Electromagnetic properties of texture composite materials based on hexagonal ferrites/multiwalled carbon nanotubes

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Electromagnetic properties of texture composite materials based on hexagonal ferrites/multiwalled carbon nanotubes

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Abstract. In this article, the frequency dependence of the absorption coefficient and electromagnetic losses of the composite based on ferrite powder and / or multi-walled carbon nanotubes are presented. The dielectric and magnetic losses in the composite were measured in the range of 0.01 – 20 GHz. It has been found to increase the absorption of electromagnetic radiation and increased losses in the samples containing multi-walled carbon nanotubes.

1. Introduction

Nowadays microwave electronics devices are used in many areas of industry, health, education. It is a reason to a problem of electromagnetic compatibility of radio electronic devices. Interference leads to a deterioration of the nominal characteristic and the stability of the devices. The high power of the microwave radiation is dangerous to biological objects. [1, 2]

Composite materials with unique physical properties: a low weight, strength, plasticity, resistance to mechanical loads and high radar-absorbing properties are developed for the decision of this problem. They can be used as radioabsorbing materials and radioabsorbing coatings. Ferrites and multiwall carbon nanotubes (MWCNT) as materials with controlled electromagnetic characteristics were investigated in the articles [3-7]. It was shown that the change of concentration of the active fraction leads to a change of electromagnetic properties of the experimental samples. Moreover, this change also depends on the type of extender. The present article is devoted the possibility of creating of multi-functional composite materials with controlled electromagnetic characteristics in during production. The coaxial method was used to investigate electromagnetic characteristics. The study was conducted in the frequency range from 0.01 GHz to 20 GHz. Micran P2M-18 (Micran, Research & Production Company, Tomsk, Russia) was used to measure the modulus of the reflection coefficient and the transmission coefficient.

2. Results and Discussions

Standard ceramic techniques were used to the fillers creation. The initial materials for the synthesis were barium oxide BaO powders, cobalt (II) oxide CoO, titan oxide TiO_2 and iron (III) oxide Fe_2O_3. Prior to synthesis, the oxides powders were dried for 3 h at temperature of 200 °C. After that powders were weighed according to a ratio

$$3BaO + 2{,}4CoO + 0{,}4\,TiO_2 + 11{,}6\,Fe_2O_3 = Ba_3Co_{2,4}Ti_{0,4}Fe_{23,2}O_{41}.$$

Powders used for sintering experiments were ground for 4 h in a vibration ball mill. The ball-to-powder mass ratio was 5:1. Powders were die-pressed at about 1000 atm. Solid samples were heated up in 10–15 min to the sintering temperature (1150 ℃), fired for 4 h and were cooled to the room temperature. After that samples were crushed. Powders were ground for 35 min in a vibration mill. Powders were die-pressed repeatedly at about 1000 atm. Solid samples fired in oxygen for 6 h 1200 °C finally. After that samples were ground once again. The powders were sifted by separator. The sizes of powders don't exceed 80 microns.

Multiwalled carbon nanotubes with a diameter of 9.4 nm were produced by the Institute of Catalysis SB RAS [4]. Epoxy resin EDP 20 was prodused by Gmbh «ChK FEM». Fillers and epoxy resin were weighed in the required proportions of mass on the scales Shimadzu AUX-320 (error ±0.5 mg) were placed into the vessel and thoroughly mixed for 15 minutes until homogeneous. The compositions of samples are presented in Table 1. The resulting mixture was poured into three identical shapes. The magnetic field intensity was 1 kOe. Duration of stay in the magnetic field of the samples was 5 hours at room temperature.

Table 1 – Descriptions of test samples

Number	Concentration (%)			Magnetic field (kOe)
	Ferrite	MWCNT	Epoxy	
1	65	1	34	1
2	66	-	34	1
3	66	-	34	0

The prepared samples were representing washers with a thickness of 1.35 mm, an outer diameter of 7 mm and inner diameter of 3.04 mm. The results of experimental measurements of the electromagnetic characteristics are shown in Figure 1 and Figure 2.

