RESONANT ABSORPTION OF ELASTIC WAVES IN SINGLE-CRYSTAL YTTRIUM IRON GARNET IN THE ABSENCE OF AN EXTERNAL MAGNETIC FIELD

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In an investigation of the laws governing the propagation of elastic waves of frequency 300 - 1800 MHz in single-crystal yttrium iron garnets we observed resonant absorption of these waves in the absence of an external magnetic field.

The elastic waves were excited with the aid of the piezoeffect, using plates of lithium niobate 50 - 100 μ thick as the converters. The investigated samples were cylinders with average dimensions 8 mm long and 3 mm diameter. The samples were cut along the [110] and [111] directions. A pulse procedure was used. We measured the dependence of the damping of the elastic waves on the frequency in the absence of an external magnetic field. The measurement results are shown in Fig. 1a.

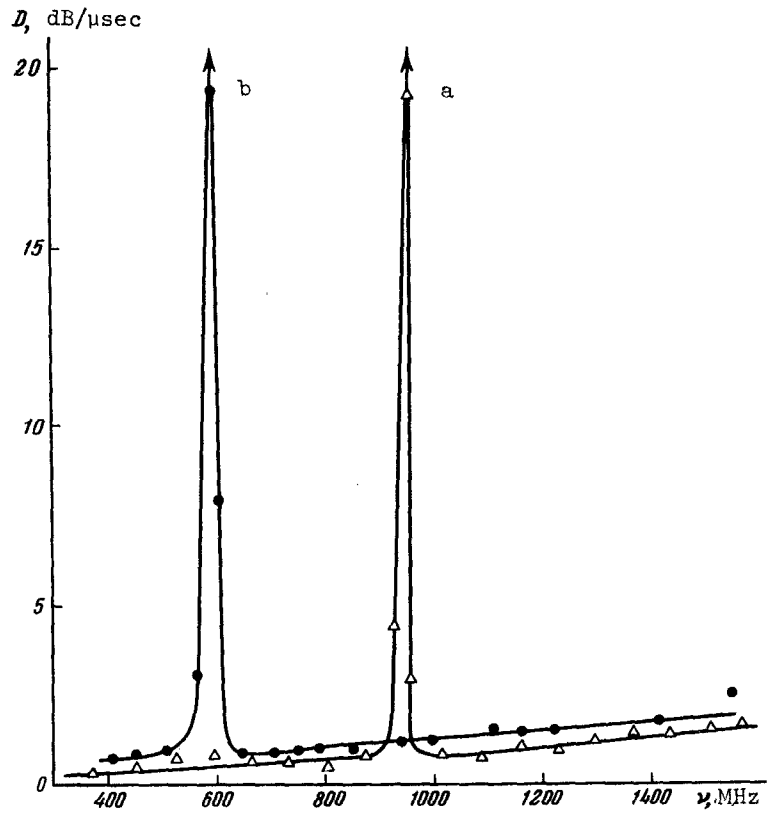

Fig. 1. Frequency dependence of the damping of transverse elastic waves propagating along [110], $H_0 = 0$, at 20°C (a) and 100°C (b).

As seen from the figure, an absorption peak is observed at a definite frequency, and in this case the damping becomes so large that the elastic pulses disappear almost completely (as a rule, several dozen pulses are registered far from the absorption peak).

It was observed that the peak position does not depend on the polarization of the elastic waves and that in the case of propagation along the [111] direction the peak is shifted about 100 MHz towards the lower frequencies compared with the [110] direction.

The external magnetic field leads to a suppression of the peak, and the peak disappears almost completely in fields of approximately 200 Oe.

The main problem was to determine the nature of the absorption peak.

One of the possible mechanism of elastic-wave absorption may be connected with the resonance of the domain boundaries [1]. However, resonance of the domain boundaries is observed as a rule at lower frequencies, and we assume that the phenomenon observed by us is not connected with this mechanism.

Resonant absorption of elastic waves in yttrium iron garnet was observed earlier in external magnetic fields H_0 of intensity such that the frequencies and the wave vectors of the elastic and spin waves were equal [2]. This phenomenon, called magnetoelastic resonance, occurs at a sound frequency ν equal to [2]

$$\nu = \gamma[H_k(H_k + 4\pi M\sin^2\theta)]^{1/2},$$

where γ is the gyromagnetic constant, M the saturation magnetization, θ the angle between the elastic-wave propagation direction and the magnetization, and the field H_k is given by

$$H_k = H_0 + H_p + H_A + Dk^2.$$

Here H_p is the demagnetizing field, H_A the anisotropy field, D the exchange constant, and k the wave number. The last term can be neglected at our frequencies.

