Simple Method for the Preparation of Fe_3O_4/MWCNT Nanohybrid as Radar Absorbing Material (RAM)

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ABSTRACT: *We have successfully prepared Fe_3O_4/MWCNT nanohybrid with a very simple and economical method. Multi Walled Carbon NanoTubes (MWCNT) encapsulated with Fe_3O_4 nanoparticles were synthesized via pyrolyzing of ferrocene. The sample was characterized with XRD, TEM and Vibrating Sample Magnetometer (VSM). Also, Permeability (μ) and Permittivity (ε) were measured. The reflection-loss was measured at 2-18 GHz with a HP8722ES vector network analyzer. In 2-18 GHz frequency range (microwave frequency), the dielectric loss (tan $\delta_E=\varepsilon'' / \varepsilon'$ with an amount between 0.5-0.6) effectively improves via the addition of Fe_3O_4/MWCNT nanohybrid in the desired composite with paraffin matrix. Therefore, it can be concluded that Fe_3O_4/MWCNT nanohybrid has good potential to improve microwave absorption and can be used as Radar Absorbing Material (RAM).*

KEYWORDS: *Composites; Electronic materials; Magnetic materials; Nanostructures; Magnetic properties; Chemical synthesis; Electrical properties.*

INTRODUCTION

Radar Absorbing Materials (RAMs) have been the focus of military aircraft technology in contemporary warfare. RAMs can be used to minimize the electromagnetic reflection from the metal plate such as aircrafts, ships, tanks and the walls of anechoic chambers and electronic equipment [1,2]. Thin, light-weight, wideband absorbing properties and strong mechanical properties are four main characteristics of absorbers required in the near future [3]. Multi-Walled Carbon NanoTubes (MWCNT) have received great attention due to their unique high intensity, excellent flexibility, low density and promising electromagnetic properties [4]. Previous works have shown that Fe and Fe-Ni filled carbon nanotubes fabricated by chemical vapour

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deposition exhibit good properties [5,6]. MWCNT has also attracted considerable interest in recent years for theoretical and practical importance in fundamental science and application [7-13]. In this paper, we report a simple and efficient route for encapsulating MWCNT with Fe_3O_4 nanoparticles and the electromagnetic properties of the prepared samples are evaluated.

EXPERIMENTAL SECTION

MWCNT were supplied by Research Institute of Petroleum Industry (RIPI) with the purity of more than 90%. In a method, MWCNT has been acid treated using concentrated HNO_3. Thus, MWCNT (2 g) were first added to a mixture of distilled water (160 mL) and nitric acid (140 mL) and allowed to reflux for 10 h. The sample was dried in an oven at 60 ºC after the filtration and neutralization with distilled water.

The functionalized MWCNT were ball milled with powdered ferrocene (1:2 by weight) and then calcined at 950 °C for 3 h in Argon stream (20–40 ml/min) using a conventional tube furnace. Characterization of the Fe_3O_4/MWCNT nanohybrid was performed by Transmission Electron Microscopy (TEM), X-Ray Diffraction (XRD) technique and Vibrating Sample Magnetometer (VSM).

RESULTS AND DISCUSSION

Morphology observation

XRD pattern and TEM image of Fe_3O_4/MWCNT nanohybrid were shown in Fig. 1 and Fi. 2, respectively. Simultaneously existence of the MWCNT and Fe_3O_4 nanoparticles can be seen in the XRD pattern. The TEM image of the sample demonstrates that MWCNT was coated and encapsulated with Fe_3O_4 nanoparticles.

Fig. 3 shows the VSM plot of Fe_3O_4/MWCNT nanohybrid, explaining the appropriate magnetic performance of the synthesized sample.

Dielectric and magnetic parameters

Figs. 4, 5 and 6 manifest the real part and the imaginary part of the relative permittivity (ε′ and ε″) and permeability (μ′ and μ″) spectra of paraffin matrix composite with different amounts of Fe_3O_4/MWCNT nanohybrid (i.e. 3.75, 7.5, 15 wt%, respectively). In all experiments, frequency range of 2-18 GHz in the microwave range was considered. Dielectric and

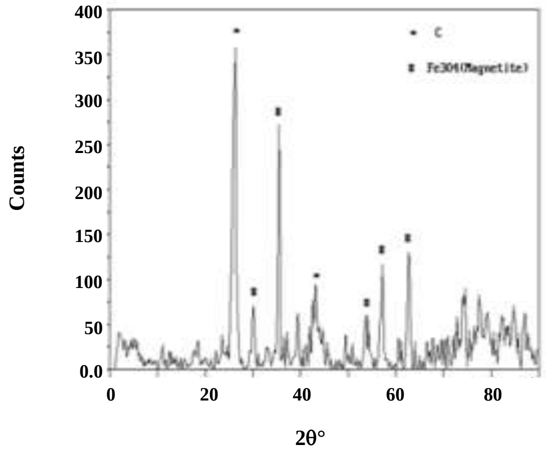

Fig. 1: XRD pattern of Fe_3O_4/MWCNT.

