Reversal of the sign of thermoelectric power in n-$Cd_{0.2}Hg_{0.8}Te$ in a quantizing magnetic field

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The reversal of the sign of magnetic thermoelectric power in $Cd_{0.2}Hg_{0.8}Te$ in longitudinal and transverse (relative to the temperature gradient) magnetic fields $\sim$5–15 kOe at temperatures of 10–30 K has been observed for the first time. The sign reversal is attributed to the logarithmic increase of the magnetic thermoelectric power with the magnetic field under conditions of the ultraquantum limit.

The sign of the magnetic thermoelectric power in a longitudinal ($\vec{H} \| \vec{\nabla} T$) nonquantizing magnetic field $\Delta\alpha_{\|}(H) = \alpha(H) - \alpha(0)$ depends on the scattering mechanism. In the solid solution $Cd_{0.2}Hg_{0.8}Te$ at low temperatures (4.2–50 K), when the current carriers are scattered by ionized impurities, according to Ref. 1, $\Delta\alpha_{\|}(H) < 0$.

In Ref. 2 it is shown theoretically that the magnetic thermoelectric power $\Delta\alpha_{\|}(H)$ of nondegenerate semiconductors depends on the quantization parameter $\nu = \hbar\omega_c/2kT$ (for $\nu \ll 1$) nonmonotonically and is characterized by sign reversal (here $\omega_c = eH/m^*c$, where m^* is the effective mass). As far as we know, however, this phenomenon has not been observed experimentally.

As the object of the study we chose the solid solution $Cd_{0.2}Hg_{0.8}Te$ with low electron density $n \approx 2 \times 10^{14}$ cm^{-3} and mobility $u \approx 1 \times 10^5$ cm^2/V·s at 4.2 K. Investigations of the thermomagnetic properties of this material are of interest because at low temperatures, due to the small width of the bandgap (63 meV) and small effective mass of the electrons ($\sim 0.006\ m_0$), in a magnetic field ~ 1 kOe the quantization condition

$$\nu > 2 \tag{1}$$

and the ultraquantum limit

$$\tfrac{3}{2}\ \hbar w_c \gg \mu, \tag{2}$$

where μ is the chemical potential, are satisfied.

Under these conditions, we have $\hbar\omega_c \approx 0.07$ eV, which results in $\nu \approx 100$. At $T = 4.2$ K the chemical potential calculated on the basis of Kane's model is $\mu = 1.6 \times 10^{-3}$ eV and $\mu/\mathrm{kT} \approx 2$; i.e., the electron gas is degenerate.

The results of our investigations of the longitudinal and transverse magnetic thermoelectric power $\Delta\alpha_{\parallel,\perp} = \alpha_{\parallel,\perp}(H) - \alpha(0)$ as functions of the magnetic field and temperature are shown in Figs. 1 and 2.

One can see that $\Delta\alpha_{\parallel}(H)$ becomes positive as the magnetic field increases and exhibits a logarithmic dependence on H. In the quantum limit ($\nu \gg 1$), according to Ref. 2, we have

$$\Delta\alpha_{\parallel}(H) = |\alpha(H)| - |\alpha(0)| = \frac{k}{|l|}\ln 2\nu = \frac{k}{|l|}[\ln\left(\frac{l\hbar}{m^* c}\right) + \ln H - \ln T]. \tag{3}$$

Quantitative agreement with the theory is not achieved, however, because the slope $\partial\Delta\alpha_{\parallel}/\partial \ln H = k/|l|$ [see expression (3)], which must be equal to 86 μV/K, actually falls into the range 18–40 μV/K. This may occur as a result of the fact that the electron gas, in contrast with the case considered in the theory, is in a state of intermediate degeneracy. The latter circumstance, and the fact that the condition of strong quantization is satisfied, make it impossible to explain the sign reversal of $\Delta\alpha_{\parallel}(H)$ on the basis of a theory that predicts it in the quasiclassical case, $\nu \ll 1$ [see expression (11) in Ref. 2]. The sign of $\Delta\alpha_{\parallel}(H)$ changes in magnetic fields $\sim$5–15 kOe at temperatures 10–30 K, in contradiction of the theoretically predicted reversal at $H \approx 20$ Oe under the conditions $\mu \ll \mathrm{kT}$ and

$$\nu = \frac{1}{2\sqrt{2\pi}\exp 1,577} = 0,024.$$

In Ref. 2 the scattering of current carriers by ionized impurities, which in $Cd_{0.2}Hg_{0.8}Te$ at these temperatures predominates and determines the negative sign of $\Delta\alpha_{\parallel}$ in nonquantizing magnetic fields, was ignored.

