Tensile, Thermal, and Electrical Properties of Carbon Filled Nylon 6,6 Conductive Resins

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Introduction

Polymers and resins are typically thermally and electrically insulating. Increasing the thermal and electrical conductivity of these materials is opening new markets for a variety of applications. The advantages of the conductive resins, as compared to metals, are improved corrosion resistance, lighter weight, and can be more readily adapted to meet the needs of a specific application.

Materials

In this research, Michigan Technological University (MTU) compounded, injection molded and tested (tensile properties, in-plane electrical resistivity, and through-plane thermal conductivity) carbon filled nylon 6,6 composites. The carbon fillers investigated included a PAN –based carbon and an electrically conductive carbon black. The carbon fibers came in two forms, 3.17mm chopped and 200μm milled. All carbon fillers were used alone in nylon 6,6. Combinations of carbon fillers were not investigated.

Experimental Methods

For the extrusion portion of the project, a Brabender Twin Screw extruder (42 mm diameter, parallel, counter-rotating, intermeshing twin screw with l/d=6.5, single feed port) was used. An Arburg Model A221-75-350 Allrounder (30 mm diameter, single screw, l/d= 14.9) was used to injection mold test specimens.

The tensile properties from all formulations were determined using ASTM D638. The volumetric longitudinal (through-plane) electrical resistivity (ER) of test specimens was measured using the four-probe technique (1). Through-plane volumetric ER was determined according to ASTM D257. Through-plane thermal conductivity (TC) was measured at 55°C using a Holometrix Model TCA-300 Thermal Conductivity Analyzer, which uses ASTM F433 guarded heat flow meter method. All samples were tested dry as molded (DAM).

Results and Discussion

Figure 1 shows the tensile strength at failure versus weight percent filler. The tensile strength of the neat nylon 6,6 is 82.7 MPa. This figure shows that over a range of increasing carbon fiber amounts, the tensile stress increased. One also notices that the strength values are similar for samples containing the milled and chopped carbon fibers. Hence, it is likely that the chopped and milled carbon fibers are degraded in the extrusion and injection molding process such that the chopped and milled carbon fiber have similar lengths in the actual composite produced. Indeed, photomicrographs of composite samples showed that the chopped and milled fiber were approximately 90 microns long. Concerning the carbon black, increasing the amounts of the carbon black lowered the tensile strength.

The ER of neat nylon 6,6 is 10^{15} ohm-cm. The data shown in Figure 2 correspond to the through-plane ER for more resistive values. In-plane ER values were used for the more conductive samples. Figure 2 shows that adding carbon black significantly reduces the ER to approximately 50 ohm-cm for a composite containing 7.5 wt% carbon black. The carbon fibers also lowered the ER of the composite from 10^{15}ohm-cm to less than $10^{2\text{-}3}$ ohm-cm, but significantly more filler was used (40 wt%).

The third test that was performed was the through-plane thermal conductivity. The thermal conductivity of neat nylon 6,6 is 0.25 W/mK. Figure 3 shows that, in general, there was a slight increase in the thermal conductivity of the composite with the addition of the carbon fibers, however the effect was minimal. Addition of the carbon black did not cause any significant effect on the thermal conductivity of the resin.

Conclusions

As a result of this project, several conclusions can be made concerning the addition of carbon fillers to nylon 6,6.

- Adding carbon fibers to nylon 6,6 increased the tensile strength of the composite material.

- Carbon black significantly lowered the electrical resistivity, but also decreased the tensile stress of the composite material. Adding carbon black to nylon 6,6 had no significant effect on the thermal conductivity of the composite.

References

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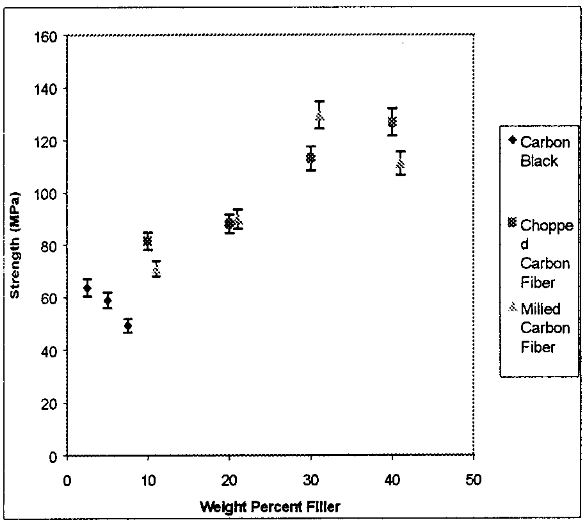

Figure 1. Tensile Strength versus Weight Percent Filler for Nylon 6,6 Based Conductive Resins

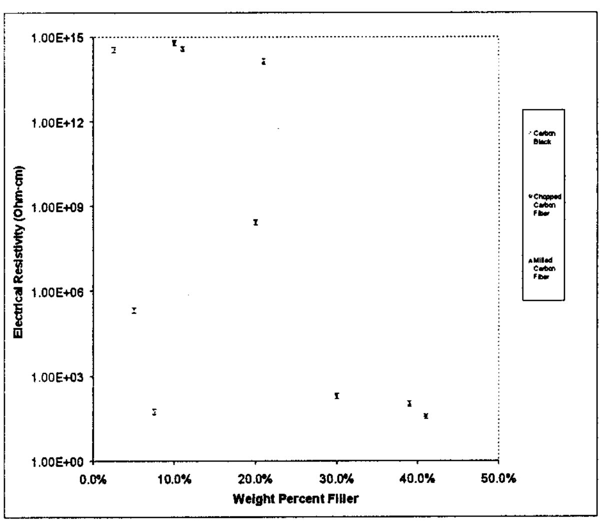

Figure 2. Electrical Resistivity (in ohm-cm) Results versus Weight Percent for Nylon 6,6 Based Conductive Resins

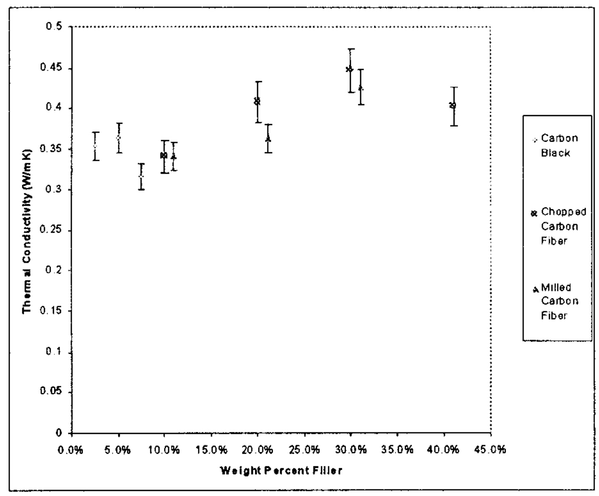

Figure 3. Through-Plane Thermal Conductivity Results versus Weight Percent filler for Nylon 6,6 Based Conductive Resins