Polymer matrix composites with nickel nanoparticles for electromagnetic shielding applications

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Nanocomposite materials are developed for improving mechanical and electrical properties, chemical resistance, and also to reduce material cost. Recently, the use of polymer matrix containing nanoparticles has received considerable attention for applications in electromagnetic shielding [1-4]. Improving electromagnetic shielding is a need in many areas such as electronics, medical industries and aeronautics. Based on recent progress in nanotechnology, especially in nanofiller production, new opportunities have emerged to provide lighter shields (cost-weight) without creating any limitation for structural designers and offering better adhesion, corrosion and oxidation resistance, recyclability, gasket compatibility and durability.

In this study, a nanocomposite material that consisted of the mixture of an electrically nonconductive polymer matrix (EPON Resin 825 + D-230) along with conductive nickel (Ni) nano-reinforcements was prepared. Scanning Electron Microscope (SEM) and Transmission Electron Microscope (TEM) were used for microstructural characterization. Ni nanoparticles were characterized from the point of view of size distribution. Thin TEM samples of the material was prepared by using microtome and the distribution of nanoparticles in the polymer matrix was investigated.

Two sizes of Ni nanoparticles were used: a) nanoparticles having an average size of about 20nm and b) nanoparticles having an average size of about 60-80nm.

Dielectric properties of the composite material were evaluated from 10MHz to 1GHz by using an Agilent E4491A impedance/material analyzer and an Agilent 16453A dielectric material test fixture. The effective permittivity of composites was theoretically estimated using Maxwell-Garnett formula [xx] and compared with the experimental results.

Figure 1-a presents a micrograph obtained by SEM of the cross section of the prepared material and shows the distribution of nanoparticles in the polymer matrix. As can be seen, nanoparticles are distributed in agglomerated islands. However, four-point electrical conductivity measurements confirmed that the prepared composite was behaving as an insulator, suggesting that the apparent agglomerated regions were not connected and that the sample was below the percolation threshold. Observation by TEM (figure 1-b) and 3D tomography confirmed that the nanoparticles were not connected, also in apparently agglomerated regions.

The measured complex permittivity of the matrix polymer samples with and without nanoparticles from 10MHz to 1GHz is shown in Figure 2. The results show that the complex permittivity of the Ni-polymer matrix composite (Ni-PMC) was significantly increased with respect to the permittivity of the polymer matrix without the nano-reinforcements.
References


Figure 1. a) SEM micrograph of Ni nano particles distribution in polymer matrix, b) TEM micrograph presenting nano particles present in agglomerated region

Figure 2. Comparison of the polymer matrix and the Ni-NPMC relative permittivity. The top plot shows the real part of the permittivity and the bottom plot shows the imaginary part