OSCILLATIONS IN THE ABSORPTION COEFFICIENT OF SOUND IN TIN AT LOW TEMPERATURES

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It has been shown by several authors[1-3] that the ultrasound absorption coefficient in metals does not vary monotonically with the magnetic field and shows a sharp anisotropy.[1] In the present work we give the results of a more detailed study of the anisotropy in absorption at 70 Mcs, made by a pulse method, using a specially constructed two-dimensional automatic plotter.

The measurements were made on a 15-mm diameter single crystal sphere of tin, which had planes cut on it for fixing the quartz. The normals to these planes were parallel to the binary and fourfold axes. The planes were cut by an electric spark, which spoils a single crystal only to a depth of about 10 μ.

The absorption coefficient was determined using longitudinal sound waves with wave vectors **k**, parallel to the binary or fourfold axes. The specimen was rotated in the magnetic field **H**, and the vector **k** was perpendicular to **H**.

The amplitude of the transmitted pulse for fields between 45 and 1000 oe ($T = 4.2°K$) is shown in Fig. 1 for the sound propagated along the binary axis, with the fourfold axis kept parallel to **H**. There are many maxima and minima on the curve, with a constant inverse field period of oscillation. This is in agreement with Gurevich's theory.[4]

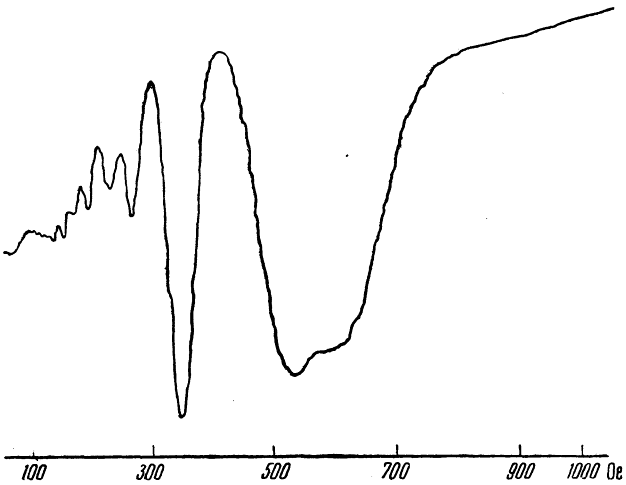

FIG. 1

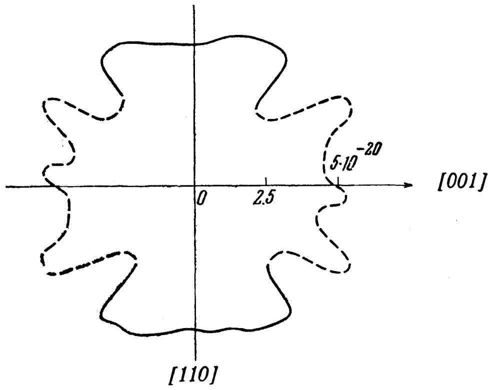

FIG. 2

The limiting electron momentum was deduced from the period of oscillation to be $p = 5 \times 10^{-20}$ g-cm/sec, and its projection on the (001) plane is shown in Fig. 2 as a function of the angles between the binary and fourfold axes. The full curve corresponds to angles for which many oscillations were found and sufficient accuracy could be achieved, whereas the dashed part corresponds to momenta which could only be obtained roughly because of the few maxima observed.

The oscillation curves for sound propagated along the fourfold axis have fewer maxima, and these are not periodic in the inverse field, due presumably to the smaller electron mean free path along the fourfold axis.

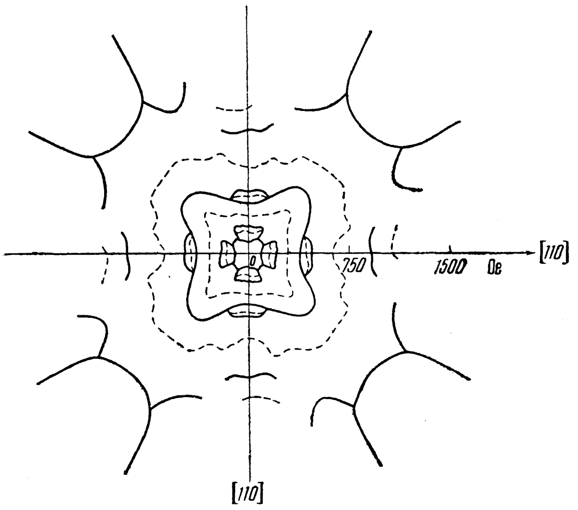

FIG. 3

Some results for the absorption coefficient as a function of magnetic field intensity and angle of rotation in the (001) plane are plotted in Fig. 3. The angle $\varphi = 0$ corresponds to the direction of the binary axis. The full curves give the magnetic field for maximum absorption as a function of angle, and the dashed curves are for the minima. Figure 4 shows the angular dependence of the

