Experimental observation of thermal oscillations of the resistance in $Mn_xHg_{1-x}Te$

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Thermal oscillations of the resistivity of $Mn_xHg_{1-x}Te$ ($x \approx 0.07$) have been observed experimentally in the temperature interval 4.2–40 K in constant magnetic fields. The high-quality single crystals used as samples have a high Hall carrier mobility [$\sim 2 \times 10^6$ cm^2/(V·s)] and a Dingle temperature below 1 K.

It has been predicted theoretically that a new quantum effect can be observed in narrow-gap semimagnetic semiconductors: thermal oscillations of the resistance, manifested as an oscillatory temperature dependence of the resistance of a crystal at a constant magnetic field.[1] This effect is similar to the Shubnikov-de Haas effect, but the temperature, rather than the magnetic field, serves as the independent variable. The thermal oscillations result from the temperature dependence of the magnetization, which determines the energy of the electrons in a narrow-gap semimagnetic semiconductor in a magnetic field by virtue of the exchange interaction of conduction electrons with the localized magnetic moments of the ions of the magnetic component.[2]

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The question of the experimental observation of this effect has remained open.[3] Dobrowolska *et al.*[1] have reported observing two maxima on the temperature dependence of the magnetoresistance, $\rho_B(T)$, of $Mn_xHg_{1-x}Te$, at 1.6 and 25–40 K in fields $B = 1.2$–1.5 T. Dobrowolska *et al.* interpreted these maxima as evidence of a thermal-oscillation effect. However, that interpretation is doubtful. Davydov *et al.*[4] have shown that thermal oscillations can be observed in the same ranges of the magnetic field and the temperature as Shubnikov-de Haas oscillations, and the amplitudes of the thermal oscillations cannot exceed those of the Shubnikov-de Haas oscillations. For this reason, it is unlikely that thermal oscillations are observed at temperatures above 25 K in fields of 1.2–1.5 T. The appearance of the second peak can probably also be attributed to a change in the position of the maximum on the $\rho_T(B_0)$ curves with increasing temperature in the $Mn_xHg_{1-x}Te$ because of a change in the contributions of various types of current carriers to the conductivity.[4] Furthermore, at temperatures in the region 25–35 K, clearly defined structural features on the $\rho(T)$ curves are observed in the absence of a magnetic field.[4] Thermal oscillations can apparently be observed experimentally only in high-quality crystals of a narrow-gap semimagnetic semiconductor, with a high electron Hall mobility and a small nonthermal broadening of the Landau levels,[3] characterized by the Dingle temperature.

In this letter we report a study of the galvanomagnetic properties of $Mn_xHg_{1-x}Te$ ($x \approx 0.07$) carried out to detect thermal oscillations of the resistance. The Hall coefficient of the samples depends on the magnetic field and goes negative in weak fields. The current-carrier densities are in the range $n = (2$–$5)\times 10^{15}$ cm^{-3} (4.2 K). The Hall mobility of the electrons reaches $\mu_H = R_H\sigma = (1$–$1.8)\times 10^6$ cm^2/(V·s) (Fig. 1), well above the previously reported values of μ_H, including those in Refs. 1 and 4. In fields $B = 0.65$ T at temperatures in the interval 4.2–20 K, Shubnikov-de Haas oscillations are observed (Fig. 2). The positions of the oscillation peaks depend on the temperature, and their amplitudes vary with the temperature in a nonmonotonic way (Fig. 1). The values of the Dingle temperature do not exceed 1 K at effective masses $m_e^* = (1$–$3)\times 10^{-3} m_0$.

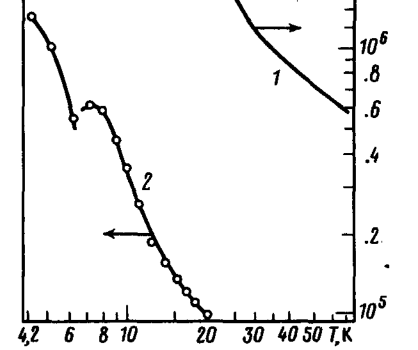

FIG. 1. Temperature dependence of (1) the Hall mobility of the carriers and (2) the amplitude of the Shubnikov-de Haas oscillations.

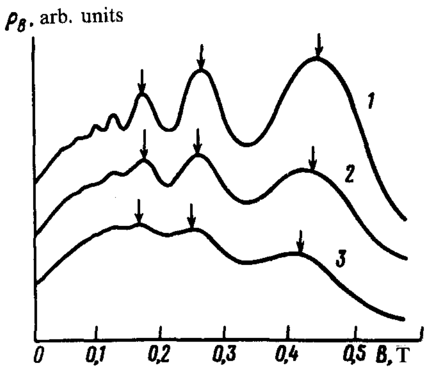

FIG. 2. Shubnikov-de Haas oscillations in a transverse magnetic field at various temperatures T, K: 1—4.2; 2—6; 3—10.

In measurements of the temperature dependence $\rho_B(T)$ in constant magnetic fields below 0.2 T, we detected oscillations (Fig. 3). In the absence of a magnetic field, we found no structural features of any sort on the $\rho(T)$ curve. The amplitude of the oscillations reaches a maximum in fields 0.02–0.04 T, falling off with a further increase in the field. At fields $B > 0.2$ T the oscillations disappear. We were able to observe up to four oscillation peaks, two of which lay in the temperature interval 20–40 K, where Shubnikov-de Haas oscillations have already been observed. It would thus be difficult to explain the existence of these peaks on the basis of the mechanism proposed in Ref. 1 for the appearance of thermal oscillations.[1,4] On the other hand, it would not be possible to explain these peaks in terms of a crossing of the maximum on the $\rho_T(B_0)$ curve through a constant magnetic field, since this maximum lay at $B_0 = 1.2$–1.8 T for the samples studied, these fields are much stronger than the fields ($B < 0.2$ T) in which the oscillations were observed.

In summary, thermal oscillations of the resistance have been observed in high-quality $Mn_xHg_{1-x}Te$ single crystals in weak magnetic fields. These oscillations disappear in the absence of a magnetic field. The observed effect cannot be explained entirely on the basis of the existing model.

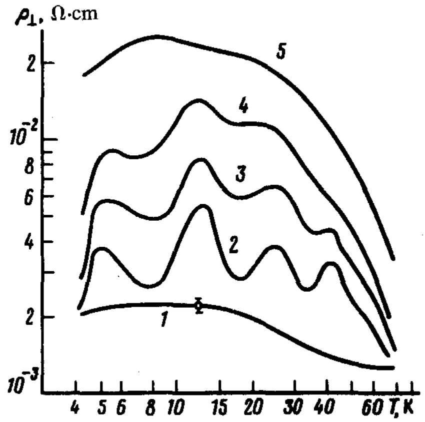

FIG. 3. Temperature dependence of the resistivity, $\rho(T)$, in various transverse magnetic fields B, T: 1—0; 2—0.04; 3—0.08; 4—0.2; 5—0.6.

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