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Short Communication

Investigation on the Microwave Absorbing Property of Fe_3O_4/CNFs Synthesized by Chemical Co-precipitation

Dexiang Li[1], *Xiaowei zhou*[1], *Keren Luo*[1], *Bo Yuan*[1], *Yongjun Liu*[1], *Li Sun*[1,2,*] *and Zhu Liu*[1,*]

[1] School of Physical Science and Technology, Yunnan Key Laboratory of Nanomaterials & Technology, Yunnan University, Kunming, Yunnan, China 650091
[2]Advanced Analysis and Measurement Center of Yunnan University, Kunming City, Yunnan Province, China 650091
[3] Department of Mechanical Engineering and Texas Center for Superconductivity (TcSUH), University of Houston, Houston, Texas 77204
[*]E-mail: lsun4@uh.edu, zhuliu@ynu.edu.cn

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In this paper, Fe_3O_4 nanoparticles have been coated on the surface of Carbon nanofibers (CNFs) by the method of chemical co-precipitation. This Fe_3O_4/coated CNFs exhibit remarkably improved microwave absorption property as compared to the bare CNFs. Our research provides an economical and highly productive approach for fabricating Fe_3O_4/CNFs nanostructures which is suitable for the application of electromagnetic wave absorption and shielding.

Keywords: Carbon nanofiber; Fe_3O_4 nanoparticles; chemical co-precipitation; Microwave absorption

1. INTRODUCTION

Carbon nanofiber (CNF) is an excellent kind of microwave absorption material that has great carrying capacity, low radar cross section, high strength and modulus [1]. It can be used for structural maintenance and multiple functions material. As compared to many other functional materials, carbon nanofibers exhibit more excellent performances in the aspects of conductivity [2,3] and electronic countermeasure [4]. It also can be adopted as a kind of electromagnetic shielding material [5,6]. The distinct advantages of CNFs, for instance, light weight, large surface area, excellent thermal and electrical conductivity property [5,7] when used as microwave absorption material, make it more competitive in practical application. However, CNFs mainly take the dielectric loss and very low magnetic loss, which limits their performance. It has been reported that introducing Fe_3O_4 coating on the carbon can improve its microwave absorption performance, but Fe_3O_4 nanoparticle possess high

surface energy and magnetic property which would cause them to aggregate with each other and not uniformly coated on the carbon surface [8-10]. Therefore, to promote the high resistivity [11] and good magnetic [12] Fe_3O_4 nanoparticles uniform coating, we use fenton regent to treat CNFs. The Fe_3O_4 coating adjusts the electric-magnetic parameters, so that make the dielectric loss and magnetic loss combined, making the composite a potential microwave absorption material.

A variety of techniques were used to fabricate Fe_3O_4/carbon composite, such as electrochemical deposition [13], magnetron sputtering [14], sol-gel [15] and chemical precipitation [16]. For these techniques, the chemical co-deposition is broadly adopted owing to its simple operation and device [17]. Furthermore, the Fe_3O_4 coating produced by this method displays great continuity and homogeneity. In this research, we have successfully prepared Fe_3O_4 coating on the surface of CNFs by chemical co-precipitation method, leading to the formation of Fe_3O_4/CNFs composite. The structure, morphology, microwave absorption properties of bare CNFs and Fe_3O_4/CNFs composite were investigated and compared with each other.

2. EXPERIMENT

Some researchers reported the electrochemical preparation and microwave absorption properties of magnetic carbon fibers coated with Fe_3O_4 films [13]. However, the procedure of electrochemical deposition is relatively tedious and the orientation of Fe_3O_4 electrochemical growth is very strong, which easily lead to the generation of large particles. Besides, Fe_3O_4 particles generated electrochemically are difficult to evenly disperse around the carbon nanofibers. Chemical co-precipitation preparation reported here is facile and scalable. CNFs (0.5 g) treated with fenton reagent were dispersed in 100 ml deionized water, then $FeSO_4$ (0.8 g) and $FeCl_3$ (0.7 g) were added to the above suspention, respectively. Subsequently, the suspension was transferred to the water bath and maintained at 90 ℃, then $NH_3 \cdot H_2O$ (30 ml) was added to the mixture solution and kept 30 min. Finally, the fresh CNFs/Fe_3O_4 composite was washed with deionized water and dried at 60 ℃ for 12 h. To test the microwave absorption property, bare CNFs（20wt%） and Fe_3O_4/CNFs composite（20wt%） were uniformly mixed with paraffin（80wt%）and pressed into wafer with the thickness of 2 mm.

The crystalline structure of the samples was detected by X-ray diffractometer (XRD, Rigaku TTR Ⅲ) using Cu Kα radiation (λ=1.5406 Å). The morphology of the composite was examined by scanning electron microscopy (SEM, FEI QUANTA 200). The relative complex permittivity and permeability of the composites were tested in the frequency range of 1~18 GHz by an HP8722ES vector network analyzer.

