DIELECTRIC STUDIES OF PDMS-BASED COMPOSITE MATERIALS WITH Fe AND Fe_3O_4 NANOPARTICLES

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Polymer-based composites are being explored for applications involving electromagnetic (EM) wave interaction (shielding and absorption) for their low weight, flexibility, and tunable electrical properties [1]. Controlling dielectric behavior over broad frequency ranges is essential for applications involving radiofrequency and microwave interactions. However, systematic studies of the influence of filler type and concentration on the dielectric response of such composites across broad frequency ranges remain limited.

This work investigates the dielectric properties of polydimethylsiloxane (PDMS) composites filled with iron (Fe) and iron oxide (Fe_3O_4) nanoparticles. The dielectric response was examined as a function of filler type and volume fraction using dielectric spectroscopy over a broad frequency range from 100 Hz to 40 GHz at room temperature. Fe-PDMS composites contained 10-60 vol% iron, while Fe_3O_4-PDMS composites contained 1-38 vol% iron oxide.

The results demonstrate that the fundamental part of the dielectric permittivity of Fe_3O_4-PDMS composites is higher than that of Fe-PDMS composites over the entire investigated concentration range (Fig. 1). Electrical conductivity increases with increasing filler concentration in both systems; however, no sharp percolation-related conductivity jump is observed (Fig. 2). This suggests that continuous conductive networks are not formed at the studied filler concentrations.

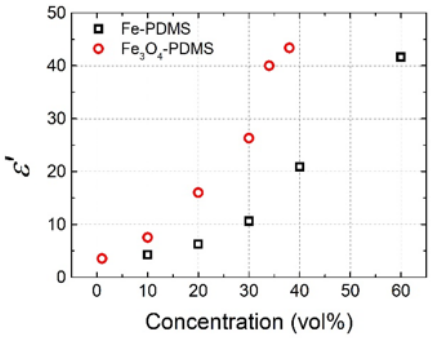

Fig 1. Dependence of the real fraction of Fe-PDMS and Fe_3O_4-PDMS composites on the filler concentration at room temperature at a frequency of 1765 Hz.

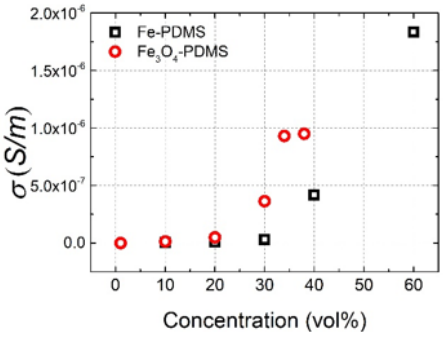

Fig 2. Dependence of the conductivity of Fe-PDMS and Fe_3O_4-PDMS composites on the filler concentration at a room frequency of 1765 Hz.

Based on the concentration dependences of dielectric permittivity and electrical conductivity, it is concluded that the percolation threshold is not reached in either Fe-PDMS or Fe_3O_4-PDMS composites. To see potential percolation behavior, future studies should investigate lower filler volume fractions.

[1] V. M. G, M. Vatnalmath, and V. Auradi, “A review on conductive polymer composites focusing on advancements in electrical conductivity, and electromagnetic shielding capabilities,” Polymer Composites, vol. 46, no. 18, pp. 16507–16537, Jun. 2025, doi: 10.1002/pc.70059.