CONCERNING A NEW TYPE OF OSCILLATION OF THE LONGITUDINAL MAGNETORESISTANCE OF n-TYPE InSb

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A study was made of the oscillation of the longitudinal magnetoresistance of n-type InSb in a strong magnetic field, due to the inelastic scattering of electrons on the optical-mode vibrations of the crystal, at various temperatures in the 90—200°K range. It is shown that with increase of temperature the minima of the oscillating part of the magnetoresistance move away from the resonance values of the magnetic field and are replaced by maxima. A considerable change in the electron density (by a factor of 30) does not produce a significant phase shift of the oscillating curves.

EXPERIMENTAL data confirming the existence of the magnetophonon resonance in electronic conductors have been reported earlier.[1] This new phenomenon, predicted theoretically by V. L. Gurevich and Yu. A. Firsov,[2] is due to the fact that the inelastic scattering of electrons by the optical phonons in a varying strong magnetic field ($uH/c \gg 1$) is periodically amplified whenever the limiting frequency ω_0 of the optical phonons is a multiple of the electron cyclotron frequency Ω:

$$\omega_0 = M\Omega = MeH / m^* c. \qquad (1)$$

It is evident from the experimental graphs reported in [1] that this periodic (with respect to the reciprocal of the field) variation of the efficiency of electron scattering produces a periodic oscillation of the transverse and longitudinal magnetoresistance of n-type InSb with a period obeying the condition (1). An experimental study has shown a considerable difference between the appearance of the magnetophonon resonance in the transverse and longitudinal magnetoresistance curves of InSb. When the resonance condition (1) is satisfied, the resonance effect curves for the transverse effect show additional resistance maxima, the positions of which are independent of temperature and the carrier density, while the longitudinal effect curve (investigated in [1] for only one temperature $T = 90$°K) at field intensities H satisfying the condition (1) shows a system of minima with the same periodicity with respect to the reciprocal field. In a later theoretical paper, Gurevich and Firsov[3] considered the case of low temperatures ($\hbar\omega_0/kT > 1$) and explained this experimental fact by suggesting that under test conditions the electrons in InSb are subjected to inelastic scattering on the optical phonons, as well as to elastic scattering on the acoustic phonons. If only the optical phonons take part in electron scattering, then, according to Gurevich and Firsov, the graphs for the transverse and longitudinal effects should be of the same form as the oscillating curves with resistance maxima at field intensities satisfying the condition (1). If both vibrational modes take part in electron scattering then, in the transverse effect case, the acoustic modes produce only a monotonic background on which additional scattering on the optical phonons is superimposed. This additional scattering occurs periodically (with respect to the reciprocal of the field) every time the resonance condition (1) is satisfied and, therefore, the transverse effect curves exhibit, irrespective of temperature and the carrier density, the same system of resistance maxima. According to Gurevich and Firsov,[3] a theoretical interpretation of the longitudinal effect must allow for the interaction between these elastic and inelastic scattering mechanisms. This interaction leads to a characteristic competitive process whereby we may find that the periodic amplification of the optical scattering mechanism markedly weakens the acoustic scattering. The overall efficiency of the thermal scattering, which is responsible for the longitudinal magnetoresistance, may thus decrease and the oscillating curve of the longitudinal effect may exhibit a system of minima at the points where the resonance condition (1) is satisfied. Since the outcome of such competition between the scattering

