Dielectric Characterization of Microwave-Heated Nanocomposites

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This paper describes a microwave measurement technique to characterize temperature-dependent dielectric properties of polymer nanocomposites heated using microwave energy. Applications of microwave heating of materials containing nanoparticles, such as carbon nanotubes and graphene, are continually evolving. Understanding the effect of microwave heating on polymer materials with varying concentrations and types of nanoparticles through dielectric characterization is essential in determining how microwave energy interacts with such materials, and it helps in optimizing the use of such materials in a variety of applications. The method presented in this paper relies on microwave heating of dielectric samples using a closed-end rectangular waveguide connected to a high power microwave generator operating at 2.45 GHz and a microwave cylindrical cavity to determine the complex dielectric constant versus temperature. In this work, we focus on polymers containing conductive nanomaterial dispersions acting as microwave susceptors.

For microwave heating, the dielectric sample is inserted through a hole in the broadside of the waveguide, located a quarter-wavelength away from the closed waveguide end. A copper tube with dimensions that do not allow the dominant mode to propagate is attached to the hole to minimize microwave leakage. For dielectric characterization, one method is to use the TE_{11n} resonant modes of the cylindrical cavity to determine the dielectric constant and loss tangent of a sample inserted through a hole in the cylindrical side of the cavity. To correlate dielectric properties with temperature, carefully obtained cooling curves are used. An alternative method is to perform dielectric characterization while high power microwave energy is applied using the same sample holder. Appropriate methods for isolating the network analyzer needed for the dielectric characterization process are used to avoid interference and potential damage due to the use of high power microwaves for heating.

To demonstrate the proposed methods, polymer samples containing different types and concentrations of conductive nanomaterials are used. Dielectric properties versus temperature are measured at microwave frequencies. The experimental setup, measurement methods, methods for extracting the complex permittivity from the measured quantities, and results will be presented at the conference.