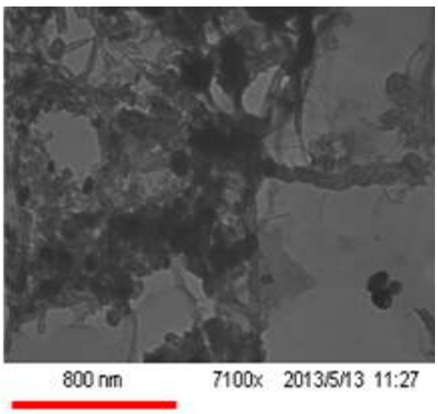

Fig. 2: TEM image of Fe_3O_4/MWCNT nanohybrid.

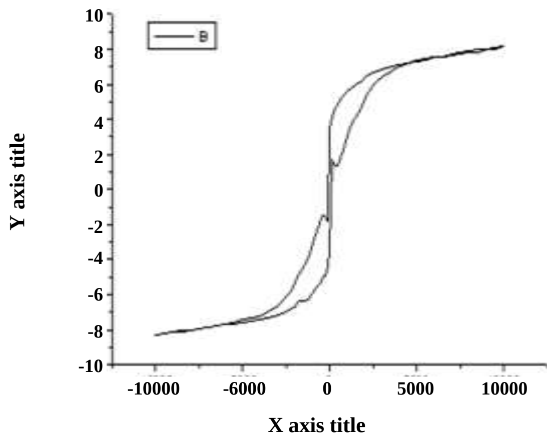

Fig. 3: VSM plot of Fe_3O_4/MWCNT nanohybrid.

