ELECTROMAGNETIC CHARACTERISTICS OF VGCNFS AT A FREQUENCY OF 12.4GHz~18GHz

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Intruduction

Vapor-grown carbon nano-fibers (VGCNFs) are one kind of pyrolytic products made by pyrolyzing hydrocarbon compounds in the presence of transition metal catalysts in a hydrogen or nitrogen atmosphere. Because of their distinctive properties, such as high strength, electric conductivity and special functional properties, scientists have shown a great attention to the application of these materials. In particular, electromagnetic interference (EMI) shielding and microwave absorption are the rapidly growing applications of VGCNFs [1]. In this paper, the wave-guide method was used to measure the relative complex permittivity ε_γ ($\varepsilon_\gamma = \varepsilon_\gamma' - j\varepsilon_\gamma''$) and the relative complex magnetic permeability μ_γ ($\mu_\gamma = \mu_\gamma' - j\mu_\gamma''$) of the VGCNFs with average diameter of 100nm imbedded in paraffin wax at a frequency of 12.4~18GHz. The rules of real and imaginary part of the relative complex permittivity and relative complex magnetic permeability of the VGCNFs/paraffin wax composite changing with the frequency were discussed in detail. The dielectric loss tangent ($tg\delta_\varepsilon$) and the magnetic loss tangent ($tg\delta_m$) were determined using the measured value of the relative complex permittivity and the relative complex magnetic permeability of the VGCNFs/paraffin wax composite.

Experimental

In the experiment, VGCNFs were obtained at 1423-1473K in the presence of sulfur by a floating catalyst method using benzene as a carbon source. The diameter distribution of the as-prepared VGCNFs can be controlled in the range of 10~500nm and the fibers with average diameter of 100nm were chosen as the sample in this study. The as-prepared VGCNFs were dispersed in molten paraffin wax after being fined, then the mixture was cast into a mold ($45.8\times7.9\times2mm^3$). The sample consisted of 4wt% VGCNFs. The relative complex permittivity and relative complex magnetic permeability of the VGCNFs/paraffin wax composite were measured by the wave-guide method based on measurements of the reflection and transmission module at a frequency of 12.4GHz~18GHz.

Rsults and discussion

Fig. 1 shows the SEM image of VGCNFs with average diameter of 100nm. The fibers are straight and the diameters are well distributed with an average diameter of about 100nm, and purity of the VGCNFs is high.

ε_γ and μ_γ of the VGCNFs/paraffin wax composite were measured at a frequency range of 12.4GHz~18GHz. The curve of ε_γ', $\varepsilon_\gamma''$and μ_γ', μ_γ'' as a function of frequency are shown in Fig. 2 and Fig. 3, respectively. It can be seen in Fig.2 that the values of $\varepsilon_\gamma'$and ε_γ'' decrease with the increase of the frequency, and the value of ε_γ'' ranges from 59.2 to 33.6. The result indicates that the VGCNFs are a kind of electric loss material, since the ε_γ''value is much more than zero whereas the values of $\varepsilon_\gamma'$and ε_γ'' of the paraffin wax are 2.26 and 0 at the same frequency range. The VGCNFs are electrically conductive and can be polarized repeatedly in high frequency electric field, which cause the electric energy being changed into heat energy, and then dissipates.

From Fig. 3, it can be seen that the values of $\mu_\gamma'$and μ_γ'' increase with the increase of the frequency and the μ_γ'value is less than one and μ_γ'' value is not zero. These results indicate that the VGCNFs have diamagnetism and can produce magnetic loss since the μ_γ'' value is not zero whereas $\mu_\gamma'$and μ_γ'' of the paraffin wax are 1 and 0 at the frequency range of 12.4~18GHz. Diamagnetism is a property of the benzene-ring structure atoms due to the intinerant nature of the π electrons[2-4]. High frequency magnetic field can cause repeated magnetization and produce magnetizing current in the VGCNFs, since the

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VGCNFs have diamagnetism. Then, the magnetic energy can be changed into heat energy because the resistance of the VGCNFs is not zero.

Fig. 4 shows the dielectric loss tangent ($tg\delta_\varepsilon$) and the magnetic loss tangent ($tg\delta_m$) of VGCNFs/paraffin wax composite, which have been caculated by Eq.1 and Eq.2, versus the frequency range (12.6~18GHz). The results show that the dielectric loss tangent ($tg\delta_\varepsilon$) range from 1.59 to 1.8 and the magnetic loss tangent ($tg\delta_m$) range from 0.03 to 0.086 with the increase of the frequency. However, the value of magnetic loss tangent ($tg\delta_m$) is much less than that of the dielectric loss tangent ($tg\delta_\varepsilon$), which means that VGCNFs with diameter of 100nm mainly are a kind of electric loss materials. The magnetic loss is very small for the weak magnetizing current caused by low magnetic permeability of the VGCNFs, which have diamagnetism.

$$tg\delta_\varepsilon = \varepsilon_\gamma'' / \varepsilon_\gamma' \quad (1) \qquad tg\delta_m = \mu_\gamma'' / \mu_\gamma' \quad (2)$$

References

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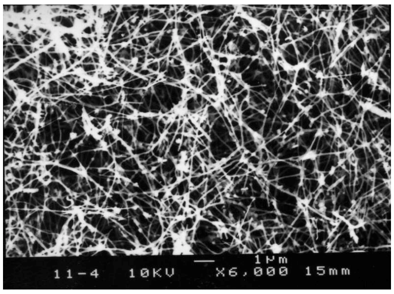

Fig.1. SEM image of VGCNFs with average diameter of 100nm

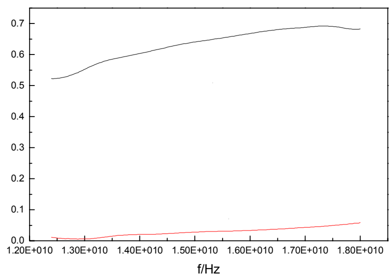

Fig. 3. the curve of $\mu_\gamma'$and μ_γ'' of VGCNFs imbedded in paraffin wax as a function of frequency

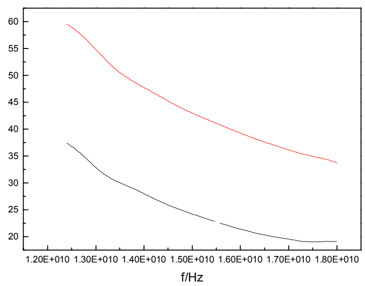

Fig.2. the curve of $\varepsilon_\gamma'$and $\varepsilon_\gamma''$of VGCNFs imbedded in paraffin wax as a function of frequency

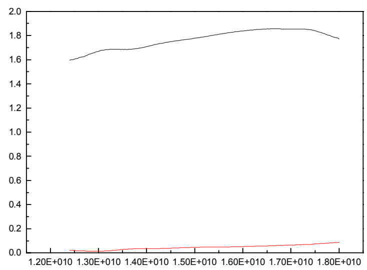

Fig. 4. $tg\delta_\varepsilon$ and the $tg\delta_m$ of VGCNFs imbedded in paraffin wax as a function of freqency