Quantum oscillations of the Hall coefficient of the narrow-gap semiconductor $Pb_{0.82}Sn_{0.18}Te$ in weak magnetic fields

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Quantum oscillations of the Hall coefficient were observed in weak magnetic fields, starting with 10 Oe, in *n*- and *p*-type solid solutions of $Pb_{0.82}Sn_{0.18}Te$ at 4.2°K. The results are attributed to singularities of the band spectrum, which lead to the appearance of an unusual group of carriers with extremely low effective mass $m^* \lesssim 1\times 10^{-4}\ m_0$, which is smaller by more than two orders of magnitude than the mass of the ordinary carriers.

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Interest in semiconducting materials with narrow forbidden bands has increased greatly of late. From the scientific point of view they are interesting as the connecting link between metals and ordinary semiconductors. One of such narrow-gap semiconductors, the band spectrum of which has not yet been well studied, is the class of solid solutions $Pb_{1-x}Sn_xTe$.

It is customary to apply to these semiconductors the model of the band spectrum established for PbTe, in which the extrema of the conduction and valence bands of the light holes are localized at points L of the Brillouin zone, and the equal-energy surfaces are ellipsoids of revolution prolate along the ⟨111⟩ direction.[1–4]

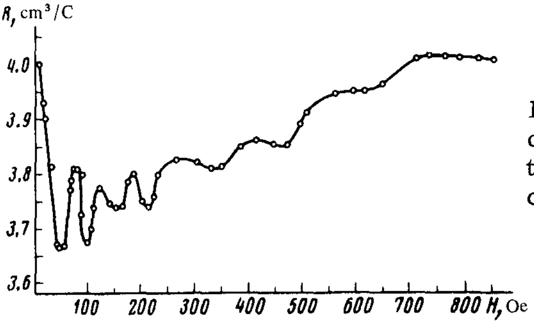

FIG. 1. Dependence of the Hall coefficient on the magnetic field for the sample $Pb_{0.82}Sn_{0.18}Te$ with hole concentration 1.2×10^{17} cm^{-3}.

Some experimental papers, however, point to a deviation of the shape of the Fermi surface from ellipsoidal. Thus, in[4,5] additional families of Shubnikov—de Haas oscillation frequencies have been observed, thus indicating that the Fermi surface has more than one extremal section. In[6], as a result of the investigation of the weak-field magnetoresistance in SnTe, a new model of the Fermi surfaces was proposed, according to which the basic ellipsoid has pockets prolate along the ⟨100⟩ axis.

It is indicated in[7] that all metals (with the exception of the first group) have relatively small Fermi-surface sections corresponding to small cavities and necks of the latter. An estimate shows that they contain up to $\sim10^{-5}$ carriers per atom, having an effective mass $m^*\sim10^{-3}m_0$.

In[8], account was taken of the correction that must be introduced into the spectrum as a result of the interelectron interaction and leads in the solid solutions $Pb_{1-x}Sn_xTe$ to a large dielectric constant and to the appearance of three bundles of wave vectors **k** lying in the vicinity of the Fermi surface in definite ranges of the Fermi energy ϵ_F. The presence of similar pockets in Bi and SnTe was also predicted theoretically in[9]. The existence of small-radius curved sections on the Fermi surface, in the form of these pockets, can cause the carriers contained in them to have an effective mass much smaller than usual, thus imitating the presence of a band of ultralight electrons or holes.[10] Thus in the case when the effective carrier mass in the pockets is $m^*_p\sim10^{-4}m_0$, one should expect the appearance of quantum oscillations of the kinetic coefficients in weak magnetic fields $H<1$ kOe at helium temperatures.

To find this effect, we have investigated the Hall coefficient R of single-crystal samples of $Pb_{0.82}Sn_{0.82}Te$ of n and p type with concentrations (2—30) $\times10^{16}$ cm^{-3} in magnetic fields 10—1000 Oe at 4.2 °K.

The oscillating component of the Hall emf and of the magnetoresistance in this range of magnetic fields is quite small. To record it continuously it is therefore necessary to use considerable amplification with almost complete cancellation of the of the non-oscillating component. The latter is made difficult by the complicated dependence of this component on the magnetic field. The Hall coefficient does not depend on H as strongly as the magnetoresistance, so that it is possible to observe the oscillations of $R(H)$ when the latter is measured point by point in weak magnetic fields.

These circumstances have dictated the experimental procedure. The measurements of R were carried out by a null method. The error in this case was 3% in fields ~ 10 Oe and did not exceed 1% at $H \sim 30$ Oe. The weak-field oscillations were observed on three samples of p type and one sample of n type. A typical $R(H)$ plot is shown in Fig. 1. It is seen that the amplitude of the oscillations exceeds the experimental error. We note that the Subnikov—de Haas oscillations connected with the usual carriers having $m^* \sim 10^{-2} m_0$ begin in the region of magnetic field $H \gtrsim 3$ kOe.[3]

Estimates of the effective magnetic mass of the unusual carriers responsible for the appearance of the weak-field oscillations were obtained by two methods: 1) from the quantization condition $\hbar\omega_c/kT \gtrsim 3$, and 2) from the frequency of the oscillations and the known ϵ_F. Both methods yielded values $m^* \lesssim 10^{-4} m_0$.

Thus, in n- and p-type solid solutions $Pb_{0.82}Sn_{0.18}Te$ we have observed quantum oscillations of the Hall coefficient in very weak magnetic fields, indicating that the Fermi surface in narrow-gap semiconductors of this type has a complicated shape.

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