# EFFECT OF MAGNETITE CONTENT ON MICROWAVE ABSORBING PROPERTY OF MAGNETITE-THERMOPLASTIC NATURAL RUBBER NANOCOMPOSITES

**Kong Ing[a], Sahrim Hj. Ahmad[a], Mustaffa Hj. Abdullah[a], David Hui[b] and Ahmad Nazlim Yusoff[c]**
[a]School of Applied Physics, Faculty Science and Technology, UKM, 43600 Bangi, Selangor, Malaysia.
[b]Department of Mechanical Engineering, University of New Orleans, New Orleans, LA 70148, USA.
[c]Diagnostic Imaging and Radiotherapy Programme, Faculty of Allied Health Sciences, UKM,
50300 Jalan Raja Muda Abdul Aziz, Kuala Lumpur, Malaysia.
*Email: kong_ing_2005@yahoo.com

## Introduction

The high frequency electromagnetic wave is drawing more attention, due to the explosive growth in the utilization of telecommunication devices in industrial, medical and military applications [1]. Naturally, a serious problem has to be solved: electromagnetic pollution in this frequency range. Aiming at controlling this problems, electromagnetic wave absorbers with the capability of absorbing unwanted electromagnetic signals are investigated, and research on their electromagnetic and absorption properties are still being carried out. In this paper, we report the investigation of the microwave absorbing properties of $Fe_3O_4$ filled thermoplastic natural rubber (TPNR) nanocomposites. TPNR was chosen as the matrix and $Fe_3O_4$ nanoparticles as the fillers. $Fe_3O_4$, a member of spinel-type ferrite, was selected mainly because of its large magnetic losses and large resistivities.

## Experimental

*Materials*
$Fe_3O_4$ nanoparticles, with the particle size ranging from 20-30 nm, were obtained from commercial suppliers in powder form (Nanostructured & Amorphous Materials, Inc., USA). Natural rubber (NR) and polypropylene (PP) were supplied by Rubber Research Institute of Malaysia (RRIM) and Mobile (M) Sdn. Bhd., respectively. Liquid natural rubber (LNR) was prepared by the photosynthesized degradation of NR in visible light.

*Preparation of nanocomposites*
TPNR filled $Fe_3O_4$ nanocomposites were prepared by melt-blending technique using laboratory mixer (Model Thermo Haake 600p). The weight ratio of PP, NR and LNR is 70:20:10 with the LNR as the compatibilizer for the mixture. Blending was carried out with mixing speed of 100 r.p.m. at 180 ˚C for 13 mins.

*Characterization*
For the studies of microwave absorbing properties, a coaxial line method was used to determine the complex permittivity and permeability of the samples with a HP8720D microwave vector network analyzer in the frequency range of 1-20 GHz. The samples were prepared in a toroidal shape with an outer diameter of 3.5 mm, inner diameter of 1.5 mm and a thickness of 4.0 mm.

## Results and Discussion

*Dielectric and Magnetic Properties*
The complex dielectric permittivity and magnetic permeability represent the dynamic dielectric and magnetic properties of electromagnetic materials. The real components (ε' and μ') of the complex dielectric permittivity and magnetic permeability symbolize the storage capability of electric and magnetic energy. The imaginary components (ε'' and μ'') represent the loss of the electric and magnetic energy. For microwave absorbers, high imaginary components of the complex dielectric permittivity and magnetic permeability are expected [2].

Figs. 1 and 2 show the real and imaginary components of the complex dielectric permittivity (ε' and ε'') and complex magnetic permeability (μ' and μ'') for TPNR, $Fe_3O_4$ nanoparticles and TPNR filled $Fe_3O$ nanocomposites in 1-20 GHz frequency range. The values of ε' and ε'' depend on the frequency of the TPNR, $Fe_3O_4$ and nanocomposites exhibit the same trends. The values of ε' of the TPNR, $Fe_3O_4$ and nanocomposites range from 2.55 to 2.71, 2.70 to 2.92 and 4.78 to 4.90 while the values of ε'' range from 0.06 to 0.56, 0.22 to 0.86 and 0.97 to 1.62, respectively.

The values of μ' and μ'' are, respectively, unity and zero in the whole frequency range for the nonmagnetic TPNR sample, while a strong decrease with an increase in frequency for both quantities is observed at the whole frequency range for the $Fe_3O_4$ nanoparticles. From Fig. 2, it can be seen that the value of μ'' of the TPNR filled $Fe_3O$ nanocomposites are larger than those of the TPNR matrix. The increase of μ'' suggests that the $Fe_3O_4$ nanoparticles embedded in TPNR matrix enhance the magnetic loss of the polymer matrix.

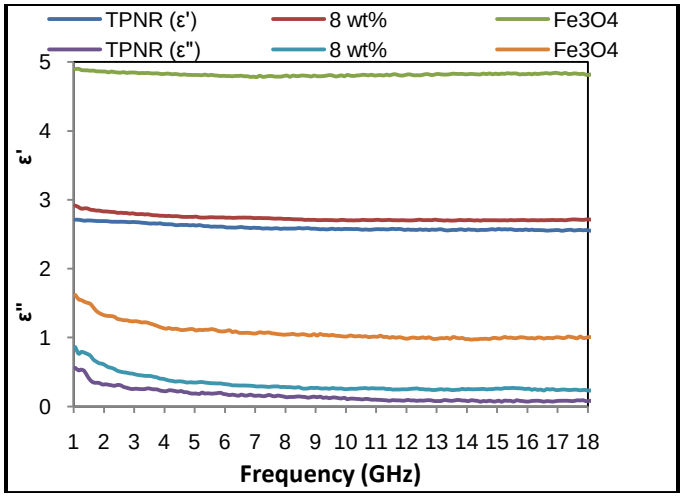


Fig . 1. Permittivity spectra of the TPNR, $Fe_3O_4$ and nanocomposites.

