NICKEL COATED CARBON FILAMENTS FOR ELECTROMAGNETIC INTERFERENCE SHIELDING

Xiaoping Shui and D.D.L. Chung

Composite Materials Research Laboratory
State University of New York at Buffalo
Buffalo, NY 14260-4400

INTRODUCTION

Electrically conducting polymer-matrix composites are used for electromagnetic interference (EMI) shielding, the need of which is increasingly important due to the increasing use of RF wireless electronics. Polymer-matrix components, as opposed to monolithic metals, are attractive due to their moldability. These composites are conducting due to the presence of an electrically conducting filler. Due to the lower cost and greater versatility of composite fabrication for discontinuous fillers compared to continuous fillers, discontinuous fillers are widely used for making electrically conducting composites. Discontinuous fillers that have been used for EMI shielding include metal particles, metal flakes, carbon particles, carbon fibers, metal fibers, metal coated carbon particles, and metal coated carbon fibers. For any filler, the shielding effectiveness increases with increasing filler volume fraction, but the maximum filler volume fraction is limited by the poor mechanical properties at high filler volume fractions. For materials and process cost saving and good mechanical properties, the attainment of a high shielding effectiveness at a low filler volume fraction is desirable. Because electromagnetic waves at high frequencies interact with a conductor only near its surface, a smaller unit size of the conducting filler enables a higher shielding effectiveness to be attained at the same filler volume fraction. Therefore, this paper emphasizes the development of a submicron diameter filament filler.

The only submicron diameter filament filler that has been previously used for EMI shielding is carbon filaments (catalytically grown from carbonaceous gases); a shielding effectiveness at 1 GHz of 45 dB was attained at a filler content of 60 wt.% (about 45 vol.%) [1]. The coating of conventional carbon fibers (~ 10 μm diameter) with nickel has been previously shown to greatly increase the shielding effectiveness, reaching 76 dB at 1 GHz [2]. In this work, by coating the submicron diameter carbon filaments with nickel, we have provided a new filler (called nickel filaments) that results in shielding effectiveness at 1 GHz of 90 dB -- a value higher than what had been previously achieved by any filler. Due to the submicron diameter of the new filler, a high shielding effectiveness was attained even at an extraordinarily low filler volume fraction, e.g., 87 dB at just 7 vol.%.

EXPERIMENTAL

A typical nickel filament measured 0.404 ± 0.022 μm in diameter, and it contained a carbon core of diameter 0.096 ± 0.018 μm. Each nickel filament contained 94.4 vol.% Ni and 5.6 vol.% C. The carbon core was present because the nickel filaments were fabricated by the electroplating of nickel on to carbon filaments. The carbon filaments were catalytically grown from carbonaceous gases. Prior to electroplating, the surface of the carbon filaments was treated; without the treatment, the Ni coating was not uniform and resulted in composites orders of magnitude higher in electrical resistivity compared to the case with the treatment. The electroplating was conducted by using a nickel anode and a nickel sulfate electrolyte solution. The nickel in the nickel filaments was crystalline.

The EMI shielding effectiveness, measured in transmission using the coaxial cable method, attained by the Ni filaments at 7-19 vol.%, was comparable to those of copper and stainless steel.

CONCLUSION

Nickel filaments of diameter about 0.4 μm, length >100 μm, resistivity 10^{-6} Ω.cm, and containing 94 vol.% Ni and 6 vol.% C, were fabricated by electroplating carbon filaments of 0.1 μm diameter with nickel. For providing composites of high EMI shielding effectiveness, at least at 1-2 GHz, the nickel filaments were much more effective than all other fillers including nickel fibers, steel fibers, carbon fibers, carbon filaments, aluminum flakes, nickel particles and silver particles, due to their combination of small diameter, large aspect ratio and low resistivity. The shielding effectiveness provided by the Ni filaments at just 7 vol.% was comparable to that of copper at 1-2 GHz.

REFERENCES

1. Makoto Katsumata, Hidenori Yamanashi, Hitoshi Ushijima and Morinobu Endo, SPIE Proc., Vol. 1916 (Smart Materials), edited by Vijay K. Varadan, 1993, p. 140-148.
2. Mal Murthy, 4th Int. SAMPE Electronics Conference, Vol. 4 (Electronic Materials -- Our Future), edited by Ron W. Allred, Robert J. Martinez and Ken B. Wischmann, 1990, p. 806-818.