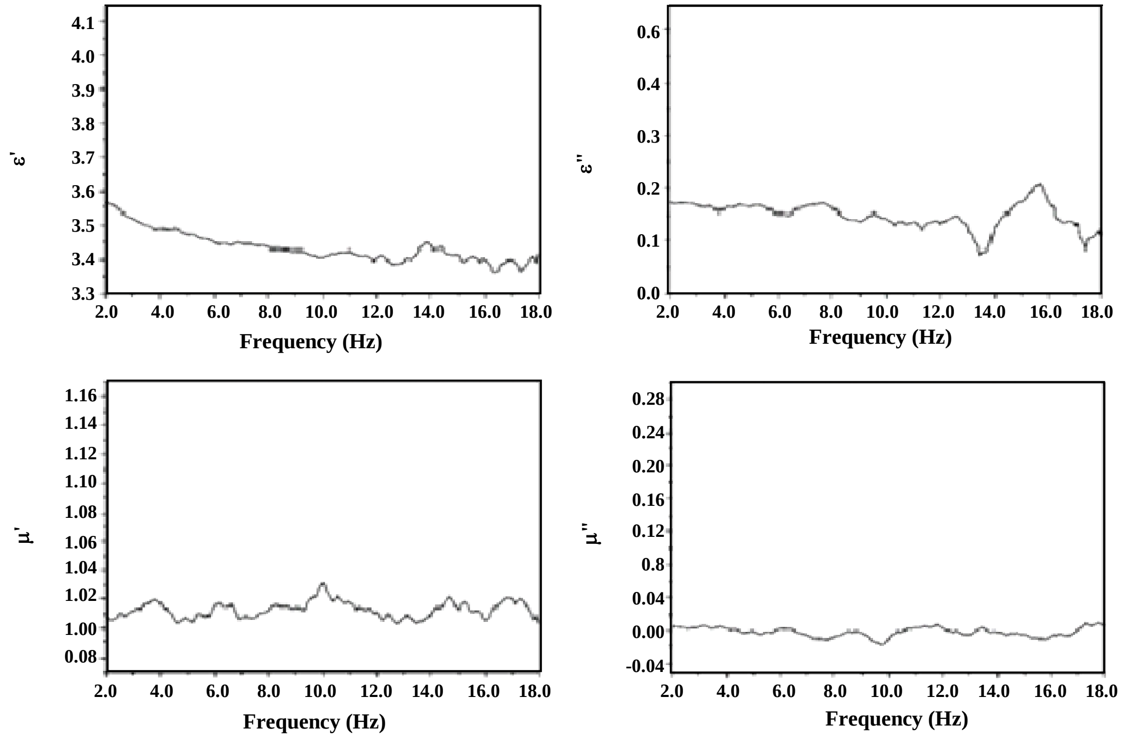

***Fig. 4:** Frequency relation between the real part and the imaginary part of the relative permittivity (ε' and ε") and permeability (μ' and μ") spectra of the composite that contains 3.75 wt% Fe_3O_4/MWCNT nanohybrid.*

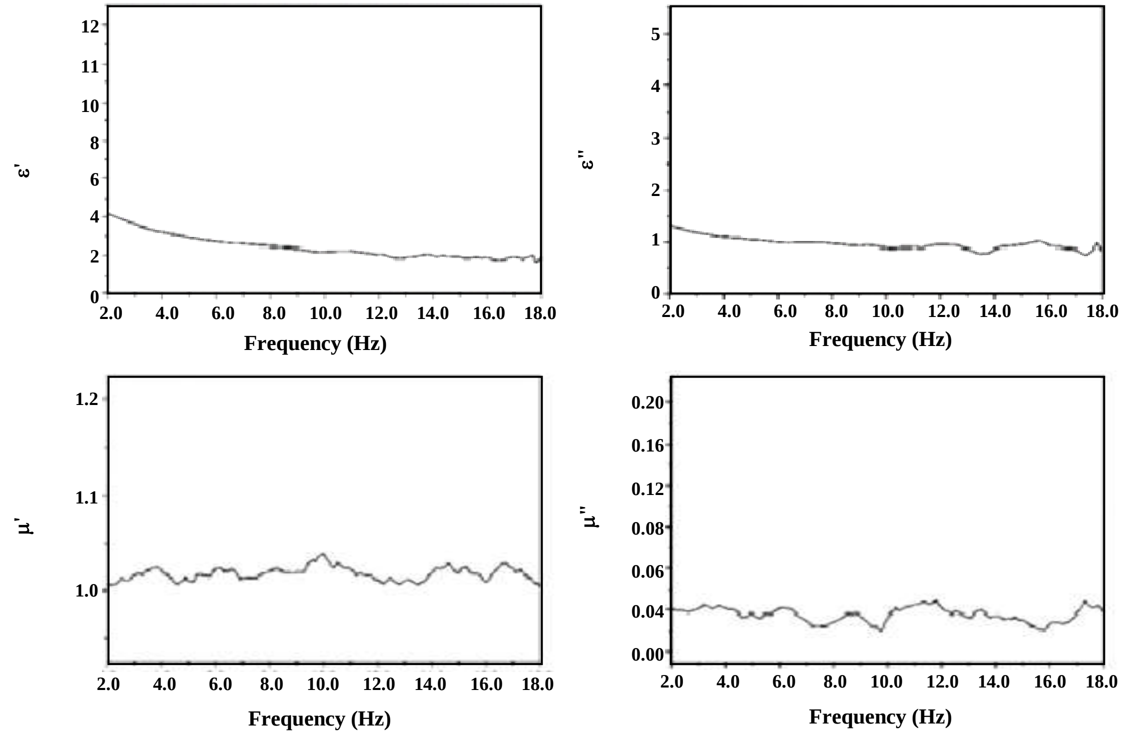

***Fig. 5:** Frequency relation between the real part and the imaginary part of the relative permittivity (ε' and ε") and permeability (μ' and μ") spectra of the composite that contains 7.5 wt% Fe_3O_4/MWCNT nanohybrid.*