It is seen from the foregoing formula that the resonant absorption of the elastic waves can occur, in principle, also in the absence of an external magnetic field in equivalent fields of the magnetic crystallographic anisotropy, the resonant frequency being given in this case by the expression

$$\nu = \gamma[H_A(H_A + 4\pi M\sin^2\theta)]^{1/2}.$$

We assume that the absorption peak shown in Fig. 1a indeed corresponds to just such a resonance.

This hypothesis can be confirmed by the following experiment.

We measured the dependence of the frequency of the magnetoelastic resonance in an external magnetic field H_0 at different angles θ on the magnitude of the field. The sample was placed in this case in a sphere of polycrystalline yttrium iron garnet, in order to ensure homogeneity of the internal magnetic field. It turned out that extrapolation of such dependences, obtained at values of the angle θ between 45 and 90°, to zero external magnetic fields yields a frequency that coincides with the experimental frequency of the resonance in the absence of an external magnetic field. This confirms our hypothesis concerning the nature of the resonance. As to the angles θ, such values of θ appear to be quite reasonable, if it is assumed that the magnetization of the greater part of the domain is close to the directions of easy magnetization <111> in the absence of an external field.

As a further check, we investigated the temperature dependence of the damping of the elastic waves (Figs. 1b and 2).

As seen from the figures, when the temperature is increased the resonance shifts towards lower frequencies, showing that the observed absorption peak is not connected with relaxation

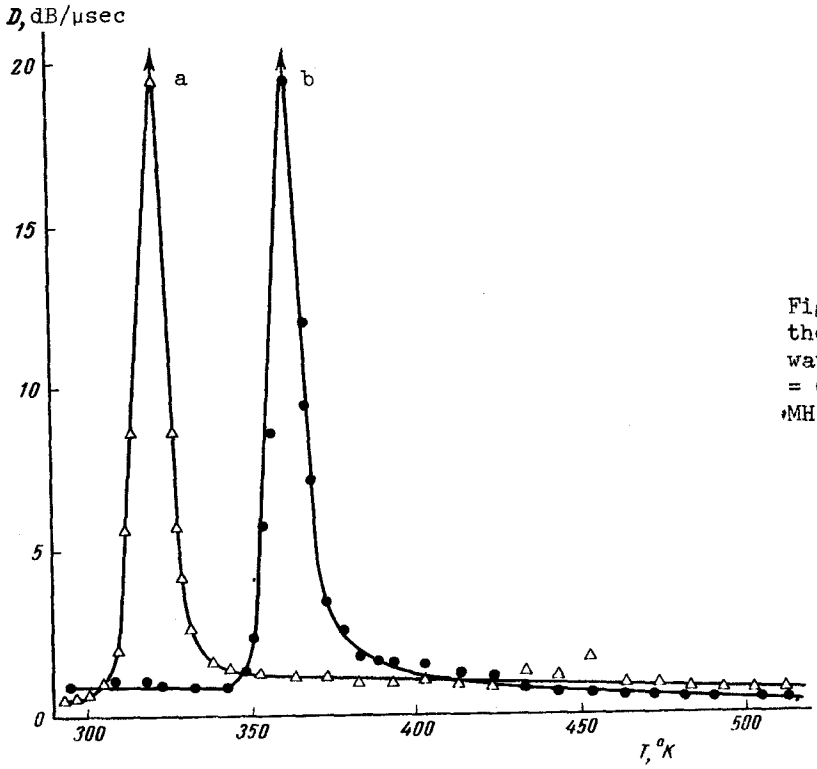

Fig. 2. Temperature dependence of the damping of transverse elastic waves propagating along [110], $H_0 = 0$, at $\nu = 840$ MHz (a) and 650 MHz (b).

