

POLYMERIC COMPOSITE BIPOLAR PLATES FOR PROTON EXCHANGE MEMBRANE FUEL CELLS

Bipolar plate is a multifunctional component within the PEM fuel cell stack. It connects and separates the individual fuel cells in series to form a fuel cell stack with required voltage, aids uniform distribution of fuel gas and oxygen over the whole active surface area of the membrane-electrode assemblies (MEA), conducts electrical current from the anode of one cell to the cathode of the next, facilitates water management within the cell, supports thin membrane and electrodes and clamping forces for the stack assembly, among other things.

The polymer composite materials can alleviate some of the concerns related to weight and volume, and hence the cost of fuel cell stacks. Conventional pure graphite bipolar plates (Figure 1) contribute significantly to the cost and weight of PEM fuel cell stacks. Metals such as stainless steel and metal alloys – alternatives favored by industry – are not preferable because of corrosion related issues. Polymer composite bipolar plates can replace heavier graphite bipolar plate in next generation PEM fuel cells.

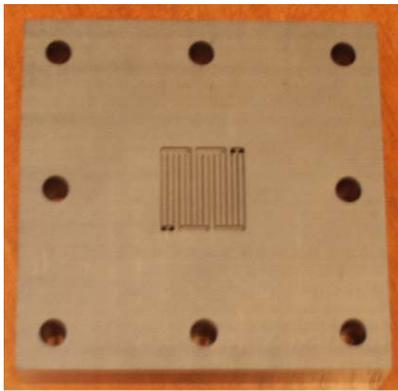


Figure 1. Graphite bipolar plate

In this work, carbon-filled thermosetting epoxy composites (Figure 2) are investigated as an alternative material for bipolar plates to meet the US Department of Energy (DOE) targets on both in-plane and through-plane conductivity, and to offer mechanical integrity at temperatures higher than 150°C. The high in-plane and through-plane conductivities (Figure 3) are obtained from the synergistic effects of highly conductive expanded graphite (EG) and carbon black (CB) particles without compromise on mechanical properties.

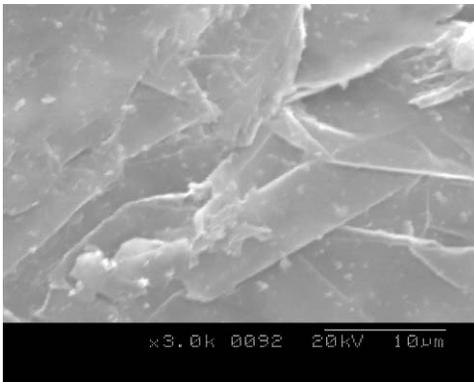


Figure 2. SEM of epoxy-expanded graphite-carbon black composite

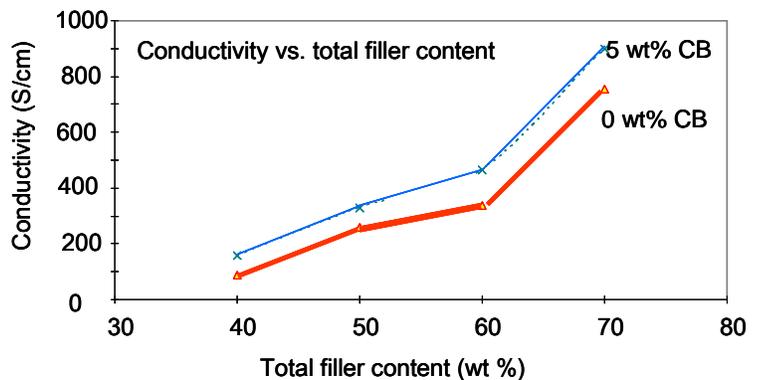


Figure 3. Electrical conductivity of epoxy-expanded graphite-carbon black composites as function of total filler loading.

Results to date:

- The study showed that highly conductive epoxy composites can be developed using synergistic combinations of EG and CB as conductive fillers.
- The data on electrical conductivity, thermal and mechanical properties, and stability against long exposure to acid solution indicate that these composites will be very suitable for bipolar plates in PEM hydrogen fuel cells. Specifically, the composites developed in this study exceeded many specifications set by the industry, e.g., these provide in-plane conductivity ~200-500 S/cm, high through-plane conductivity of 77 S/cm, low area specific resistance, high glass transition temperatures ($T_g \sim 180^\circ\text{C}$) and high thermal degradation temperatures ($T_2 \sim 415^\circ\text{C}$).
- It was seen that water diffusion in both unfilled epoxy resin and composites followed linear Fickian diffusion behavior. It was also seen that incorporation of EG rendered composites more hydrophobic and significantly decreased the maximum water uptake and water diffusivity. Accordingly the composites studied in this work would yield favorable performance for water management in PEM fuel cells.
- It was seen that composites were dimensionally stable and did not undergo changes in surface appearance and in morphology. The water desorption profile showed that water absorption process was reversible. DSC and TGA data indicated that the composites would be thermally and chemically stable under the PEM fuel cell service conditions. Also long term hygrothermal exposure would have very little effects on electrical conductivity and mechanical properties of the epoxy composites.

Papers published:

1. Du, L., Jana, S.C. 2008 Hygrothermal Effects on Properties of Highly Conductive Epoxy/Graphite Composites for applications as bipolar plates. *J. Power Sources*, in review.
2. Du, L., Jana, S.C. 2007 Highly conductive epoxy/graphite composites for bipolar plates in proton exchange membrane fuel cells. *Journal of Power Sources*, 172, 734-741.
3. Du, L., Jana, S.C., 2007 Highly conductive epoxy composites for application as bipolar plates in proton exchange membrane fuel cells (PEMFCs), *SPE ANTEC 65*, 235-239.
4. Du, L., Jana, S.C., 2006, Carbon-filled polymer composites bipolar plates for proton exchange membrane fuel cells (PEMFC), *SPE ANTEC 64*, 456-460.