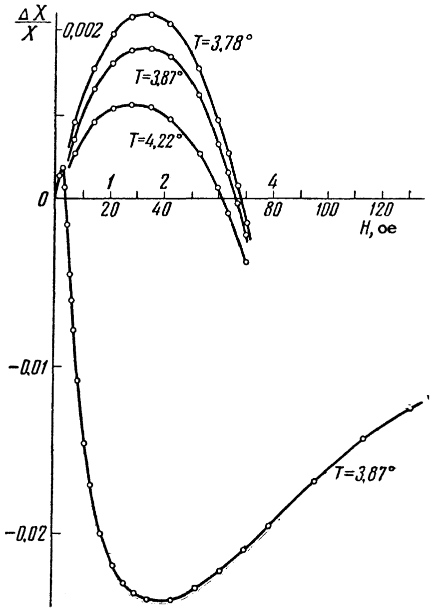

netic field which was parallel to the axis of the coil and the specimen. Along the ordinate axis is plotted the relative change of the reactive component of the impedance relative to the total magnitude, the latter being determined from the change in the oscillator frequency when the sample has passed into the superconducting state. In the top portion of the diagram are plotted the first parts of the curves at various temperatures on a larger scale.

The samples, to which the quoted results apply, consisted of some large crystals, whose orientations differed by 2 — 3°, and, obviously, were grown from one seed. The [001] axes of these crystals were at an angle of ~ 35° with the sample axis, and the angle between the [100] axis and the projection of axis of the sample on the (001) plane was ~ 30°. Similar results were obtained on another sample, the axis of which made an angle of ~ 70° with the [001] axis.

These two specimens were prepared from tin, containing approximately $< 10^{-4}\%$ impurities $[\rho(4.2°K)/\rho(20°K) \approx 1 \times 10^{-5}]$ and cast in cylindrical quartz ampules, the ends of which were drawn out (sample diameter 8 mm, length of the cylindrical portion 40 mm, total length of the sample 60 mm.) The inner surface of the ampule was covered with a layer of carbon before casting. The sample was placed in the apparatus together with the ampule, which protected it from damage. After one of the samples had undergone a series of changes, it was removed from the ampule and the investigation repeated. In this case the character of the ΔX/X dependence was completely altered. Instead of a curve with two extrema, a monotonic reduction of X was observed in all the ranges of the field investigated. For a series of samples, prepared from some less pure tin and removed from the ampule before the measurements, the X-H dependence was also monotonically decreasing.

At present it is difficult to state any definite conclusions about the nature of the observed phenomena. A cyclotron-resonance experiment to explain its origin would require the introduction of a mean free path on the order of several centimeters. There is a striking similarity between our results and the oscillations of surface impedance at 9400 Mc/sec in a field of the order of several oersted, observed by M. S. Khaĭkin, for which there is still no explanation. A conjecture can be made that both the two effects are based on a mechanism which is independent of the frequency. To us it seems advisable to measure the impedance at still lower frequencies and make a static measurement of the magnetic susceptibility in the weak-field range.

We express our thanks to M. S. Khaĭkin for acquainting us with his results prior to their publication.

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Translated by K. J. S. Cave
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CONCERNING CYCLOTRON RESONANCE IN TIN

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In order to use cyclotron resonance studies[1] to explain the features of the structure of the Fermi surface of a metal, it is necessary to develop methods for analyzing cyclotron resonance spectra, which sometimes contain several tens of minima of the metal surface resistance.[2] The Kaner and Azbel' investigation[1] of the relative depth of resonances as a function of the order of resonance is unreliable, primarily because the depth of resonances can only be determined approximately. This is clearly illustrated by the spectrum in Fig. 1, where the observable resonances partially overlap. However such indeterminacy occurs also in the more favorable spectrum of Fig. 2, and at the same time it is always made worse by the strong dependence of the depth of resonances on temperature and on the inclination of the magnetic field relative to the surface of the sample. A study of the depth of resonances as a function of the electromagnetic-field frequency[1] is also inadvisable, owing to the difficulty of varying the frequency substantially; a small frequency variation, which is relatively easy to realize, obviously cannot give precise results.