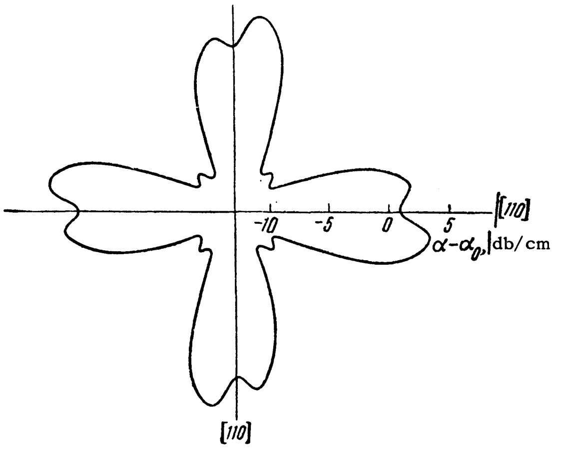

FIG. 4

absorption coefficient at a field of 7×10^3 oe for the field rotated in the (001) plane.

The absorption measured with the field $\mathbf{H} \parallel \mathbf{k}$ has singular points in the $\alpha(H)$ curve. In agreement with Gurevich's theory, the magnetic field at these points satisfies the relation H_i = const/n, where n is an integer.

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[1] A. A. Galkin and A. P. Korolyuk, J. Exptl. Theoret. Phys. (U.S.S.R.) **37**, 310 (1959), Soviet Phys. JETP **10**, 219, this issue.

[2] H. E. Bömmel, Phys. Rev. **100**, 758 (1955).

[3] Morse, Bohm, and Gavenda, Phys. Rev. **109**, 1394 (1955).

[4] V. L. Gurevich, J. Exptl. Theoret. Phys. (U.S.S.R.) **37**, 71 (1959), Soviet Phys. JETP **10**, 51, this issue.

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FINE STRUCTURE IN THE PARAMAGNETIC RESONANCE SPECTRUM OF NATURAL SAPPHIRE

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WE have investigated the paramagnetic resonance spectrum of several natural sapphire single crystals at room temperature, in the range 9600 to 9200 Mcs.

The grey-blue color of sapphire is due to the Fe^{3+} and Ti^{3+} ions replacing Al^{3+} isomorphically in the corundum lattice.[1] The Ti^{3+} ions do not produce any effect because of the short spin-lattice relaxation time at room temperature. One can, therefore, assume that the effect is produced by the Fe^{3+} ions, and the analysis of the spectrum is made on this assumption.

Kornienko and Prokhorov[2] have recently examined the fine structure of the electron paramagnetic resonance spectrum of Fe^{3+} ions artificially introduced into the Al_2O_3 lattice. The interpretation of the spectrum observed was carried out using the following Hamiltonian:*

$$\mathcal{H} = g\beta\,\mathbf{HS} + DS_z^2 + \frac{F}{180}\left[35\,S_z^4 - 30S(S+1)\,S_z^2 + 25S_z^2\right] + \frac{a}{6}\left[S_\xi^4 + S_\eta^4 + S_\zeta^4\right], \qquad (1)$$

where g is the spectroscopic splitting factor, β the Bohr magneton, S the spin operator, H the magnetic field strength, a the cubic field constant, and D and F the trigonal field constants. The coordinate system ξ, η, ζ is constructed on the cubic crystal field axes, and the z axis, directed along the trigonal axis, is also the (111) axis of the ξ, η, ζ system. The approximate energy levels were calculated by Kornienko and Prokhorov on the assumption that the last two terms in Eq. (1) can be treated as perturbations. This is not suitable for explaining the spectrum at a wavelength $\lambda \sim 3.2$ cm, as the second-order corrections can then be larger than the unperturbed values, and each term in Eq. (1) must be evaluated.

The required solution of Eq. (1) can be written in explicit form only for the case of a constant magnetic field directed along the trigonal symmetry axis of the electric field. The problem then becomes one of finding the roots of a sixth-order secular equation. Computations yield the follow-

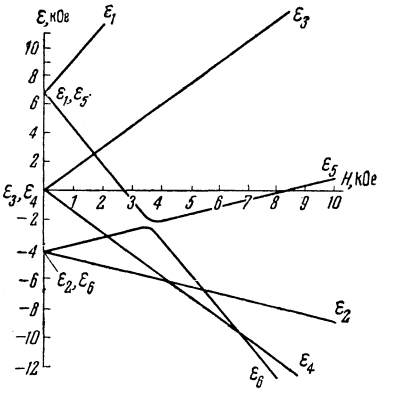

FIG. 1. Dependence of spin energy levels ε_i of Fe^{3+} atoms in sapphire on the magnetic field H, for $\mathbf{H} \parallel \mathbf{z}$.