Ferromagnetic resonance in hexagonal ferrite $BaFe_{12}O_{19}$ at the EHF frequency range

A. V. Badin, K. V. Dorozhkin, G. E. Kuleshov, V. A. Zhuravlev, V. I. Suslyaev, G. E. Dunaevskii, and K.V. Bilinskii

National Research Tomsk state University, Tomsk 634050 Russia

Abstract — **Results of research of electromagnetic response of $BaFe_{12}O_{19}$ hexaferrite at frequencies 34-250 GHz at room temperature are presented. At the vicinity of the frequency ~ 50 GHz the resonance absorption of electromagnetic wave energy was observed. We explain this by the presence of natural ferrimagnetic resonance in the effective field of magnetocrystalline anisotropy.**

I. INTRODUCTION

Due to the large values of the magnetocrystalline anisotropy fields (H_a) and the saturation magnetization (M_s) [1–3] the hexaferrite with M-type crystal structure $BaFe_{12}O_{19}$ (Ba-M) are widely used as permanent magnets and radar-absorbing materials for EHF range. Maximum absorption of EMW energy by these compounds is observed within the frequency band of natural ferromagnetic resonance (NFMR) which is defined by the magnitude of anisotropy field and size/shape of ferrimagnetic powders grains. According to Refs. [1–3] the NFMR frequency of the polycrystalline Ba-M sample is close to 47 GHz. Thus, this material is promising for the development of radar-absorbing materials and coatings for the millimeter wavelength range.

II. RESULTS

The five composite samples in the form of plane-parallel polished plate 1.13-1.21 mm thick based on epoxy resin with different content of Ba-M powders was prepared for researches. Ba-M powders was prepared from a 19BA260 ferrite permanent magnet. The magnet was demagnetized by heating above the Curie temperature, held at a temperature of 600°C for 2 h, and cooled in the switched off furnace. Then it was grinded in an MBP planetary ball mill. The particle sizes were from 90 to 160 μm. The concentration of Ba-M powders in the composites was 15, 30, 45, 60 and 75 mass. %.

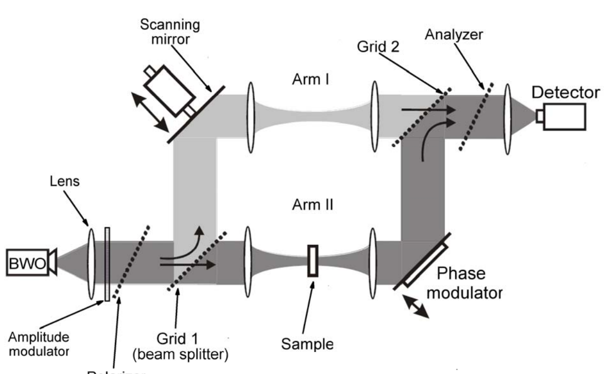

Fig 1. The experimental setup of the Mach-Zender interferometer for researching of the electromagnetic properties on solid materials at THz region.

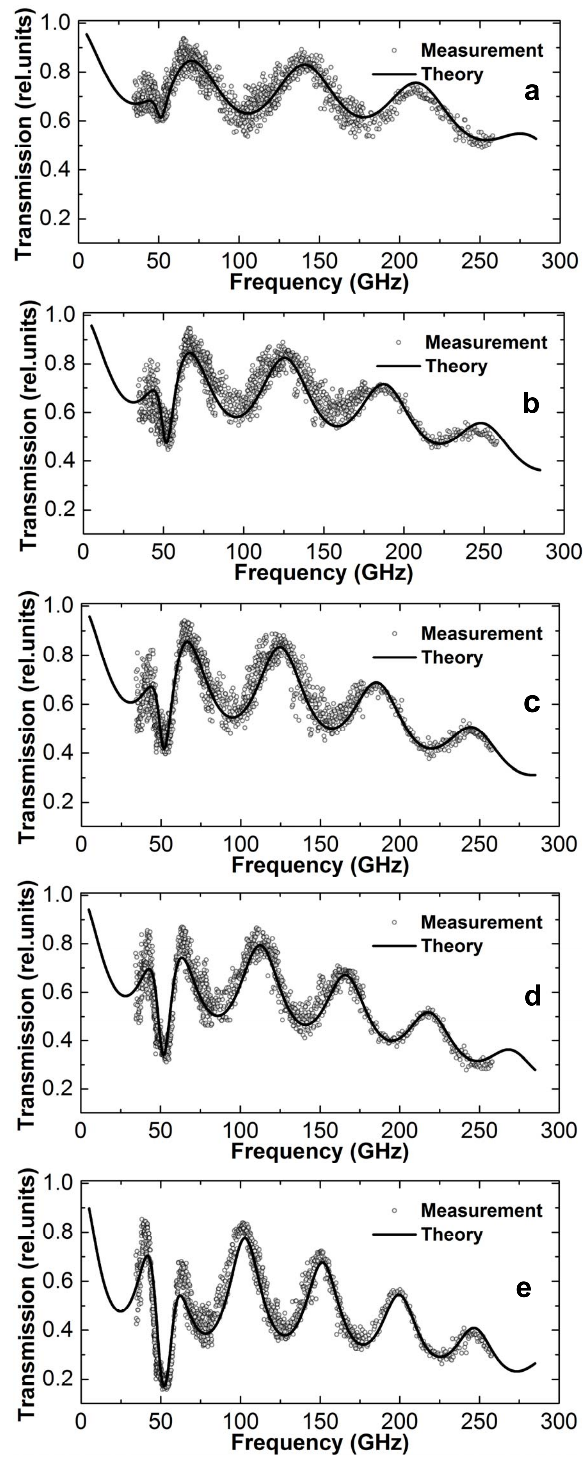

Fig. 2. Measured and calculated EMW transmission coefficients of composite samples with $BaFe_{12}O_{19}$ ferrite powder filler at room temperature. Mass concentration of $BaFe_{12}O_{19}$ ferrite in epoxy: a) 15%; b) 30%; c) 45%; d) 60%; e) 75%.

