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COMPLEX OSCILLATION OF THE PHOTOMAGNETIC EFFECT IN n-InSb IN A STRONG MAGNETIC FIELD

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The quantization of the electron spectrum of a semiconductor in a strong magnetic field ($uH/c \gg 1$) leads, under certain conditions, to an oscillatory field dependence of all the physical quantities characterizing the phenomena in which the carriers play a noticeable role. Kikoin and Lazarev [1] have shown that these quantities include also the Kikoin-Noskov photomagnetic-effect emf (PME).

We know at present of two types of oscillations of the kinetic coefficients, which are periodic in the reciprocal field. The Shubnikov - de Haas (SH) oscillations are observed only in the case of strong degeneracy ($\zeta \gg kT$) and low temperatures ($kT \ll \hbar\Omega$). The occurrence of these oscillations is connected with a displacement of the Landau levels relative to the Fermi level ζ when the magnetic field is varied. The condition for the crossing of these levels

$$\zeta(H) = \hbar\Omega(N + \frac{1}{2}) \pm \frac{1}{2}|g|\mu_B H \qquad (1)$$

($\Omega = eH/m^*c$, g - spectroscopic splitting factor, μ_B - Bohr magneton) determines the periodicity of the SH oscillations. In the case of a spherical zone, without account of the spin splitting, the oscillation period is determined only by the concentration:

$$\Delta(1/H) = 3{,}18\cdot 10^6 \cdot n^{-2/3}. \qquad (2)$$

Variation of n, which can be readily realized in semiconductors, makes it possible to shift the SH oscillation pattern along the scale of the magnetic field [2].

The second type of oscillations, predicted by Gurevich and Firsov (GF), is the consequence of the resonant character of inelastic scattering of electrons by optical crystal vibrations in a strong magnetic field [3]. In this case the oscillation period does not depend on n and is determined by the electron effective mass m* and by the frequency ω_0 of the longitudinal optical phonons:

$$\Delta(1/H) = e(m^* \omega_0 c)^{-1}. \qquad (3)$$

We shall show here that both types of oscillations appear in the odd PME observed in n-InSb at $T \leq 4°K$. The PME signal produced by white light (~0.5 - 2.8 μ) in a sample placed in liquid helium was amplified and recorded with a two-coordinate automatic plotter. The measurements of the PME voltage and short-circuit current in six n-InSb single crystals ($2 \times 10^{14} \leq n \leq 3.5 \times 10^{16}$ cm^{-3}) revealed a complicated oscillation pattern: One group of extrema shifted along the field with variation of n and their periodicity corresponded to Eq. (2), while the position of the second group of extrema did not depend on n and their periodicity ($\Delta(1/H) = 3 \times 10^{-5}$ Oe^{-1}) corresponded to Eq. (3).

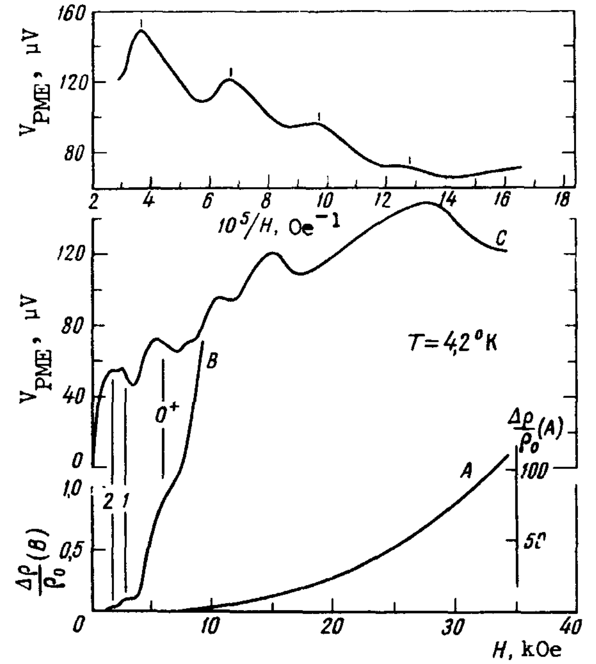

Fig. 1. Experimental plots of the magnetoresistance $\Delta\rho/\rho_0$ (A and B) and of the photomagnetic voltage V_{PME} (C) vs. the field H for single-crystal n-InSb with $n = 1.35 \times 10^{15}$ cm^{-13}, $u = 1.2 \times 10^5$ cm^2/V-sec, and $T = 4.2°K$. Curve B is a strongly magnified section of curve A. The vertical lines indicate the values of the field H at which condition (1) is satisfied (with $|g| = 50$). The upper part of the figure shows a plot of V_{PME} vs. the reciprocal field.

