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NOTE

Microwave Absorption Properties of Fe_2O_3/Paraffin Wax Nanocomposite

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The aim of this study is to investigate the electromagnetic properties of Fe_2O_3/paraffin wax nanocomposite in the frequency range 12-18 GHz, with focus on the electromagnetic absorption mechanisms at microwave frequencies. Results show that, high microwave absorption properties in the frequency range of 12.5-14.5 GHz with the thickness of 1.8 mm. An optimal reflection loss value of “16.0009 dB is obtained at 13.676 GHz. The nanocomposite is a good candidate for microwave absorption in the gigahertz range.

Key Words: Nanocomposite, Microwave absorber, Iron oxide nanoparticles.

The absorption of electromagnetic wave has been important issues for commercial and military industrials. On the other hand, the stealth technique is the most typical application of electromagnetic wave absorption technology. By reducing the detectability of aircrafts or warships, of which the radar cross section (RCS) is a measure, they could evade radar detection, which affects not only the mission success rate but also survival of them in the hostile territory[1-6]. In facts, the stealth technique can be categorized into two methods. One is the shape optimization of the body so that incident electromagnetic wave can be scattered yielding minimum reflective wave. The other is the use of electromagnetic wave absorption materials and/or structures. In the early stage, many researchers mainly concentrated on the reduction of radar cross section and development of the radar absorbing materials (RAMs). In recent years, extensive investigations have been carried out to fabricate microwave absorption materials with good electromagnetic match, such as CNTs/Fe[7], CNTs/$CoFe_2O_4$[8], Ni(C) nanocapsules[9] Mn and Ti doped strontium hexaferrite[10], SnO_2 nanowire/paraffin[11], $CoFe_2O_4$ nanoparticles[12] and Fe_3Al/Al_2O_3 fine particle composites[13]. These nanocomposites showed better microwave absorption than the pure core or shell materials. Therefore, it is significant to search other approaches to fabricate microwave absorption materials with good electromagnetic match. In this letter, Fe_2O_3/paraffin nanocomposite were fabricated and the microwave absorption properties were investigated.

Various methods of synthesis of nanosized iron oxide particles have been elaborated such as the sol-gel[14], micro emulsion[15], sonochemical[16], ultrasonic spray pyrolysis[17], microwave plasma[18]. Each preparation method has its advantages and disadvantages, which mainly relate to particles size distribution, production scale and cost. The Fe_2O_3 nanoparticles were obtained *via* the sol-gel method based on the hydrolysis and condensation of iron nitrate precursors, followed by heat treatment[19]. In a typical experiment, 400 mL of iron nitrate (0.1 M) was gelated by using 1600 mL of mono hydrated citric acid solution (0.05-0.20 M) as ligand molecules. The singly distilled water used as the solvent. The iron solution was added to the citric acid solution drop wise with vigorous stirring. The solution was then heated to 70 ºC, while maintaining vigorous stirring until the gel was formed and the contained water was evaporated. The dried gel was annealed at temperatures ranging from 180- 400 ºC, typically yielding Fe_2O_3 nanoparticles. Subsequently, the Fe_2O_3/paraffin wax composite (weight ratio = 1:1) was pressed into a toroidal shape with outer diameter of 7 mm and inner diameter of 3 mm for microwave measurement (Fig. 1). It was then inserted into the waveguide to measure the S-parameter using the HP vector network analyzer in the frequency range of 12-18 GHz.

(a) (b)

Fig. 1. (a) Device for the preparation of toroidal shape. (b) Waveguide (inner diameter 3 mm and outer diameter 7mm)

The morphology of the nanocomposite was investigated by FE-SEM (Fig. 2). This image exhibits the effective dispersion of Fe_2O_3 in paraffin wax matrix.