Researches of electromagnetic response of the samples were carried out by use quasioptical Mach-Zehnder interferometer (Figure 1) at room temperature.

At Figure 2 transmission coefficients of composite samples with $BaFe_{12}O_{19}$ ferrite powder filler (mass concentration 15% - 75%) at room temperature are presented.

Analysis of the frequency dependences of the transmission coefficients in the frequency range of 34 - 250 GHz showed the presence of the absorption region with a maximum at the frequency ~52 GHz (Figure 2).

Approximation of the transmission index with permeability μ calculated by model of ferromagnetic resonance [4-5] with parameters from Table 1 shows agreement with the measured results.

$$\mu = 1 + \frac{4\pi M_s\left[H_r + i(\omega/\gamma)\alpha\right]}{H_r^2 - (1+\alpha^2)(\omega/\gamma)^2 + 2i\alpha(\omega/\gamma)H_r} \qquad (1)$$

In formula (1) M_S is saturation magnetization, H_r is the value of the resonant field, ω is the angular frequency of the electromagnetic field, γ is magnetomechanical ratio (γ/2π = 2.8 GHz/kOe), α is damping constant. The values M_S, H_r and α were chosen from the condition of maximum correspondence between the model (1) and the measured transmission coefficient spectra. The results of calculating the spectra of the real and imaginary parts of permeability are shown in Figure 3-4.

Mass concentration (%)	*d* (mm)	ε'	ε"	H_r (kOe)	M_S (kG)	α
15	1.18	3.26	0.1	18.35	0.23	0.08
30	1.2	4.03	0.13	18.35	0.56	0.08
45	1.13	4.57	0.18	18.35	0.69	0.08
60	1.21	5.02	0.22	18.35	0.85	0.08
75	1.13	7.09	0.24	18.35	1.34	0.08

Table 1. Parameters of the composite based on epoxy resin with different content of $BaFe_{12}O_{19}$ powders. Here *d* is diameter of composite sample, ε' is real part of permittivity, ε" is imaginary part of permittivity, M_s is saturation magnetization, H_r is the value of the resonant field, α is damping constant.

With increasing concentration of $BaFe_{12}O_{19}$ ferrite powder in a composite value of permittivity and saturation magnetization increases. (Table 1).

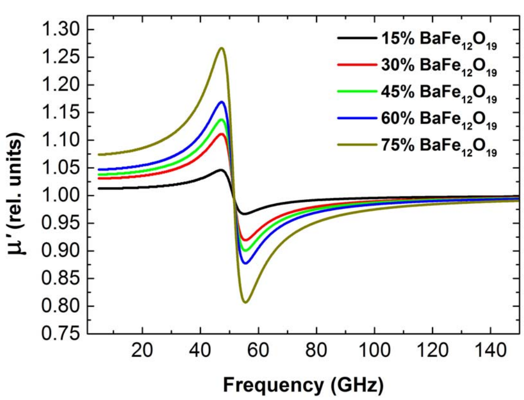

Fig. 3. Real part of permeability of $BaFe_{12}O_{19}$ composite at the frequency range 5-150 GHz at room temperatures.

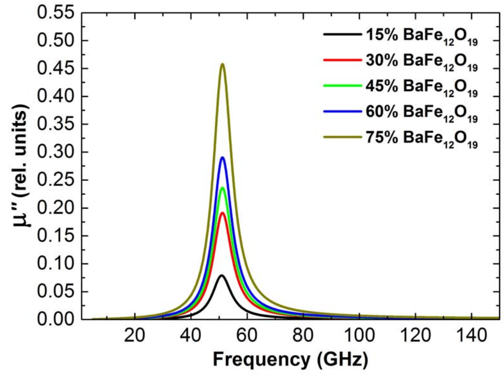

Fig. 4. Imaginary part of permeability of $BaFe_{12}O_{19}$ composite at the frequency range 5-150 GHz at room temperatures.

The value of H_r is close to the value of the magnetocrystalline anisotropy field hexaferrite BaM (H_a = 17 kOe) [1].

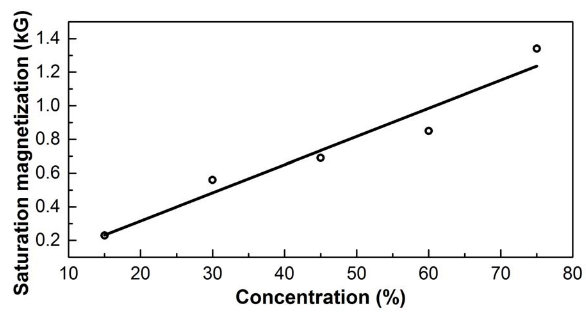

Fig. 5. Saturation magnetization of $BaFe_{12}O_{19}$ ferrite as a function of mass concentration.

When the mass concentration tends to 100%, the saturation magnetization of the composite tends to pure $BaFe_{12}O_{19}$ ferrite. The increasing of concentration of ferrite in the composite increases saturation magnetization and permeability at the resonant frequency at room temperature.

III. Summary

Thus, in this study we observed and studied resonant absorption region near the frequency of 50 GHz, which is well described by magnetic resonance model. The estimations of the NFMR parameters were performed.

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