THE COMPLEX PERMITTIVITY AND PERMEABILITY OF PMMA/Fe_3O_4 NPS/Ag NPS COMPOSITES IN THE MICROWAVE RANGE

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Introduction

As an increasing demanding of reducing the unwanted electromagnetic radiation and interference in wireless devices and high-speed digital devices, and shielding the electromagnetic radiation from a large numbers of mobile phones and local wireless networks, the high-performance electromagnetic absorbing materials become important to avoid the EM radiation pollution. Compared to traditional microwave absorbing and shielding materials such as metals and carbon black [1][2], polymer–matrix composites containing electrically conducting fillers are frequently used for shielding the EM radiation, due to the electrical conductivity in the conducting polymer insulates effectively the electromagnetic wave. However, metal-type composites are too heavy and only provide the function of reflecting the EM wave. The need of materials that function efficiently for both electromagnetic absorption and shielding becomes critical to meet the EMI demands for the growth of electronic industry and its widespread use of electronic equipment in communications, computations, automations, biomedical, space etc.. In contrast to conductive polymer composites, ferrites are not conductive and not inexpensive, and contain various oxide components, which enhance the capability of EM absorption. Fe_3O_4 is one of typical magnetites, which is strongly ferrimagnetic and widely studied for the EM absorbents in the past years [3][4]. Compared with Fe_2O_3, Fe_3O_4 posses more magnetic than Fe_2O_3. However, it is less effective for EM shielding than Fe_2O_3 [5]. This suggests that the shielding performance is not just dependent only on magnetic properties but also on electric property. This article focuses on studying the microwave absorbing property of the PMMA mediated Fe_3O_4 nanoparticles (PMMA/Fe_3O_4NP) and improved its conductivity by adding nano-size silver particles (AgNP). As it has been well known, a good electrical conductivity is the main mechanism for EM shielding. The mobile electrons reflect the insert EM wave. Metals are by far the most common materials for EM shielding. They function primarily by reflection due to the free electrons in them. Recent years, metal nanoparticles have drawn a great attention in various research, this is not only because of their unique properties, which are different from their bulk materials, but also for their potential applications. Metal nanoparticles have a very large surface-to-volume ratio with a high electrical conductivity has been proved to be a good candidate of the EM shielding. In this paper, the PMMA/Fe_3O_4NP medium doped by silver nanoparticles is systemically fabricated and studied for their complex permittivity and permeability. We will conclude the behaviors of the permittivity and permeability of the PMMA/Fe_3O_4NP/AgNP composites at microwave frequencies.

Sample Fabrication and Measurement

Including a study of the effect of PMMA mediated Fe_3O_4NP/AgNP composites, three different percentage of Fe_3O_4 nanoparticles were studied in the experiment. The PMMA is given to matrix the Fe_3O_4NPs to be 5%, 10% and 15% of weight fraction (PMMA 47.5g and Fe3O4 2.5G to form 5% of PMMA/Fe_3O_4NPs). Each of the PMMA/Fe_3O_4NPs medium is added a 0.5, 1.0, 1.5 1nd 2.5g of AgNPs to form the PMMA/Fe_3O_4NPs/AgNPs composite, respecttively. In the experiment, a microwave rectangular resonator is used to pick up the permittivity and permeability by using the resonant frequency. The rectangular resonator is designed to operate at 7 GHz. In order to obtain a high sensitivity, the unloaded quality factor of the resonant pick was controlled more than 4000 during the measurement. The cavity resonator is attached to the Network Analyzer (Agilent 8510C). The sample is then placed into the position of maximum electric field in the resonator and its response f_0 and f_s (S parameter) is read from the Vector Network Analyzer (VNA). The permittivity and permeability are extracted from the perturbation method. They are given by

$$\epsilon' = 1 + \frac{1}{2}\cdot\left(\frac{f_0 - f_s}{f_s}\right)\cdot\left(\frac{V_0}{V_s}\right) \quad (1)$$

$$\epsilon'' = \frac{1}{4}\cdot\left(\frac{1}{Q_0} - \frac{1}{Q_s}\right)\cdot\left(\frac{V_0}{V_s}\right) \quad (2)$$

$$\mu' = 1 + \frac{(\lambda^2 + 4a^2)}{8a^2}\cdot\left(\frac{f_0 - f_s}{f_s}\right)\cdot\left(\frac{V_0}{V_s}\right) \quad (3)$$

$$\mu'' = \frac{(\lambda^2 + 4a^2)}{16a^2}\cdot\left(\frac{1}{Q_0} - \frac{1}{Q_s}\right)\cdot\left(\frac{V_0}{V_s}\right) \quad (4)$$

Where V_0 , V_s , Q_0 , Q_s and a represent the cavity volume, sample volume, cavity quality factor, sample quality factor and cavity dimension, respectively. The complex permittivity and permeability of the PMMA/Fe_3O_4NPs/AgNPs composite are given in Figs. 1 to 4.

