation for the subsequent deposition of the electrolyte and electrode materials (on top of the LSC).

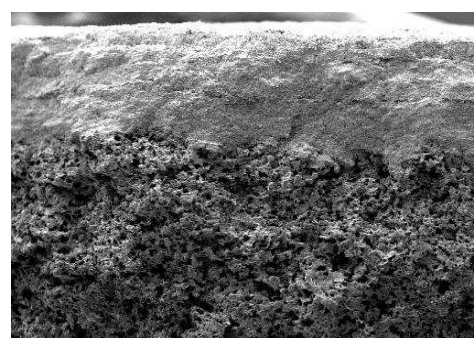


Figure 2. Micrograph of LSC/NiAl interface showing mechanical interlocking.

The composite structure of the LSC coated NiAl plate forms the complete bipolar plate used in the SOFC design fabricated at the INEEL. By minimizing induced stresses resulting from thermal shock or thermal expansion mismatches the LSC coating is kept crack free, allowing full protection of the intermetallic NiAl microstructure from oxidation.

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