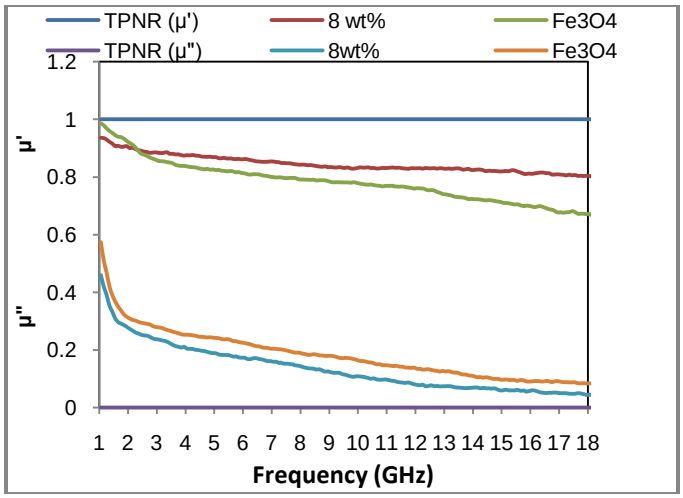


Fig. 2. Permeability spectra of the TPNR, $Fe_3O_4$ and nanocomposites.

It is obvious that the dielectric loss and magnetic loss of nanocomposites have been improved compared with pure TPNR. It indicates that the nanocomposites have a good and stable dielectric loss and magnetic loss properties. These characteristic electromagnetic properties can be applied to the microwave absorbing material.

*Microwave Absorption Properties*

The electromagnetic wave-absorbing performances usually can be evaluated by the following equation [3]:

$$R_L = 20\log\left|\frac{Z_{in}-Z_0}{Z_{in}+Z_0}\right| \quad (1)$$

where the $R_L$ denotes the reflection loss in dB unit. $Z_0$ is the impedance of the free space. $Z_{in}$ is the input impedance at the absorber/free space interface, which can be expressed as

$$Z_{in} = Z_0\sqrt{\frac{\mu_r}{\varepsilon_r}}\tanh\left[j(2\pi fd/c)\left(\sqrt{\mu_r\varepsilon_r}\right)\right] \quad (2)$$

where f is the frequency of the electromagnetic wave, d is the thickness of the single-layered absorber and c is the velocity of light.

The variation of the minimum reflection loss ($R_L$) for TPNR, $Fe_3O_4$ nanoparticles and TPNR filled $Fe_3O_4$ nanocomposites at the thickness of 9 mm are shown in Fig. 3. TPNR almost does not absorb microwave when there are no filler in it and it can be considered as weak microwave absorber. For nanocomposites, the maximum absorbing peak is about -16.10 dB at 13.15 GHz and the bandwidth below -10 dB is 2.0 GHz. The microwave enhancement absorption of nanocomposites was attributed to both dielectric and magnetic losses.

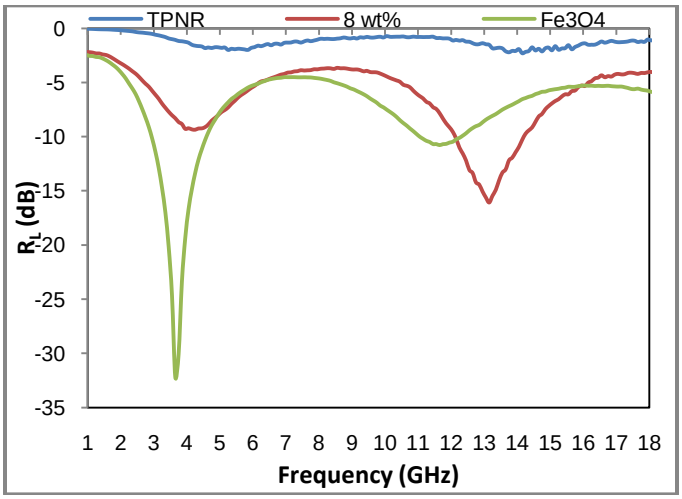


Fig. 3. Absorption characteristics of the TPNR, $Fe_3O_4$ and nanocomposites

## Conclusion

In this work, the microwave absorbing properties of $Fe_3O_4$/TPNR nanocomposites were investigated in the frequency range of 1-20 GHz. The improved absorbing properties are proposed to be the result of the modification of the electromagnetic parameters by $Fe_3O_4$ nanoparticles. The microwave absorbing properties of the nanocomposites can be manipulated easily by changing the filler concentration and thickness of the sample.

## References

[1] X. Tang & K.A. Hu. 2007. Mater. Sci. Eng., B 139: 119-123.
[2] N. Chen, G.H. Mu, X.F. Pan, K.K. Gan & M.Y. Gu. 2007. Mater. Sci. Eng., B 139: 256-260.
[3] H. Lin, H. Zhu, H. Guo & L. Yu. 2007. Mater. Lett. 61: 3547-3550.