Exfoliated Graphite as a Filler to Enhance the EMI Shielding of Polymers

M. Boehle[1], K. Lafdi[1], E. Zinsser[2] and P. Collins[2]

1. Carbon Research Laboratory, UDRI 300 College Park Dayton OH. 45469, USA

2. Air Force Institute of Technology, 2950 Hobson Way WPAFB, OH 45433

Introduction

Recent focus has been placed on nano-material based composites in electromagnetic interference (EMI) shielding applications. With an ever increasing density of electronic devices in consumer, business, industrial and military settings, effective EMI shielding has become more important than ever. Electromagnetic interference can damage or otherwise disrupt normal operation of these electronic devices. Traditionally, electromagnetic shielding has been accomplished through the use of metal, but the need for lightweight, non-corrosive, flexible materials has led to the exploration of conductive polymers to create new materials which are effective EMI shields. [1-5].

In the past a variety of fillers have been used with resins in an attempt to create conductive polymers. A number of studies have been done with metal particles, fibers and filaments. Historically, small particle size and high aspect ratio have lowered the percolation threshold, the filler concentration at which conductivity increases dramatically. A lower percolation threshold means less filler is required to reach the conductivity needed for effective EMI shielding. With this progression, the focus of research has now turned to the nanoscale, particularly with carbon.

Material Preparation

The graphite used in this study was natural flake graphite which had an average diameter between 170 and 500 µm, depending on the mesh size. The polymer used for the matrix material was EPON Epoxy Resin 862. Exfoliated graphite (EG) was prepared as described by Debelak et al. [6] Three different EG particles sizes were prepared, EG50, EG100, and EG150 with their respective particles sizes being 50, 100, and 150 mesh. The graphite was graded by sifting through wire mesh. The particles were graded by the smallest mesh size which allowed the particles to pass through. The 50 mesh particles had an average diameter of 500 µm, while the 100 and 150 mesh had diameters of 250 and 170 µm respectively. The following convention was used to label the samples: EP-EG(mesh size)-(wt. %)-S-(sample #).

Composite panels containing epoxy and exfoliated graphite loading of 8, 12, 16, and 20 wt. % were prepared. The exfoliated graphite was dispersed into the polymer by high shear mixing. A solvent (acetone) was added to ease mixing. The blade of the shear mixer rotates and breaks the larger graphite flakes into even smaller nanosheets. The application of ultrasonication further improves the dispersion of graphite nanosheets. After the mixing processes were completed, the mixture was dried in a vacuum oven to remove the solvent and then loaded into a silicone rubber mold. The loaded mold was placed in a heated press to cure. The panels were cured under 44 kN force at 120°C for 2 hours and then at 175°C for 2 more hours.

Experimental Investigation:

EMI shielding testing was performed to characterize the shielding properties of each specimen. Figure 1 shows the test setup used for EMI testing. The samples were taped to the aperture of the shielded box using copper foil tape backed with conductive adhesive. This adhesive tape insured good electrical contact between the specimen and the box to reduce errors due to contact resistance. A baseline run was first performed with an open aperture. The HP 8350B Sweep Oscillator was used to vary the frequency from 500 MHz to 18 GHz in 500 MHz steps. The HP 8349B Microwave Amplifier was used to amplify the signal from the oscillator to the necessary power levels. At each step, the reading of the HP 436A power meter was allowed to stabilize and then the data point was recorded. This procedure was repeated for each of the prepared specimens, as well as one specimen with no filler, labeled “Neat Epoxy”, to serve as a comparative baseline.

The EMI shielding test results are shown in Figures 2 and 3. Each figure shows the SE data for a given weight percentage of exfoliated graphite filler.

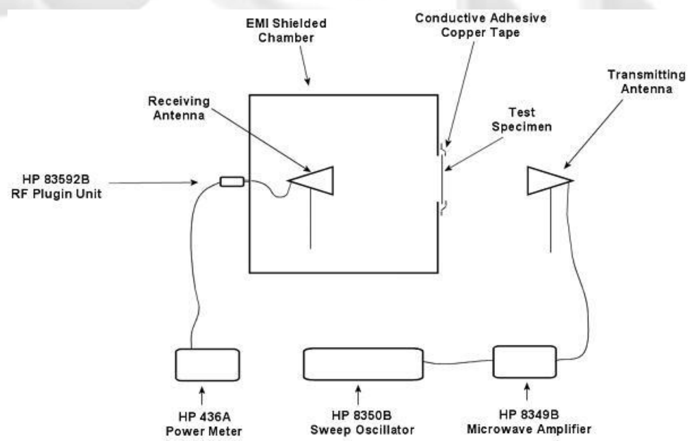

Figure 1. EMI Test fixture diagram

At each weight percent level, there were three specimen, one of 50 mesh filler, one of 100 mesh filler, and finally one of 150 mesh filler. It is important to note that the SE readings of several samples were clipped near 70 dB due to the limitations of the test apparatus. A SE of greater than 70 dB could not be measured with this equipment and therefore any reading exceeding this value was recorded as 70 dB.

The trend found in the resistivity data is echoed in the EMI shielding results. At low filler loadings, the difference between the filler sizes is negligible. As the concentration of filler is increased, the difference becomes quite apparent. The addition of more filler again reduces the difference in performance between the filler sizes.

