Microwave characterization of polymeric nanocomposites containing copper nanoparticles as conducting filler

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The polymeric nanocomposite sheets that contain conductive copper filler dispersed in an insulating polyethylene oxide (PEO) matrix are usually prepared by the vigorous mixing of the components via solution casting method. The X-ray diffraction (XRD), Scanning Electron Microscopy (SEM) and Vector Network Analyzer tools are employed to analyze the crystallinity, surface morphology and the microwave dielectric properties of the synthesized samples, respectively. The effective dielectric properties of the resultant nanocomposite sheets are measured in the X-band of microwave frequency using cavity perturbation technique. Two different rectangular cavities are fabricated for testing of the dielectric properties of nanocomposite sheets. The real and imaginary parts of the complex electrical permittivity of synthesized nanocomposite sheets are found to be increased with the addition of copper content (10, 20, and 30 wt% of copper), which may be attributed to the interfacial polarization mechanism. The effect of copper addition in altering the semi crystalline nature of PEO polymer matrix in their nanocomposites has not been observed, while the shrinkage at the surface of the synthesized nanocomposite sheets is getting reduced with the higher value of copper content.

Figure 1: Variation of dielectric constant and loss factor as function of Cu content at 9.35 GHz in X-band

The microwave dielectric properties of prepared samples are evaluated using the cavity perturbation method (CPM). The CPM is well known for precise measurement of the complex permittivity of the sample [1]. The complex permittivity of the test specimen $\epsilon_r = \epsilon_r' - j\epsilon_r''$ is calculated by the well-known formula [1]. The real part of complex permittivity ϵ_r' is responsible for storage of the electric energy and the imaginary part of complex permittivity ϵ_r'' is responsible for loss of the electric energy present in the system, which are given as

$$\epsilon_r' = 1 + \frac{2V_c}{AV_s} \left(\frac{f_1 - f_s}{f_s} \right), \quad \epsilon_r'' = \frac{V_c}{AV_s} \left(\frac{1}{Q_s} - \frac{1}{Q_1} \right)$$

Figure 2: Variation of dielectric constant and loss factor as function of Cu content at 10.87 GHz in X-band

Where, f_s and Q_s are the resonating frequency and quality factor of the sample loaded cavity measured by VNA. V_s and V_c are the volumes of the sample and the cavity, respectively.

Reference

1. D. C. Dube, M. T. Lanagan, J. H. Kim, S. J. Jang, Dielectric measurements on substrate materials at microwave frequencies using a cavity perturbation technique, *J. Appl. Phys.* 63, 2466-2468 (1988), DOI:http://dx.doi.org/10.1063/1.341024.