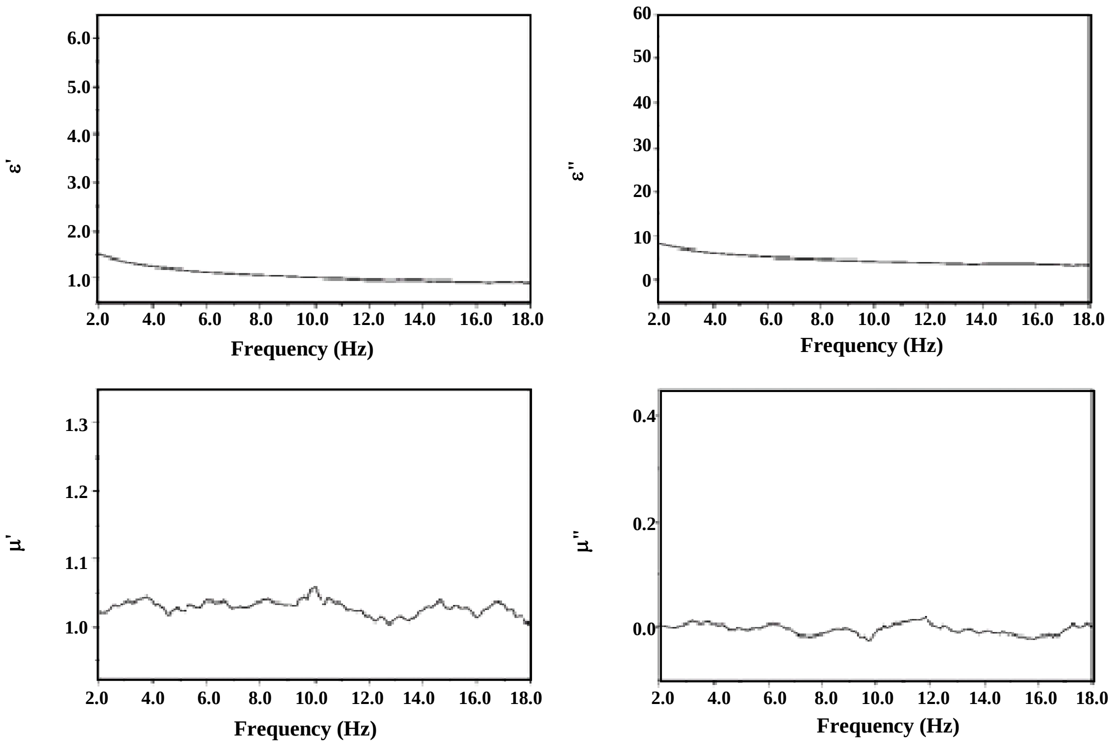

Fig. 6: Frequency relation between the real part and the imaginary part of the relative permittivity (ε' and ε'') and permeability (μ' and μ'') spectra of the composite that contains 15 wt% Fe_3O_4/MWCNT nanohybrid.

magnetic properties of the composite containing Fe_3O_4/MWCNT nanohybrid were evaluated with ε and μ, respectively. The results indicate that although additional amounts (wt %) of Fe_3O_4/MWCNT nanohybrid in the desired composite has no effect on the magnetic loss $\tan\delta_M=\mu''/\mu'$ in 2-18 GHz frequency range (microwave frequency), the dielectric loss $\tan\delta_E=\varepsilon''/\varepsilon'$ (with an amount between 0.5-0.6) improves obviously. Accordingly, Fe_3O_4/MWCNT nanohybrid (especially at 15 wt%) has good ability to improve the microwave absorption and it has a great potential for application as Radar Absorbing Material (RAM).

Based on the aforementioned results, the enhanced microwave absorption property of Fe_3O_4/MWCNT nanohybrid should be related to dielectric loss, conduction loss and multiple reflections in the porous structure of Fe_3O_4. As schematically shown in Fig. 7, Fe_3O_4/MWCNT nanohybrid can be seen as an antenna. When radar wave is projected on this structure, the energy of the radar wave will transfer in the form of micro current. When the generated current transmits along the tubular MWCNT structure, it serves as an electrically conductive network which effectively attenuates the radar wave energy. Moreover, as shown in Fig. 7, there are residual oxygen functional groups and defects in the MWCNT structure which act as polarized/scattering centers and enhance the absorption of radar energy. Also, the higher BET surface area of Fe_3O_4/MWCNT nanohybrid causes the formation of mangy diploes, interfacial polarization, and the associated relaxation, improving the possibility of radar wave absorbtion. Meanwhile, the porous structure of Fe_3O_4/MWCNT nanohybrid offers an additional opportunity for multiple reflections of the incident wave, leading to effectively enhanced radar absorption and attenuation [14, 15].