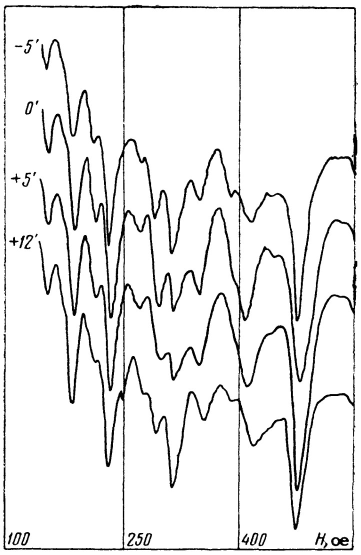

FIG. 1. The effect of inclination of a constant magnetic field to the surface face of a specimen on the character of cyclotron-resonance spectra. The ordinates represent the logarithmic derivative of the surface reactance of tin (in relative units). The angles of inclination of the field are indicated to the left of the curves, with an accuracy of ±1′. The temperature of the sample was 2.4 deg K.

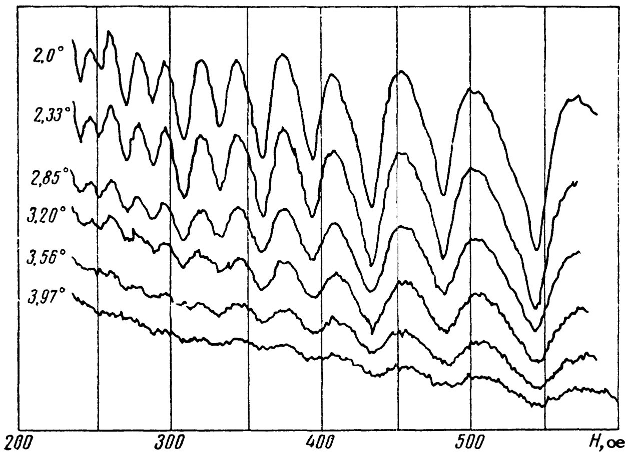

FIG. 2. The effect of the sample temperature on the nature of the cyclotron-resonance spectra. The temperature in deg K is indicated on the left of the curves. The magnetic field is directed along the bisector of the angle between the tetragonal and binary axes of the tin crystal.

Chambers[3] noted that the dependence of the depth of cyclotron resonances on the inclination of the magnetic field ought to be different for different groups of electrons: strong for electrons with velocity along the field, and weak for electrons which do not have such a velocity and move in closed (or almost closed) orbits.* Observation of this effect should obviously facilitate the analysis of cyclotron resonance data. Fawcett[5] has observed a different dependence of the depth of two broad minima in the surface resistance of aluminum on the field inclination, within the limits of ±4 deg.

Figure 1 presents the results of an experiment on the effect of a small inclination of the magnetic field to the surface faces of the sample on the character of the cyclotron resonance spectra. The measurements were carried out by the frequency-modulation method.[2,6] The sample was a single crystal of very pure tin with dimensions 13 × 6 × 1 mm. The tetragonal axis of the crystal was directed along the sample, and the binary axes were parallel to its two smaller dimensions. The high-frequency current flowed along the sample, and the high-frequency and constant magnetic fields were parallel to the binary axis in the face of the sample.[2]

As is apparent in Fig. 1, inclination of the magnetic field by a few minutes of angle affected strongly the depth of resonance of one sequence without affecting the five deeper and sharper resonances. These latter are related to the main sequence of resonances, found in reference 2 for a given field orientation, which correspond to an effective mass 0.27 m_e. The insensitivity to the inclination of the field indicates that these resonances are caused by electrons which do not have a significant velocity along the field direction, i.e., by electrons belonging to the central section of the Fermi surface by the (100) plane perpendicular to the constant magnetic field.

The other sequence of resonances, which disappear rapidly with increasing inclination of the field, is due to the group of electrons which have a significant velocity along the direction of the magnetic field. This group of electrons, the effective mass of which is equal to 0.49 m_e, should belong to a non-central extremal section of the Fermi surface by the (100) plane.

