Fabrication Methods of a Leaky SOFC Design

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Fabrication methods are discussed for the separate components comprising the INEEL-designed Solid Oxide Fuel Cell (SOFC). Each layer/component within the cell has distinct characteristics tailored for a specific function such as a fully dense electrolyte for hermetic sealing or a porous electrode material for maximum gas transportation (1). Specific microstructural characteristics have been achieved using plasma spray techniques with multiple material injection systems to create material and porosity gradients within the deposits. Creating microstructural gradients within each distinct material layer has succeeded in reducing material mismatch issues while satisfying the porosity, structural strength, and electrochemical efficiency requirements (2).

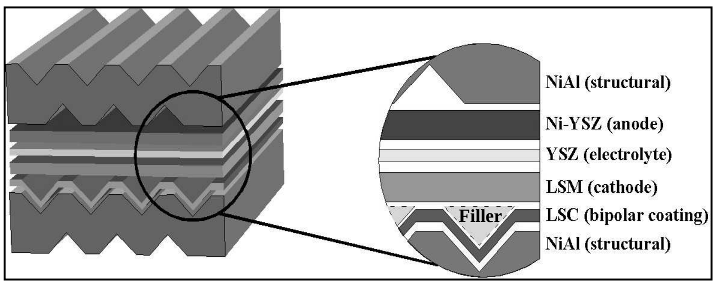

Figure 1. Exploded schematic view showing layers of a single SOFC cell.

The ceramic electrode, electrolyte, and interconnect layers are deposited on a planar intermetallic bipolar plate using plasma spray. For our planar SOFC design, plasma deposition allows the greatest flexibility in fabricating graded layers. To form the unique layer microstructures combinations of dry powder, slurry suspension, and liquid injection material transport deposition techniques are used.

Figure 1 shows a schematic of all layers that are formed for the INEEL fuel cell design. The Lanthanum-Strontium-Chromate (LSC) layer in combination with the thick, porous nickel-aluminide (NiAl) structural plate forms a bipolar plate which acts as a stable substrate for all other subsequent deposited layers. The NiAl plate has extensive porosity and surface roughness which allows significant bonding to occur between the LSC ceramic and NiAl intermetallic through mechanical interlocking. This strong bond creates structural stability and enhances electrical conductivity across the interface.

The LSC coated air channels are filled with a removable filler material. A composite of both graphite particles and furfural alcohol is injected into the channels and carbonized to form a thermally stable filler that can withstand the plasma spray deposition process but can be easily removed by oxidation of the carbon material once the electrolyte and electrode layers have been deposited.

After filling the air channels with the removable filler material a graded, porous LSM coating is sprayed directly onto the LSC layer and filled air channels. Combinations of dry powder, slurry suspension, and liquid injection plasma deposition techniques were used to deposit graded porosity electrode layers and the material gradients at each layer interface. A pneumatic powder feed system was used to deposit large (~ 35 – 50-µm) particles creating a coarse microstructure. Small particles (~ 0.5 - 1.7-µm) suspended in a slurry were used to produce a finer porosity (3) while an extremely fine microstructure (particle diameters ~ 100 - 250 nm) used in the interface areas directly adjacent to the electrolyte was produced by Liquid Plasma Injection Deposition (LIPD) using chemical solutions.

A 2-mm wide zirconia seal coat (Yttrium-Stabilized-Zirconia, YSZ) was deposited on top of the LSM coating along the outer edges of the cell. The seal coat is a dense, thick strip of stabilized zirconia that provides a frame to bond to the thin, hermetic zirconia electrolyte. Our SOFC design allows for some controlled leakage of spent fuel from the cells (4) which eliminates the stringent requirement of perfect hermetic edge seals. However, a fully dense electrolyte is required to eliminate gas leakage to the cathode and anode sides of the cell. A stabilized zirconia film is deposited through a special chemical vapor deposition (CVD) technique. The extremely thin (10 – 20 µm), hermetic layer allows easy transport of oxygen ions through the electrolyte for maximum efficiency.

The last layer deposited in a single cell is the graded porosity anode (nickel-YSZ) layer adjacent to the zirconia electrolyte. Deposition varies somewhat from the cathode in that two constituents (nickel and YSZ) are injected into the plasma simultaneously. All other parameters are similar to the cathode deposition.

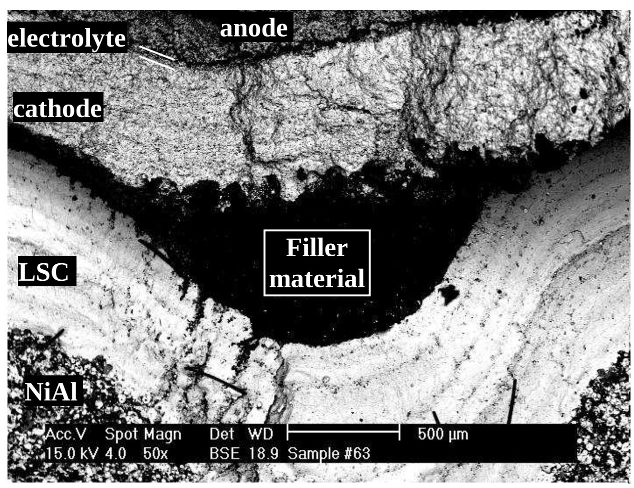

Figure 2. Backscatter image of fracture surface showing all deposited layers in a single cell

Finally, the completed single cells are joined at the edge seals using a brazing compound to form a stack. The braze joins the fuel side of the NiAl to the anode layer. Successful braze joints have been fabricated using precious metal braze compounds but to keep future costs of fabrication low cobalt-based brazes have also been used successfully.

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