CONCLUSIONS

In this work, we report a simple and economical method for the preparation of Fe_3O_4/MWCNT nanohybrid. The composite relative permittivity and permeability spectra and their relationship with microwave absorbing were investigated for composites with paraffin matrix loaded with different amounts of Fe_3O_4/MWCNT nanohybrid. The experimental results

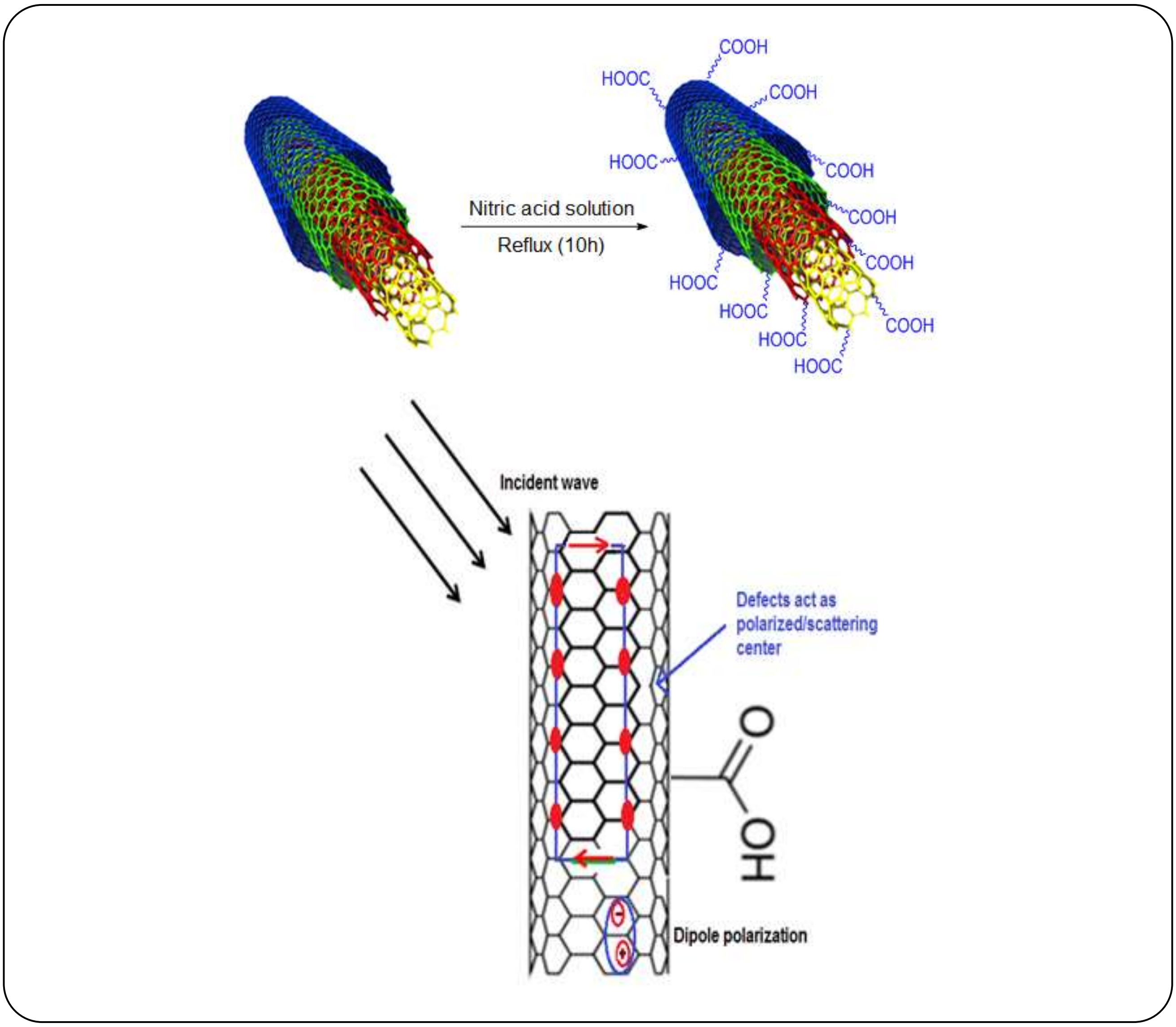

Fig. 7: Schematic diagram for possible enhanced radar absorption mechanism of Fe_3O_4/MWCNT nanohybrid.

indicate that the encapsulation of Fe_3O_4 in multi-walled carbon nanotubes can improve the microwave absorbing behaviour of the desired composite and the mentioned hybrid can be regarded as radar absorbing material.

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