Figure 1 shows some of the obtained experimental plots of V_{PME} and of the transverse magnetoresistance $\Delta\rho/\rho_0$. It is seen from the figure that oscillations of the SH type appear in the region H < 7 kOe, and a series of GF oscillations with period given by Eq. (3) appears in the region of the quantum limit $\hbar\Omega > \zeta$ (H > 7 kOe), where the equilibrium electrons (with respect to temperature) do not produce SH oscillations [2]. The amplitude of PME oscillations of the GF type decreases sharply when T rises to 20°K, and the GF effect does not appear at all at T = 77°K. Damping of the GF oscillations occurs also when n is reduced to 10^{14} cm^{-3} ($T \leq 4°K$).

Figure 2 shows V_{PME} and $\Delta\rho/\rho_0$ plots for an n-InSb sample with concentration that ensures propagation of SH oscillations over the entire scale $H \leq 35$ kOe. We see that in this case the periods of the oscillations of $\Delta\rho/\rho_0$ and V_{PME} coincide, and maxima of $\Delta\rho/\rho_0$ and minima of V_{PME} occur near values of H given by condition (1). Determination of the g-factor from the (1^+, 1^-) spin splitting in Fig. 2 yields: $|g| \simeq 35$ from the $\Delta\rho/\rho_0$ curve [2] and $|g| \simeq 50$ from the V_{PME} curve. The latter value agrees with the paramagnetic-resonance data. No GF effect is seen in Fig. 2 against the background of the SH oscillations. A notable fact in this figure is the large oscillation amplitude, which leads to a reversal in the sign of the PME.

The physical nature of the SH type oscillations of the PME is in principle understandable (i.e., the same as in the case $\Delta\rho/\rho_0$ [2]), although at present there is no detailed theory for these PME oscillations permitting a comparison with the experimental data when $\zeta \simeq \hbar\Omega$, when $\zeta(H)$ must be taken into account. A different question is that of the nature of the PME oscillations of the GF type at $T \leq 4$°K, when the optical phonons are not excited in normal fashion. It can be assumed that they are generated in a thin layer of the sample by hot photoelectrons and cause subsequently, in some manner, the magnetophonon GF resonance. The possibility of emission of optical phonons by hot photoelectrons is indicated by experiments which reveal an oscillatory dependence of the photoconductivity on the wavelength at $T < 10$°K [4].

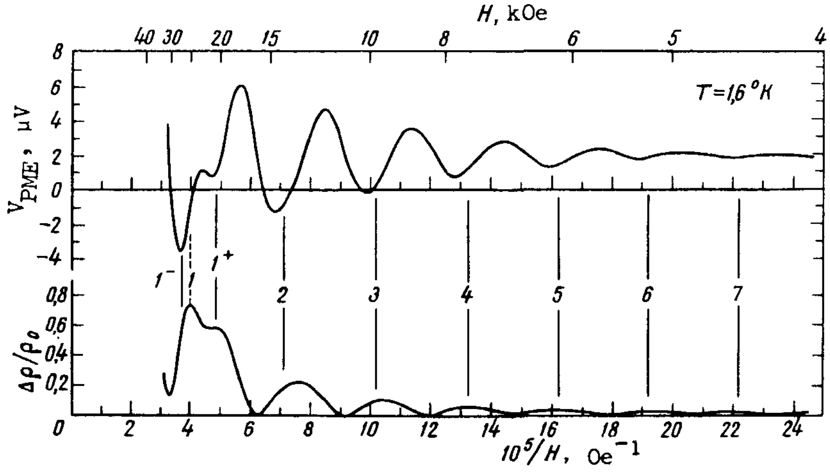

Fig. 2. Experimental plots of the magnetoresistance $\Delta\rho/\rho_0$ and V_{PME} vs. $1/H$ for single crystal n-InSb with $n = 3.5 \times 10^{16}$ cm^{-3} and $u = 8.5 \times 10^4$ cm^2/V-sec at T = 1.6°K. The vertical lines correspond to condition (1).

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