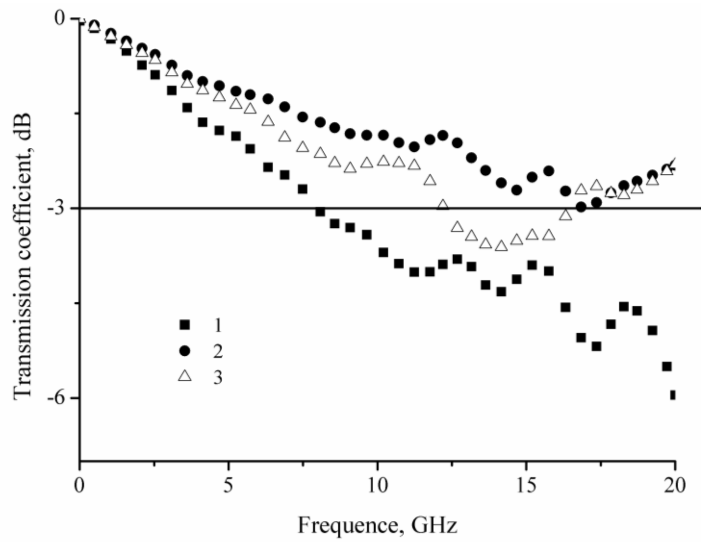

Figure 1. Coefficient of transmission experimental samples

The comparison of the samples line was held at the level 3 dB in Figure 1. This line corresponds to the absorption capacity of 50% of the incident wave. Figure 1 shows that in the frequency range from 8 to 20 GHz 1 wt.% of nanotubes sample absorbs EMR in 2-2.5 times more compared to the same sample without nanotubes. For a sample that is polymerized without external magnetic field at all similar parameters absorption power is worse in 1.2-1.8 times. The sample number 1 has a several distinct areas of the dispersion. They are from 12 to 15 GHz with a peak of absorption minus 4.3 dB, from 16 to 18 GHz with a peak of absorption equal minus 5.2 dB and also from 19 to 20 GHz, but the peak of absorption is not observed in this range. The maximum value of the absorption power is minus 6 dB in the range from 19 to 20 GHz. The sample number 3 has a clearly expressed dispersion region. It is in the range from 12 to 16 GHz. The sample number 2 has nothing special in this frequency range.

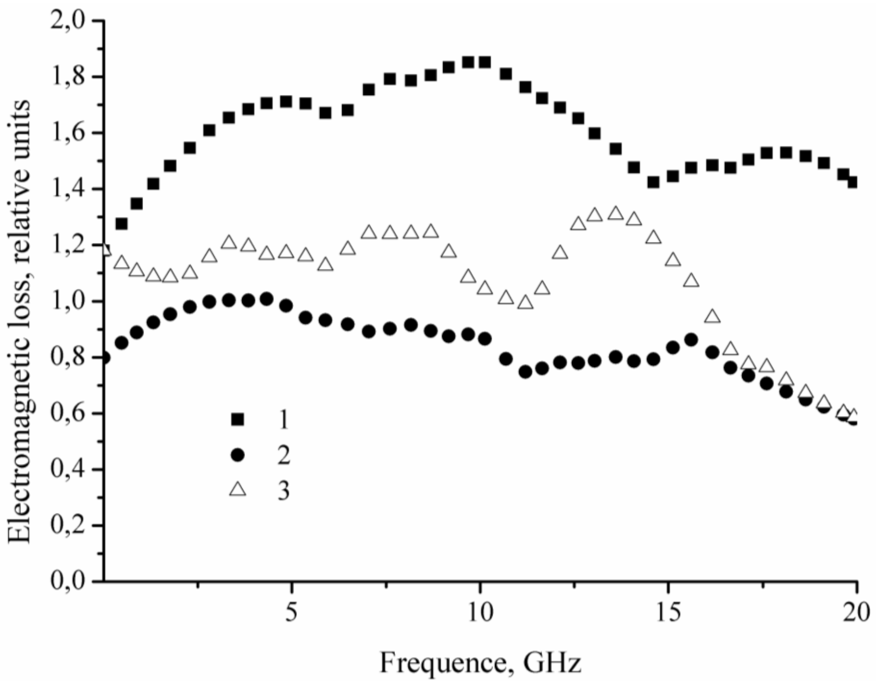

Figure 2. Coefficient of electromagnetic loss

The results of calculation of cumulative electromagnetic losses for thin dielectric layer are shown in Figure 2. For sample number 1 in the range from 0.01 to 14 GHz dispersion electromagnetic losses is observed with a maximum value of 1.85 rel. units at a frequency of 10 GHz and a small peak of absorption between 15 and 20 GHz at 1.5 rel. units. Comparison with samples of composite materials, fillers which are the MWCNTs [4, 7], and carbonyl iron [8] shows that result obtained can be explained by large dielectric losses in the MWCNT. Comparison samples number 2 and number 3 showed that the effect of an external magnetic field to the sample during the polymerization resulted in a reduction of losses in the material, which worsened its absorbent properties.

3. Conclusion

The study showed that the addition of MWNTs into the mixture until fabrication of textured materials increases the absorbing properties of the composite material. The effect of external magnetic field during the polymerization of samples and the addition of MWNT leads to a broadening of the absorption spectrum.

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