3. RESULTS AND DISCUSSION

Fig.1a shows the XRD patterns for bare CNFs. Fig.1b gives the XRD patterns of the sample, which coincides well with the standard date of Fe_3O_4(magnetite, JCPDS 10-716337). And the diffraction peak appearing at 2θ=25 degree is due to the presence of CNFs in the composite. The

strong and sharp Fe_3O_4 diffraction peaks at XRD patterns confirmed the formation of well-crystallized Fe_3O_4. The average crystal size was estimated to be about 10 nm by scherrer formula for the generated Fe_3O_4 nanoparticles.

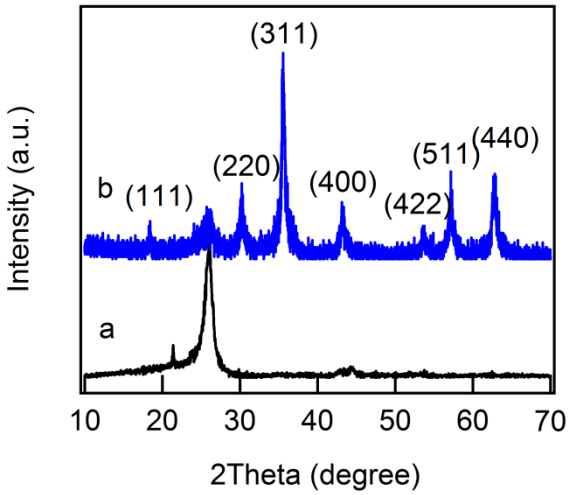

Figure 1. XRD patterns of (a) bare CNFs and (b) Fe_3O_4/CNFs prepared by chemical co-deposition

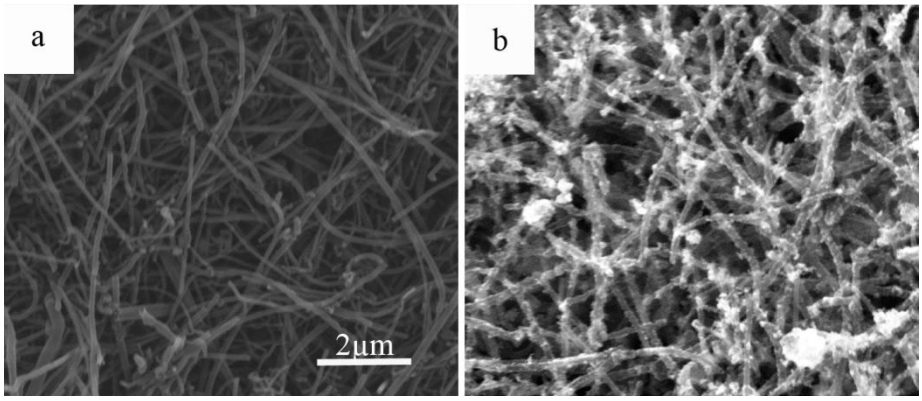

Figure 2. SEM images of (a) bare CNFs and (b) Fe_3O_4/CNFs prepared by chemical co-deposition

The surface morphologies of bare CNFs and Fe_3O_4/CNFs composite were shown in Fig.2. Fig. 2a presents the morphology and structure of the CNFs, in which CNFs have smooth surface with diameters ranging from 50 nm to 200 nm. Fe_3O_4 deposited on the CNFs has been investigated by SEM as shown in Fig.2b. We could see that the Fe_3O_4 nanoparticles anchored on the surface of CNFs uniformly.

For researching the microwave absorption property, the relative complex permittivity and permeability of bare CNFs and Fe_3O_4/CNFs composite were measured at the range from 1 GHz to 18 GHz. With the increase of the frequency, the real part of complex permittivity keeps constant below 4 GHz and then decreases until 15 GHz as shown in Fig.3a. And the imaginary part decreases to 100

GHz. The real part of complex permeability decreases to about 0.45 at 5 GHz and then increases slightly. The imaginary part increases slightly and then decreases to about 0.1. The dielectric loss and magnetic loss factors are presented in Fig.3c. The magnetic loss factor is close to 0, it indicates that the main attribution to the dielectric loss is the reflection loss (RL) of CNFs.

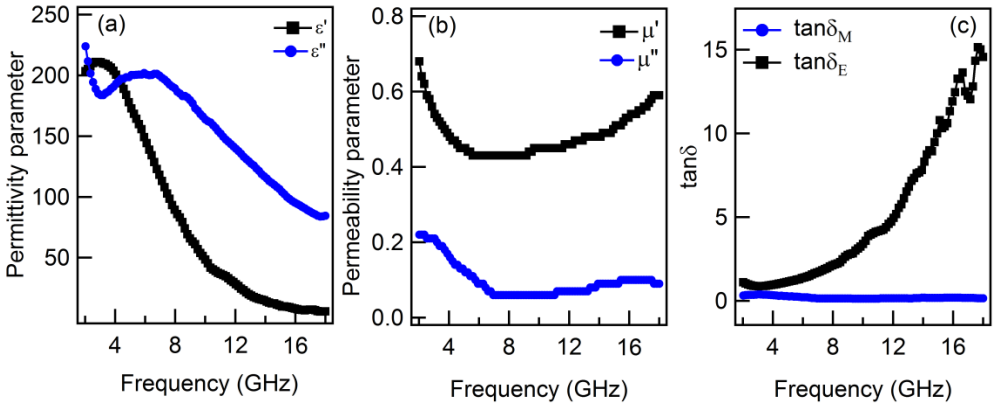

Figure 3. Measurements of electromagnetic parameters for blank CNFs/paraffin(20wt%): (a) Permittivity spectra, (b) permeability spectra, (c) loss factor.