Results and Discussion

Fig. 1. Shows the dielectric constant for the different Ag doping (i.e., 0.5g, 1.0g, 1.5g , 2.5g) in the 5%, 10%, 15% of

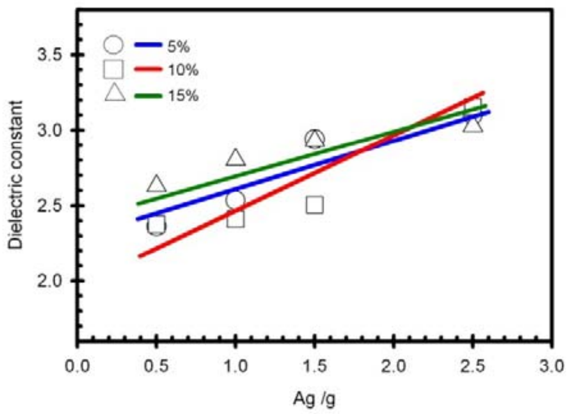

Fig. 1 The dielectric constant of the PMMA/Fe_3O_4NP/AgNP composites.

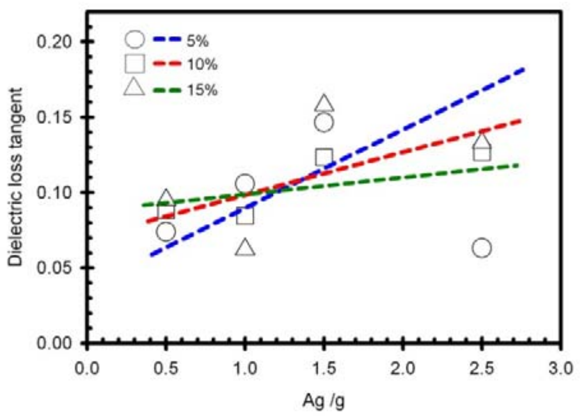

Fig. 2 The dielectric loss tangent of the PMMA/Fe_3O_4NP/AgNP composites.

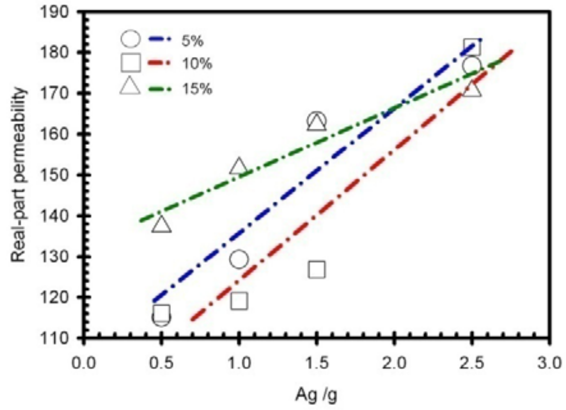

Fig. 3 The real-part permeability of the PMMA/Fe_3O_4NP/AgNP composites.

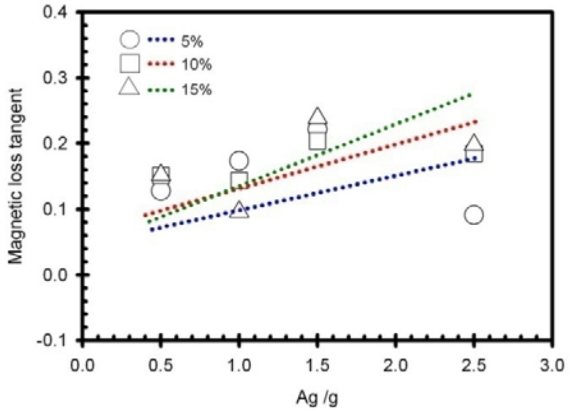

Fig. 4 The magnetic loss tangent of the PMMA/Fe_3O_4NP/AgNP composites

PMMA/Fe_3O_4 NPs medium. As it can be seen in Fig.1, the dielectric property is improved by adding the AgNPs. The dielectric constant raises from 2 to 3 for different Fe_3O_4 weight fraction. This can be attributed to the metal(Ag)-insulator(PMMA/Fe_3O_4) increasing for the testing samples. Fig. 2 exhibits the dielectric loss tangent that are relative to the Fig. 1. As it can be seen from the plot, the dielectric loss does not exhibit a obvious change because of the AgNPs. As can be seen in Fig. 3, the real-part permeability also exhibits a increasing tendency, as the Ag NPs are adding to the PMMA/Fe_3O_4NP. The value is given from 110 to 180 varied by adding the Ag NPs. The magnetic loss tangent are presented in Figs. 4, however shows the same tendency as the dielectric loss. It seems not has a relation with the silver nanoparticles.

Conclusion

In this paper, we demonstrate the complex permittivity and permeability of PMMA/Fe_3O_4NP/AgNP composites at the 7 GHz. It can be conclude that Ag NPs do affect the dielectric property and real-part permeability but not their dielectric and magnetic loss under the 5%, 10% , 15% of PMMA/ Fe_3O_4 NPs.

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