A. A. Galkin, E. A. Kaner, and A. P. Korolyuk

1960

SovietRxiv

Fig. 1. Recording of the dependence of the absorption coefficient of longitudinal ultrasound on the magnetic-field strength in tin, $\nu = 220$ Mc, $\mathbf{k}$ along the axis [101]; $\mathbf{H} \perp \mathbf{k}$ and lies in the plane (110). The purity of the specimen is characterized by the resistance ratio $R_{4.2}/R_{300} = 1.6 \cdot 10^5$ at helium and room temperatures.

Figure 1: Fig. 1. Recording of the dependence of the absorption coefficient of longitudinal ultrasound on the magnetic-field strength in tin, $\nu = 220$ Mc, $\mathbf{k}$ along the axis [101]; $\mathbf{H} \perp \mathbf{k}$ and lies in the plane (110). The purity of the specimen is characterized by the resistance ratio $R_{4.2}/R_{300} = 1.6 \cdot 10^5$ at helium and room temperatures.

Abstract

Full Text

PHYSICS

A. A. Galkin, E. A. Kaner, and A. P. Korolyuk

ON A NEW TYPE OF OSCILLATION OF THE ULTRASOUND ABSORPTION COEFFICIENT IN METALS IN A MAGNETIC FIELD

(Presented by Academician L. D. Landau, 26 IV 1960)

In a number of theoretical and experimental works it has been established that the dependence of the ultrasound absorption coefficient in metals on the magnetic field $\mathbf{H}(00H)$ is sinusoidal ($^{1-4}$). In the present communication it is shown that, under certain conditions, the change of the absorption coefficient in a magnetic field has a resonant character; the absorption maxima are sharper than the broad and blurred minima (Fig. 1).

Fig. 1. Recording of the dependence of the absorption coefficient of longitudinal ultrasound on the magnetic-field strength in tin, $\nu = 220$ Mc, $\mathbf{k}$ along the axis [101]; $\mathbf{H} \perp \mathbf{k}$ and lies in the plane (110). The purity of the specimen is characterized by the resistance ratio $R_{4.2}/R_{300} = 1.6 \cdot 10^5$ at helium and room temperatures.

The presence of sharp absorption maxima is associated with the inequality to zero of the projection, onto the direction of the wave vector $\mathbf{k}$, of the displacement of the electrons averaged over a period during their motion in a magnetic field,

$$\bar{\beta} = \frac{\mathbf{k}\bar{\mathbf{v}}}{2\pi} T \neq 0 \tag{1}$$

($\bar{\mathbf{v}}$ is the electron velocity averaged over a period).

For closed trajectories the condition $\bar{\beta} \neq 0$ is fulfilled if the angle ϑ between $\mathbf{k}$ and $\mathbf{H}$ differs substantially from a right angle. Resonance is observed when $|\bar{\beta}(p_{\text{ext}})| \simeq n$ $(n = 1, 2, \ldots)$. Here p_{ext} $(|p_{\text{ext}}| < p_{z\,\text{gr}})$ is the projection of the electron quasimomentum onto the direction of the magnetic field $\mathbf{H} \parallel Oz$, for which $d\bar{\beta}/dp = 0$, or the value of the limiting momentum $p_{z\,\text{gr}}$, if on the electron trajectory $\varepsilon(p) = \mu_0$ there is one point for which $\mathbf{kv} = 0$.

Far from resonance $\alpha \sim \alpha_0$ (α_0 is the absorption for $H = 0$), while at resonance $\alpha_n \sim \alpha_0(n\gamma_0)^{-1/2} \sim H_n$ $(\gamma_0 = T/t_0 \ll 1,\ t_0$ is a characteristic time) grows linearly with the field.

On open periodic trajectories, resonant oscillations can be observed for $\mathbf{k} \perp \mathbf{H}$, provided only that the vector $\mathbf{k}$ is not parallel to the direction of the open trajectory Ox. In this case the resonance is sharper, since

$$\bar{\beta} = \frac{k_y c \Delta p_x}{2\pi |e| H} = \text{const} \tag{2}$$

(Δp_x is the period on the open trajectory along Ox), and there is no additional averaging over p_z, while the resonant part $\alpha_n \sim \alpha_0 \gamma_0^{-1}$, which is qualitatively confirmed by experiment.

The initial phase of these oscillations is equal to zero (Fig. 2), whereas for sinusoidal oscillations it is equal to $\pm\pi/4$ (^{1,3}). The width of the resonance peaks $\Delta H \sim (kvt_0)^{-1} H_n$ increases with the field, which is in good agreement with experiment (see Fig. 1).

Fig. 2. Dependence of the number of maxima of the resonant oscillations on the inverse field. The vector $\mathbf{H}$ lies in the plane (110) for both straight lines.
1 –vector $\mathbf{k}$ along the axis [101], oscillation period $\Delta H^{-1} = 1.71 \cdot 10^{-4}$ Oe^{-1};
2 –vector $\mathbf{k}$ at an angle of 40° to the axis [001] in the plane (100), period $\Delta H^{-1} = 1.82 \cdot 10^{-4}$ Oe^{-1}.

The study of tin single crystals at a frequency of 220 MHz showed the presence of resonant oscillations in a certain interval of angles. In Fig. 3 are shown stereographic projections of the directions of the wave vector $\mathbf{k}$ and the magnetic field $\mathbf{H}$ for which oscillations of this type are observed. Since the vectors $\mathbf{k}$ and $\mathbf{H}$ are perpendicular, the observed resonant oscillations are associated with open trajectories.

Fig. 3. Stereographic projection of the directions of the vector $\mathbf{k}$ (points) and the vector $\mathbf{H}$ (hatched regions), which lead to resonant oscillations in tin. The lines show projections of the planes in which the vector $\mathbf{H}$ was rotated.

On the basis of an analysis of the stereographic projection with the aid of expression (2), it was established that the direction of the open periodic trajectory coincides with the axis [110], which agrees with the results of galvanomagnetic investigations (5). Calculations using formula (2) made it possible to determine the value of the period along the open trajectory, $\Delta p_x = 15 \cdot 10^{-20}$ g · cm/sec. This value coincides with the size of the Brillouin zone for tin in the indicated direction, as given by Chambers (6).

Starting from the known value of the period Δp_x, one can calculate the change in the oscillation period for two directions of the vector $\mathbf{k}$. Experimental-

A direct check has shown that in this case the oscillation period changes by an amount differing by no more than 1% from the calculated one.

Institute of Radiophysics and Electronics
Academy of Sciences of the Ukrainian SSR

Received
25 IV 1960.

References

1. V. L. Gurevich, ZhETF, **37**, 71 (1959).
2. A. A. Galkin, A. P. Korolyuk, ZhETF, **37**, 310 (1959).
3. A. A. Galkin, A. P. Korolyuk, ZhETF, **38**, No. 6 (1960).
4. D. H. Reneker, Phys. Rev., **115**, 303 (1959).
5. N. E. Alekseevskii, Yu. P. Gaidukov, ZhETF, **37**, 672 (1959).
6. R. G. Chambers, Canad. J. Phys., **34**, 1395 (1956).

Note: Figure translations are in progress. See original paper for figures.

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.