Carbon Composite Bipolar Plate for PEM Fuel Cells

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The ORNL carbon composite bipolar plate effort has achieved several programmatic goals in scaling to size, electrical properties, cell performance, strength, and of particular importance, weight (0.96 g/cm^3). Single-sided components 1.5 mm in thickness and two-sided plates 3 mm in thickness with 100 cm^2 active area have been produced. It has been demonstrated that projected costs would meet program goals.

Fibrous component preforms for the bipolar plate are prepared by slurry molding techniques using 400-μm carbon fibers (Amoco DKD-x mesophase pitch fiber) in water containing phenolic resin. The approach is such that a vacuum molding process produces a low density preform material. A phenolic binder is used to provide green strength, and which also assists in providing geometric stability after an initial cure.

The surface of the preform is sealed using a chemical vapor infiltration (CVI) technique in which carbon is deposited on the near-surface fibers sufficient to make the surface hermetic. This is accomplished by placing the preforms in a furnace which is heated 1400-1500°C and methane under reduced pressure is allowed to flow over the component. The hydrocarbon reacts and deposits carbon on the exposed fibers of the preform, and when sufficient deposition has occurred the surface becomes sealed. Thus the infiltrated carbon provides both an impermeable surface as well as the necessary electrical conductivity so that power can be obtained from the cell. Processing times are in the range of 5 h. Initial specimens were provided to LANL for determining bulk conductivity. The values were measured by four point probe to be 200-300 S/cm. Surface resistivity measured at ORNL was 12.2±4.2 Ω/cm as compared to POCO graphite having 7.8±2.62 Ω/cm.

Prototypical 100-cm^2 active area plates were prepared to the specifications provided by LANL. The flow field was machined for these initial developmental components. A single-sided, 100-cm^2 active area plate was prepared and forwarded to LANL for evaluation in a PEM fuel cell. The plate tested very well exhibiting good kinetics and exceptionally low cell resistance. An observed drop-off in cell voltage at high currents was likely due to leakage from seals around the edge of the plate in the cell (Fig. 1).

The mechanical properties of the bipolar plate material were tested in biaxial flexure. Samples of material 3.8 cm in diameter (disks) and 1.5 mm in thickness, with one side sealed were prepared. A biaxial load fixture was fabricated which applies a load to a ring centered on the disk, with the edge of the disk supported by a second ring. The stress is applied such that the sealed surface is in tension. The results indicate the material has a strength of 175±26 MPa (25.3±3.8 ksi). To indicate the onset of cracking the fixture was fitted with an acoustic detector and acoustic emissions did indicate cracking at relatively low loads. However, samples that had been subjected to 100 MPa stresses and which

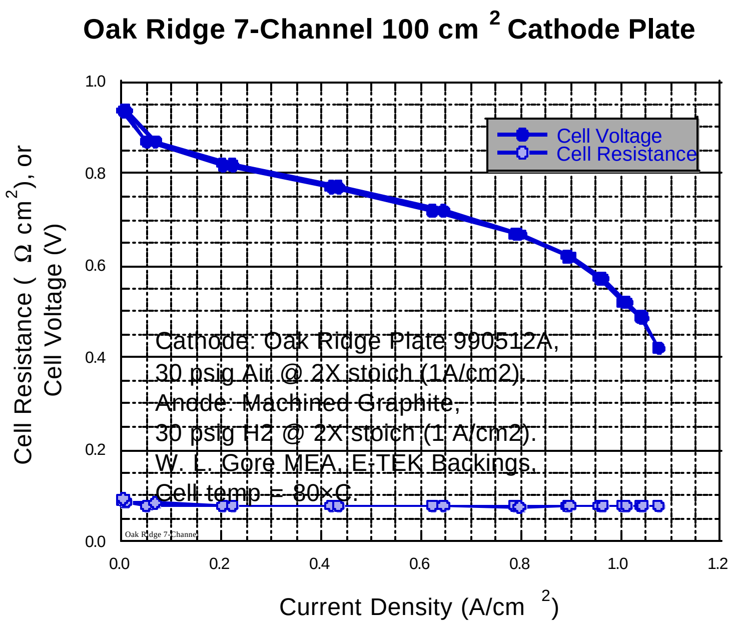

Fig. 5. Fuel cell resistance and voltage test results from LANL using the 100-cm^2 active area bipolar plate sample.

emitted acoustic signals during testing were found not to suffer through-thickness gas leakage. Thus the material can be stressed to close to failure strength without loss of integrity.

The bipolar plates tested to date have been fabricated with machined flow fields. In production these plates would need to use embossed or otherwise impressed features as machining would be too costly. A preliminary evaluation of the ability to emboss features in the composite material prior to infiltration with carbon was performed. A small aluminum mold was fabricated with 0.78 mm (31 mil) deep and wide channels. The mold was used to impress channels into the preform material. It was demonstrated that the preform material can take impressed features with the necessary tolerances and dimensions.

In summary it has been established that the carbon composite bipolar plate approach results in a component with:

- significantly higher strength than competing materials
- component weight about half that of other materials
- very high electronic conductivity
- very low cell resistance
- good cell kinetics
- gas impermeability
- materials and processing costs that meet goals
- ability to be scaled to prototype dimensions