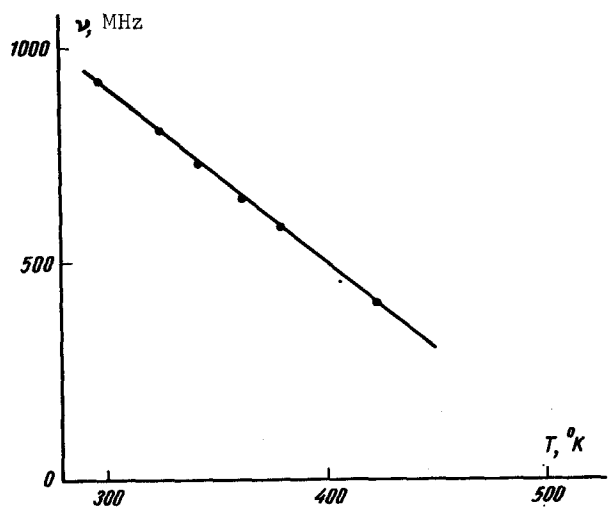

Fig. 3. Temperature dependence of the resonance frequency (longitudinal and transverse waves)

processes having a definite activation energy.

Figure 3 shows the temperature dependence of the resonant frequency. An analysis shows that the character of this dependence agrees well with the temperature dependence given in [3] for the quantity

$$[H_A(H_A + 4\pi M\sin^2\Theta)]^{1/2},$$

and the best agreement is obtained again at angles θ from 45 to 90°.

Thus, all the presented experimental data offer evidence favoring the assumption that the observed absorption peak corresponds to natural magnetoelastic resonance. Nonetheless, this phenomenon requires further study.

[1] J. Smit and H. P. J. Wijn, Ferrites, Wiley, 1959.
[2] A. I. Akhiezer, V. G. Bar'yakhtar, and S. V. Peletminskii, Spinovye volny (Spin Waves), Nauka, 1967.
[3] Handbook of Microwave Ferrite Materials, W. H. Aulock, ed., N. Y. - London, 1965.

SIZE EFFECTS IN ZINC WHISKERS

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A number of recent papers are devoted to a most consistent and complete analysis of the electric conductivity of thin metal samples under the condition $\lambda_\infty \gg d$ (λ_∞ - electron mean free path connected with scattering by phonons, impurity atoms, and defects, and d - transverse dimension of sample).

In this connection, we investigated the galvanomagnetic properties of zinc whiskers - filamentary (F) and platelike (P) thin single crystals. They are convenient because it is easy to satisfy for them the condition $\lambda_\infty \gg d$.

The whiskers were grown by a method described in [1], uzing zinc for which $\rho_{295}/\rho_{4.2} \approx 10{,}000$ ($\lambda_{\infty;4.2} \approx 300\ \mu$). The electric connections of the samples were produced by the "clamping contact" method.

We investigated more than a hundred F and P, the thicknesses of which ranged from 10 to 0.2 μ. We present below the main results, and a brief comparison with the conclusions of the theoretical papers [2, 3].

1. Influence of transverse dimensions on the resistivity at T = 4.2°K. It is well known [4, 5] that the connection between the resistivity and the thickness of the sample under the condition $\lambda_\infty \gg d$ is given by the formulas

$$\rho_d = [(1 - p)/(1 + p)]\lambda_\infty\rho_\infty/d = Ad^{-1} \quad \text{for F} \qquad (1)$$

$$\rho_d = (4/3)[(1 - p)/(1 + p)](\lambda_\infty\rho_\infty/d)(1/\ln\lambda_\infty/d) \quad \text{for P} \qquad (2)$$

where p is the coefficient of specular reflection of the electrons from the surface. In the processing of the results on the dependence of ρ_d on d, we assumed that the value of $\lambda_\infty\rho_\infty$ for zinc is known and equals 1.8×10^{-11} ohm-cm^2 [6]. For most F the plot of $\rho_{d;4.2}$ vs. d^{-1} is a straight line. For some F there is a scatter of the points, apparently due to the deformations introduced during the course of wiring, and to differences in the crystallographic orientations of the F. According to the parameters of the line $\rho_d = Ad^{-1}$, we get for the investigated F $\lambda_{\infty;4.2} \geq 200\ \mu$ and $p \approx 0.6$.

The same values of $\lambda_{\infty;4.2}$ and p are obtained by using formula (2) to process the $\rho(d)$ dependence for P.

2. Temperature dependence of resistance. The possible temperature dependence of the