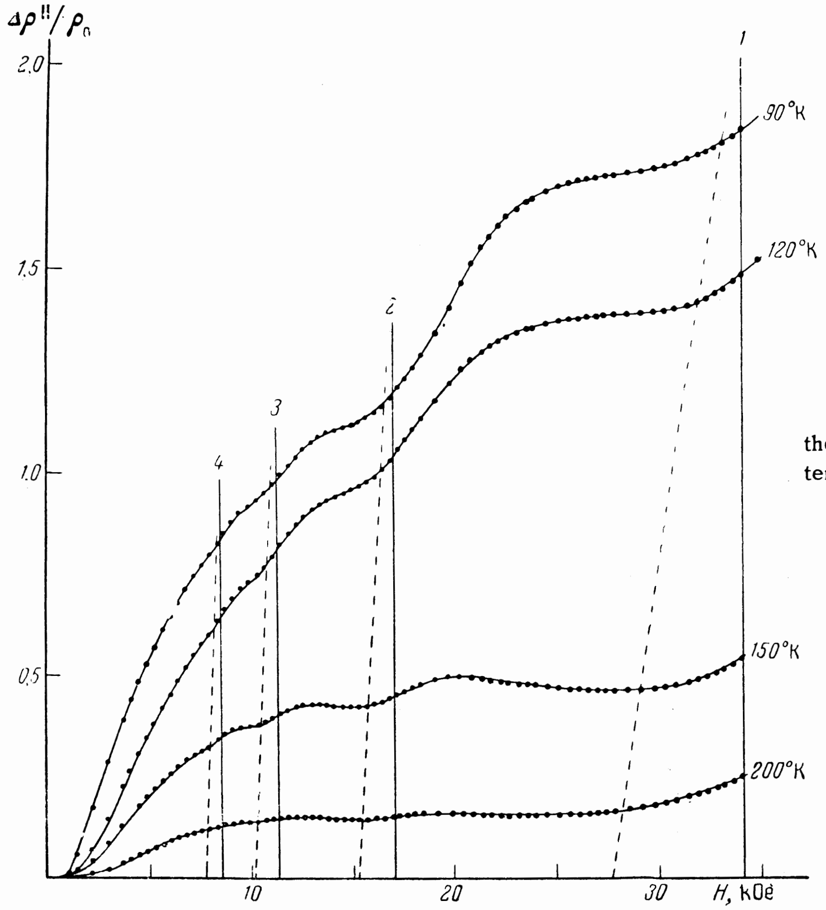

FIG. 1. Longitudinal magnetoresistance curves of the investigated sample of n-type InSb at various temperatures.

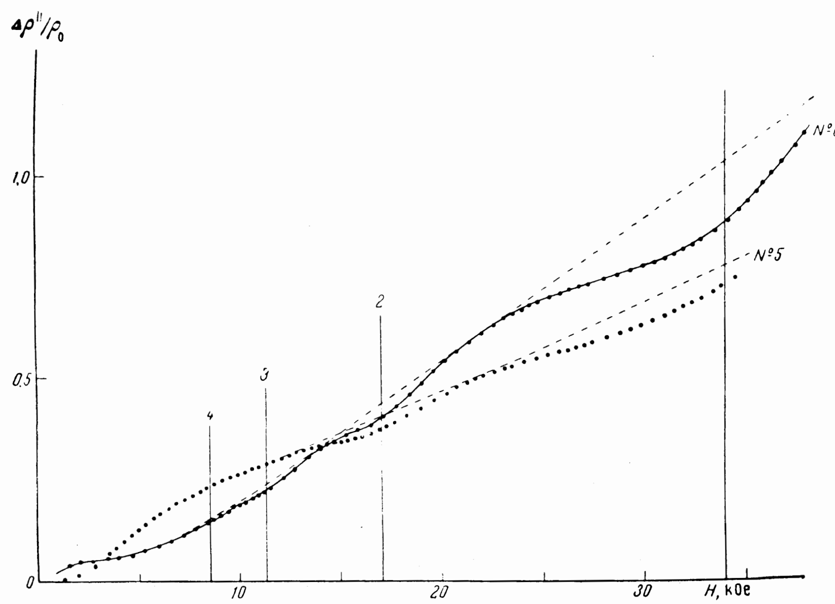

FIG. 2. Longitudinal magnetoresistance curves for two samples of n-type InSb at T = 90°K. The carrier densities were: 1.3×10^{15} cm^{-3} for sample No. 5; 4.1×10^{13} cm^{-3} for sample No. 6 (for details about these samples see [1]). Dashed lines show the postulated magnetoresistance background without the oscillating part. The vertical lines denote those values of the magnetic field which satisfy the resonance condition (1).

mechanisms depends on their relative efficiency, and the latter varies with temperature, it seemed of interest to carry out an experimental study of the longitudinal magnetoresistance of n-type InSb at various temperatures.

Figure 1 shows the experimental longitudinal magnetoresistance curves obtained by a study of a single crystal of n-type InSb ($n = 4 \times 10^{13}$ cm^{-3}, $u = 4.9 \times 10^5$ cm^2 V^{-1} sec^{-1} at T = 90°K) in the temperature region from 90 to 200°K. The vertical lines denoted by the numbers M = 1—4 indicate the values of the magnetic field intensity which satisfy the condition (1); the sloping dashed lines indicate how the positions of the minima (and, consequently, of the maxima) are displaced in the oscillating curves of the longitudinal magnetoresistance when temperature is varied. This shift of minima and maxima is greatest near M = 2 and 3 in Fig. 1. It is known that, in pure n-type InSb samples at $T \geq 200°K$, the optical phonons play the main role in the scattering of electrons and, consequently, when the temperature increases from nitrogen to room the relative role of the optical scattering increases.[4] This allows us to understand why, in Fig. 1, an increase in temperature causes the system of minima to move gradually away from the vertical lines, being replaced by a system of maxima. A reduction of the oscillating fraction of the magnetoresistance, which occurs with an increase in temperature, may be due to an increase in the thermal scatter of electrons in Landau's energy bands.

Note added on July 9, 1964. Figure 2 shows the experimental curves of the longitudinal magnetoresistance of two n-type InSb samples with different carrier densities. It is evident from this figure that a change in the carrier density by a factor of 30 does not produce a significant phase shift of the oscillating curves.

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