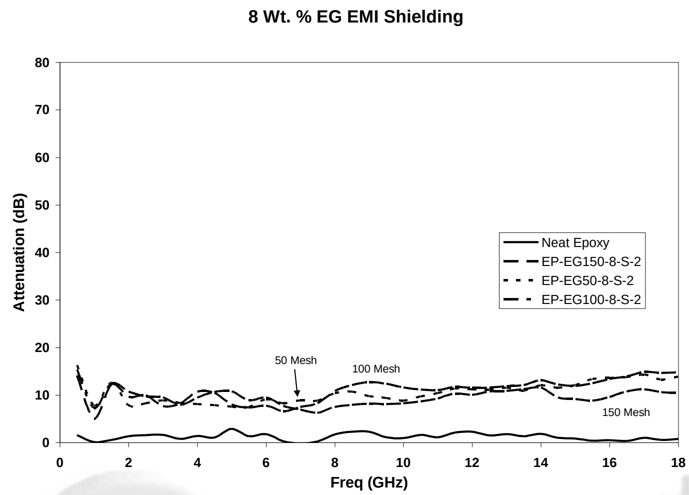

Figure 2. SE data versus 8 Wt. % of EG filler

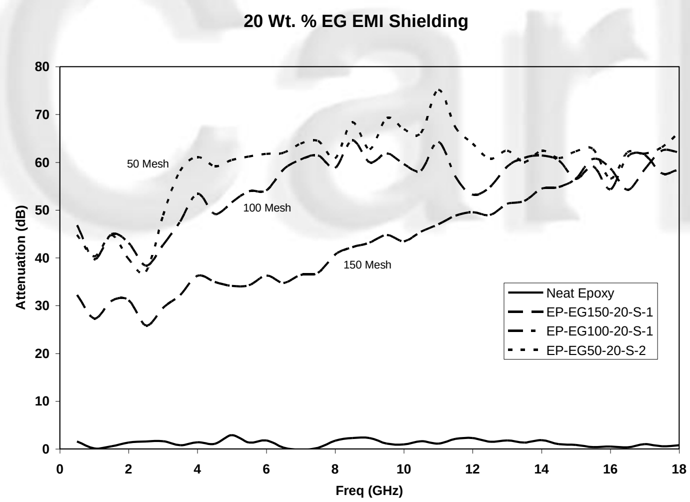

Figure 3. SE data versus 20 Wt. % of EG filler.

The resistivity data was combined with the EMI shielding data and plotted to visualize the relationship between resistivity and EMI shielding. Figure 4 shows a Log-log plot of resistivity vs. average EMI attenuation. The average was calculated over the measured range of .5 to 18 GHz. This plot shows the strong correlation between electrical properties and EMI shielding. Low resistivity values correspond to high SE while higher resistivity yields lower SE.

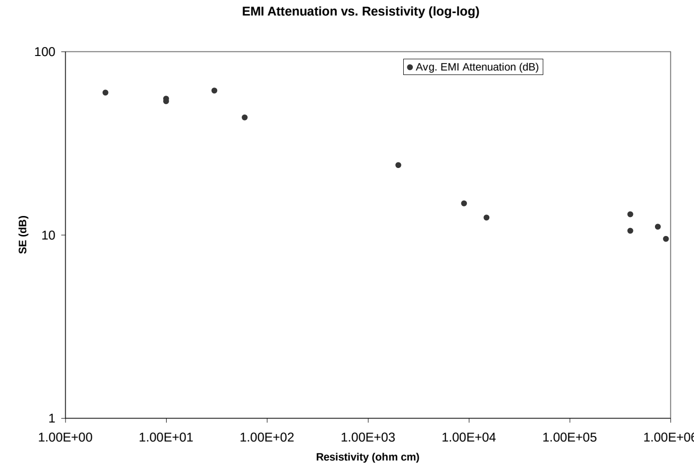

Figure 4. Log-log plot of EMI attenuation vs. resistivity. The sharp change in SE at low resistivity shows that a percolation threshold exists.

Discussion and Conclusions

Conductive polymer composites can be manufactured to provide excellent EMI shielding properties. The use of carbon materials provides a weight advantage over metallic fillers. Exfoliated graphite, which is one of the least expensive nano-scale carbon materials, provides adequate EMI shielding potential while keeping costs low. By manipulating the dimensions of the exfoliated graphite filler, the shielding effectiveness can be optimized such that a polymer matrix composite will remain lightweight and cost effective, without the need for metallic shielding materials or extra coating processes.

Figures 2 and 3 show several trends in shielding effectiveness over the range of frequencies tested. As expected, composites with a higher concentration of graphite had higher shielding effectiveness. The size of the graphite particles also had a significant effect on the performance of the composite. The larger particles attained higher shielding effectiveness values and had a lower percolation threshold, the point at which the composite becomes an effective shielding material.

The strong correlation between conductivity and SE reveals that electrical properties dominate the EMI shielding characteristic of the composite (figure 4). Therefore, electrical properties can be used as a predictor for shielding effectiveness.

References

1. Huang Y et al., Carbon 45(8), 1614-1627 (2007)
2. Chung DDL, Carbon 39, 279-285 (2001)
3. Li N. et al., Nano Letters 6, 1141-1145 (2006)
4. Heiser, J., King, J., Konell, J., Sutter, L., Polymer Composites 25(4), 407-416 (2004)
5. Du, X.S.; Xiao, M.; Meng, Y.Z., Journal of Polymer Science, Part B: Polymer Physics 42, 1972-1978 (2004)
6. Debelak, Bryan.; Lafdi, Khalid, Carbon 45(9), 1727-1734 (2007)