Synergistic Effects of Carbon Fillers on Tensile and Flexural Properties in Liquid-Crystal Polymer Based Resins

Julia A. King,1 Jason M. Keith,1 Odell L. Glenn Jr.,1 Ibrahim Miskioglu,2 Andrew J. Cole,1 Scott R. McLaughlin,1 Rachel M. Pagel1

1Department of Chemical Engineering, Michigan Technological University, Houghton, Michigan 49931-1295
2Department of Mechanical Engineering and Engineering Mechanics, Michigan Technological University, Houghton, Michigan 49931-1295

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ABSTRACT: One emerging market for thermally and electrically conductive resins is bipolar plates for use in fuel cells. Adding carbon fillers to thermoplastic resins increases the composite thermal and electrical conductivity. These fillers have an effect on the composite tensile and flexural properties, which are also important for bipolar plates. In this study, various amounts of three different types of carbon (carbon black, synthetic graphite particles, and carbon fibers) were added to Vectra A950RX liquid-crystal polymer. In addition, composites containing combinations of fillers were also investigated via a factorial design. The tensile and flexural properties of the resulting composites were then measured. The objective of this study was to determine the effects and interactions of each filler with respect to the tensile and flexural properties. The addition of carbon black caused the tensile and flexural properties to decrease. Adding synthetic graphite particles caused the tensile and flexural modulus to increase. The addition of carbon fiber caused the tensile and flexural modulus and ultimate flexural strength to increase. In many cases, combining two different fillers caused a statistically significant effect on composite tensile and flexural properties at the 95% confidence level. For example, when 40 wt% synthetic graphite particles and 4 wt% carbon black were combined, the composite ultimate tensile and flexural strength increased more than what would be expected from the individual additive effect of each single filler. It is possible that linkages were formed between the carbon black and synthetic graphite particles that resulted in improved ultimate tensile and flexural strength.

Key words: composites; fillers; liquid-crystalline polymers (LCP); mechanical properties; tension

INTRODUCTION
Most polymer resins are electrically and thermally insulating. Increasing the conductivity of these resins allows them to be used in other applications. One emerging market for electrically and thermally conductive resins is bipolar plates for use in fuel cells. The bipolar plate separates one cell from the next, with this plate carrying hydrogen gas on one side and air (oxygen) on the other side. Bipolar plates require high thermal and electrical conductivity (to conduct heat and to minimize ohmic losses), low gas permeability, good dimensional stability, and moderate tensile and flexural properties. The U.S. Department of Energy has set a target flexural strength for bipolar plates of 25 MPa.1 PlugPower has set a desired flexural strength of greater than 59 MPa and a desired tensile strength of greater than 41 MPa.2

One approach to improving the electrical and thermal conductivity of a polymer is the addition of a conductive filler material, such as carbon or metal.3–16 Currently, a single type of graphite powder (often 60 wt%) is typically used in thermosetting resins (often a vinyl ester) to produce a thermally and electrically conductive bipolar plate material.17–20 Thermosetting resins cannot be remelted.

The addition of conductive fillers can degrade the mechanical properties of the conductive composite. Hence, these mechanical properties cannot be ignored. Thongruang et al.21 investigated the electrical conductivity and mechanical properties of composites containing both graphite particles and carbon fiber in high-density polyethylene and ultrahigh-molecular-weight polyethylene.

In this work, researchers performed compounding runs followed by injection molding and mechanical testing of carbon/Vectra A950RX composites. Vectra