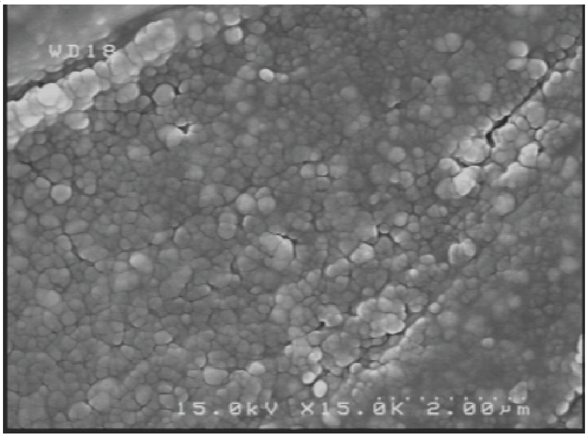

Fig. 2. Cross-sectional FESEM images of the toroidal Fe_2O_3/paraffin wax composite, showing an effective dispersion of Fe_2O_3 in paraffin wax matrix

According to the transmission line theory, the reflection loss (RL) of normal incident electromagnetic wave at the absorber surface can be calculated from the relative permeability and permittivity at a given frequency and absorber thickness using the following equations:

$$Z_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} \quad (1)$$

$$Z_{in} = \sqrt{\frac{\mu}{\varepsilon}} \tan h\left(j\frac{2\pi fd}{e}\right)\sqrt{\mu\varepsilon} \quad (2)$$

$$RL = 20\log\left|\frac{Z_{in} - Z_0}{Z_{in} + Z_0}\right| \quad (3)$$

Here, Z_0 is the impedance of air, μ_0, ε_0 are the permeability and permittivity of air, respectively, f the frequency of the electromagnetic wave, d is the thickness of the absorber, c is the velocity of light, Z_{in} is the input impedance of the absorber and μ and ε are the complex permeability and complex permittivity of absorber, respectively.

Fig. 3 shows the typical relationship between reflection loss (RL) and frequency of the nanocomposite. The effective microwave absorption (RL < -10 dB) is obtained in a wide frequency range of 12.5-14.5 GHz with the thickness of 1.8 mm. The optimal RL value of -16.0009 dB is obtained at 13.674 GHz with an absorber thickness of 1.8 mm.

In general, electromagnetic waves absorbers are required to have excellent reflection loss values and be thin to cater to military as well as civilian applications. Moreover, they must have good formability. The method described in this work satisfies these requirements and is projected to play an important role in the new design of microwave absorbers.

Conclusion

The Fe_2O_3/paraffin wax nanocomposite exhibits excellent microwave absorption properties in the frequency range of 12.5-14.5 GHz with the thickness of 1.8 mm. An optimal reflection loss value of -16.0009 dB is obtained at 13.676 GHz. As stated above, the nanocomposite is a good candidate for microwave absorption in the gigahertz range. This novel fabrication method can be opens the way for more effective and simpler design and synthesis of microwave absorbers in military and commercial applications.

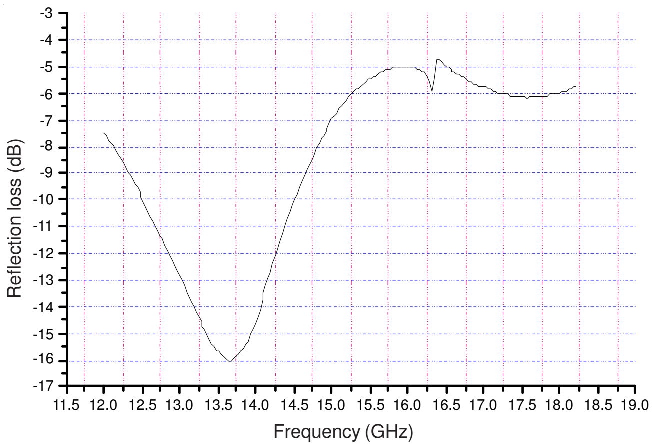

Fig. 3. Frequency dependence of reflection loss (RL) of the nanocomposite. An optimal RL value of -16.0009 dB is obtained at 13.674 GHz with an absorber thickness of 1.8 mm

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