Accordingly, the longitudinal magnetic thermoelectric power in magnetic fields,

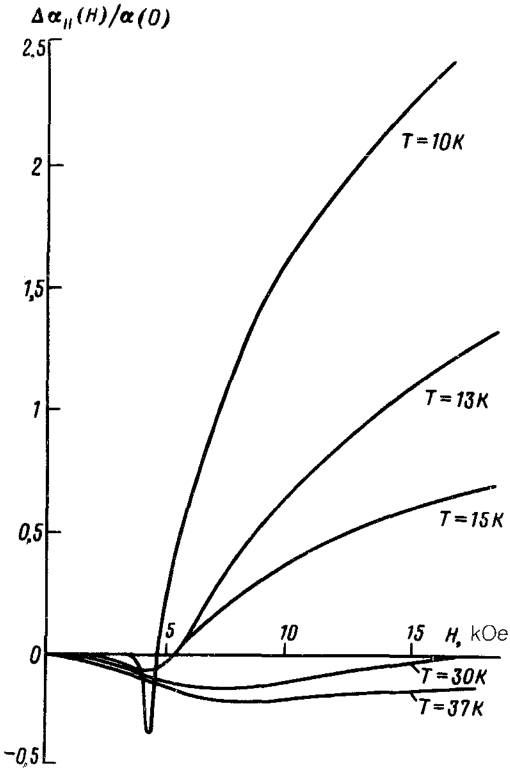

FIG. 1.

in which the ultraquantum limit is reached, reverses sign because of the logarithmic increase of the positive magnetic thermoelectric power $(\Delta\alpha_{\|})_{uq}$ with magnetic field against the background of the negative magnetic thermoelectric power $(\Delta\alpha_{\|})_{class}$ which is attributable to the scattering by ionized impurities.

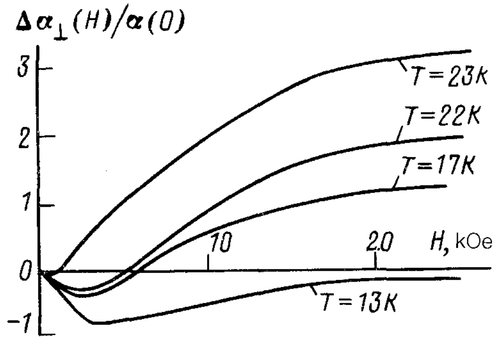

FIG. 2.

The structural feature on the $\alpha_{\parallel}(H)$ curve at $H=4$ kOe and $T=10$ K, which manifests itself in the form of a sharp δ-like extremum, could be caused by an unknown property of the band structure (distortion of the isoenergetic surface) or by a local level of defects and requires a special study.

The transverse magnetic thermoelectric power $\Delta\alpha_{\perp}(H)$, just like $\Delta\alpha_{\parallel}(H)$, exhibits nonmonotonic dependence on H in magnetic fields in the range 0–25 kOe. In contrast with $\Delta\alpha_{\parallel}(H)$, however, the magnetic field in which the sign becomes positive decreases as the temperature is raised. It should be noted that there is no extremum at $H\sim 5$ kOe, and that $\Delta\alpha_{\perp}$ is smaller in magnitude than $\Delta\alpha_{\parallel}$.

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[1] B. M. Askerov, *Kinetic Effects in Semiconductors* [in Russian], Nauka, Leningrad (1970), p. 303.
[2] B. M. Askerov *et al.*, Phys. Status Solidi B **151**, 157 (1989).

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