Effects of Carbon Fillers on Tensile and Flexural Properties in Polypropylene-Based Resins

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ABSTRACT: A potential application for conductive resins is in bipolar plates for use in fuel cells. The addition of carbon filler can increase the electrical and thermal conductivities of the polymer matrix but will also have an effect on the tensile and flexural properties, important for bipolar plates. In this research, three different types of carbon (carbon black, synthetic graphite, and carbon nanotubes) were added to polypropylene and the effects of these single fillers on the flexural and tensile properties were measured. All three carbon fillers caused an increase in the tensile and flexural modulus of the composite. The ultimate tensile and flexural strengths decreased with the addition of carbon black and synthetic graphite, but increased for carbon nanotubes/polypropylene composites due to the difference in the aspect ratio of this filler compared to carbon black and synthetic graphite. Finally, it was found that the Nielsen model gave the best prediction of the tensile modulus for the polypropylene based composites.


Key words: composites; fillers; polypropylene; mechanical properties; modeling

INTRODUCTION

Most polymer resins are insulating materials but they can also be used for other applications if their properties, such as electrical and thermal conductivity, are modified. One emerging market for conductive resins is bipolar plates for use in fuel cells. The bipolar plate has different functions. It separates one cell from the next, carrying hydrogen gas on one side and oxygen on the other side. Bipolar plates must be made of a material with low gas permeability, good dimensional stability and moderate flexural and tensile properties and with high thermal and electrical conductivity to conduct heat out of the cell and to minimize ohmic losses. The target set by the Department of Energy for flexural strength of bipolar plates is 25 MPa.1 Plug Power (Latham, NY) 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 conductivity of a polymer is the addition of a conductive filler material, such as carbon or metal.3–9 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.10–13 Thermosetting resins cannot be remelted.

Significant progress is being made to develop new recyclable materials with good mechanical properties for application in fuel cell bipolar plates.9,14–29 Kalaitzidou et al.26 and Akinci28 added concentrations up to 50 wt % of graphite to a polypropylene matrix observed an increase in the tensile and flexural modulus of the composite. Other research groups19,20,22,23,27,29 have measured the mechanical properties of composites containing carbon nanotubes concentrations up to 6 wt % in different polymer matrices. Their results have shown an improvement in both the tensile modulus and the ultimate tensile strength of the materials produced. A summary of tensile and flexural strength tests using carbon black, carbon nanotubes, and synthetic graphite is shown in Table I later.9,14–18,21,22,24–26,28,29 In general, this table shows relatively consistent results for the fillers used. We noted that in this table, the work of Chodak et al.18 compares composites made by injection molding (+ symbol) and compression molding (++) symbol. Better results were obtained with injection molding. Furthermore, Mali24 investigated strength properties using acetylene carbon black and Vulcan carbon black and found similar results with both fillers.

With regard to utility in bipolar plates, Blunk et al.30 prepared two formulations with polypropylene as the matrix. For a filler concentration of 15 wt % graphite fiber, 5 wt % carbon black, and 30 wt % carbon fiber, they obtained a flexural strength of 83 MPa and a flexural modulus of 16.9 GPa. For