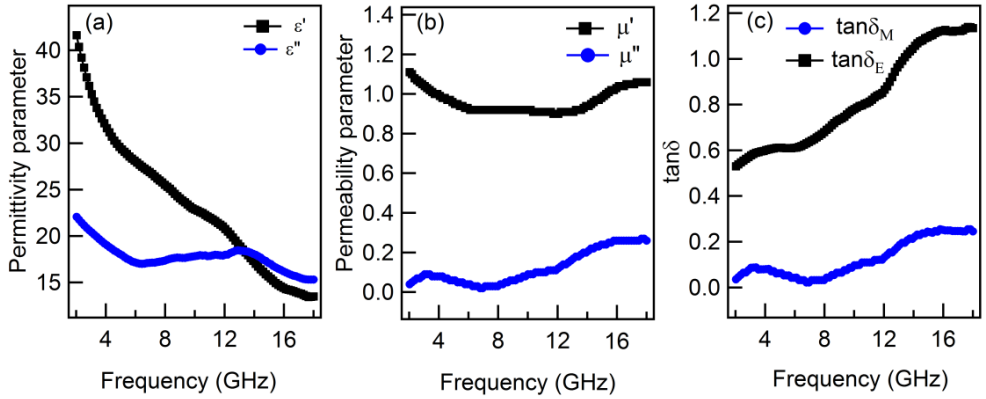

Figure 4. Measurements of electromagnetic parameters for Fe_3O_4- CNFs/paraffin(20wt%): (a) Permittivity spectra, (b) permeability spectra, (c) loss factor.

In the Fig.4, the fact tan δ_E is higher than tan δ_M suggests that the RL of Fe_3O_4/CNFs composite is also due to the dielectric loss. Comparing the Fig.3c and 4c, it is obvious that tan δ_M of Fe_3O_4/CNFs composite is much larger than that of bare CNFs. Thus, Fe_3O_4/CNFs composite will exhibit better microwave absorption performance.

Fig.5 shows the plots of microwave RL for bare CNFs and Fe_3O_4/CNFs composite. The results confirm that bare CNFs and Fe_3O_4/CNFs composite have different absorption properties. Bare CNFs almost exhibit no absorption property because its RL is -1.5 dB at 2.5 GHz. By contrast, the absorption peak of Fe_3O_4/CNFs composite material shifts to the higher frequency at 7 GHz. Meanwhile, the

frequency bandwidth of 6 GHz and the RL values of -11 dB have been achieved. It indicates that this composite material is more suitable as EM wave absorber. The reflection loss of Fe_3O_4/carbon composite material is less than -10 dB [18]. Various methods are proposed to prepare the different structural composites and adjust the thickness of the absorber to achieve the better absorbing performance. Many of the preparation methods are tedious and involve in severe experimental conditions as well as sophisticated equipments [19, 20]. In comparison, chemical co-precipitation method has the advantages of easy operation and mass production. Furthermore, Fe_3O_4 nanoparticles obtained by chemical co-precipitation can be well dispersed on the surface of carbon nanofibers. We can also achieve better microwave absorbing performance through controlling the amount of Fe_3O_4 in the composite material.

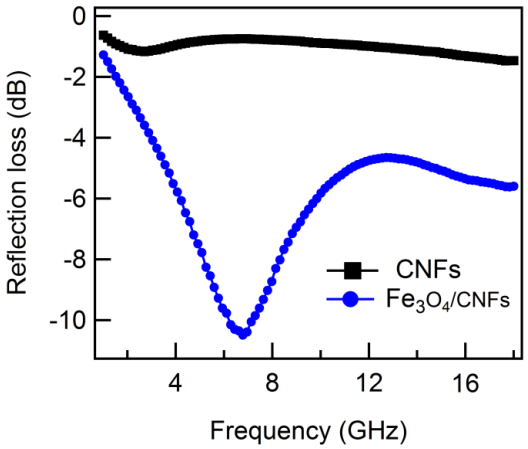

Figure 5. Microwave absorbing characteristics of both samples.

4. CONCLUSIONS

In this study, CNFs/Fe_3O_4 composite was synthesized by chemical co-precipitation method. A large number of function groups were introduced to the surface of CNFs through the treatment of fenten reagent, which made Fe_3O_4 coating grown on the CNFs more uniform. The fabricated Fe_3O_4/CNFs composite shows lower RL and broader absorption frequency domain compared with bare CNFs. For optimizing the microwave absorption property of Fe_3O_4/CNFs nanocomposite, we could control the quantity of coated Fe_3O_4 or adjust the thickness of product/paraffin composite. Such kind of Fe_3O_4/CNFs composite, which is light-weighted and flexible, is expected to become a promising microwave absorbing material in the future.

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