Experiments, the results of one of which are presented in Fig. 2, have shown that the depth of cyclotron resonance increases quickly with decreasing temperature of the sample, and that their width also decreases somewhat; for several other orientations of the field such a relation is even steeper than in Fig. 2. This indicates that the parameter $\omega\tau$ is not large enough in spite of the fact that the samples were made of very pure tin (an estimate yields $\omega\tau \sim 50$) in which the mean free path of the electrons, is possibly already limited by isotopic inhomogeneity of the metal.[7] Obviously a lowering of the sample temperature is necessary to resolve the resonances and to increase the accuracy of measurements of the resonant field values. However a more important result of these experiments is that, as seen from Fig. 2, the resonant field values do not depend on the temperature, at least, in regions below 3 deg K (an insignificant increase in the resonant fields values is noticed above 3 deg K). This fact permits us to assume that the values of the effective masses found from the cyclotron-resonance spectra actually correspond to definite sections of the Fermi surface. The insufficient value of the parameter $\omega\tau$ could lead to an averaging of the experimentally-obtained effective masses over a considerable region of the Fermi surface, thus greatly reducing the value of these data. A similar partial averaging apparently takes place at temperatures above 3 deg K.

It is appropriate to note the sharp increase in the number of observable resonances in each sequence with decreasing temperature, owing to the increase in the value of $\omega\tau$. This guarantees a substantial increase in the accuracy of measurements of the effective mass at lower sample temperatures.

The author thanks P. L. Kapitza and A. I. Shal'nikov for their interest in this work.

*The fundamental theory of cyclotron resonance in an inclined magnetic field is examined by Kaner.[4]

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INSTABILITY OF UNIFORM PRECESSION OF MAGNETIZATION

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It is obvious that the occurrence of inhomogeneous magnetization in magnetic systems in a constant external magnetic field leads to a breakdown of the uniform precession. We shall consider therefore that the homogeneous precession is unstable if small fluctuations lead to growing magnetization waves. We shall investigate the stability of the uniform precession of a series of ferromagnetic and ferrimagnetic systems.

1. The change in the magnetization of a ferromagnet can be described by the equation

$$\dot{\mathbf{M}} = -\gamma[\mathbf{M}\times\mathbf{H}_{\text{eff}}],$$

$$\mathbf{H}_{\text{eff}} = \mathbf{H}_0 + \lambda\mathbf{M} + H_{ex}(l^2/M)\nabla^2\mathbf{M} + \mathbf{H}_d, \tag{1}$$

where $\mathbf{H}_0$ is the external field, λ the constant of the molecular field, H_{ex} the magnitude of the molecular field, l the interatomic distance, and $\mathbf{H}_d$ the demagnetizing field.

If we seek a solution of (1) in the linear approximation in the form of magnetization waves (spin waves) with the frequency ω_k and the wave vector $\mathbf{k}$, then the waves of wavelengths smaller than the dimensions of the system* satisfy the following dispersion relation

$$\omega_k = \gamma\,[(H_i + H_{ex}l^2k^2)(H_i + H_{ex}l^2k^2 + 4\pi M\sin^2\theta)]^{1/2}, \tag{2}$$

where $H_i = H_0 - 4\pi MN_z$, $N_x = N_y$ and N_z are demagnetizing factors, the field H_0 is along the z axis, and θ is the angle between $\mathbf{k}$ and $\mathbf{H}_0$. The nonequilibrium state will be unstable with respect to spin waves if the following relation is satisfied

$$-4\pi M < H_i + H_{ex}l^2k^2 < 0. \tag{3}$$

(In this case the frequencies ω_k become imaginary.)

For magnetostatic types of oscillation (for small $\mathbf{k}$)[1] we must replace $\sin^2\theta$ in (2) by

$$\beta_{nmr} = \delta^2(1 - z^2_{nmr})/\delta^2(1 - z^2_{nmr}) + z^2_{nmr},$$

where δ is the ratio between the major and the minor axes of the ellipsoid, and z^2_{nmr} is the square of the r-th root of the associated Legendre polynomial $P^m_n(z)$ with $0 < z^2_{nmr} < 1$.