ELECTRON AND LATTICE PROPERTIES OF WEAKLY DEGENERATED SYSTEMS AT LOW TEMPERATURES

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In the present paper two independent methods were used. By the field and temperature dependences of the phonon thermopower in the ultraquantum limit (UQL) and by the temperature dependence of the size-sensitive part of heat conductivity it was found that in alloys bismuth-stibium in the helium temperature range the Saiman mechanism of phonon-phonon relaxation $\tau_N^{-1} \approx \omega T^4$ is realized.

1. In the temperature interval (1,5÷30) K in transverse ultraquantum magnetic fields (H≤18 kOe) we have measured the galvano- and thermomagnetic coefficients of a series of $Bi_{0.88}Sb_{0.12}$ semiconductor alloy samples oriented along the bisector axes with the carrier concentration determined from the Hall coefficient, P=10^{14} cm^{-3}. In the region of the impurity conductivity and temperature dependences of the thermopower a characteristic fracture is shown at T=6 K. Measurements on a strongly doped sample allowed us to identify an additional thermopower as a contribution of the phonon drag. The electron part of the thermopower in the UQL decreases anomalously in contrast to the usual logarithmic growth in other semiconductor materials. One of the reasons for the anomalous behaviour of the electron thermopower may be the asymmetrical scattering influence on the magnetic moments available in the opinion of the authors [1] in semiconductor alloys bismuth-stibium. In our samples, as in the n-type alloys, the Hall resistance saturation in the fields (3÷5) kOe, logarithmic temperature dependence of the resistivity in the interval (1,3÷8) K were observed.

An alternative reason for the anomalous behaviour of the electron thermopower may be realization of the double flow in pure alloys bismuth-stibium. The thermopower phonon part in the UQL is shown at T≤10 K, it rapidly increases with the temperature decreasing and exceeds by several times the electron thermopower at minimal temperatures of our experiment fig 1.

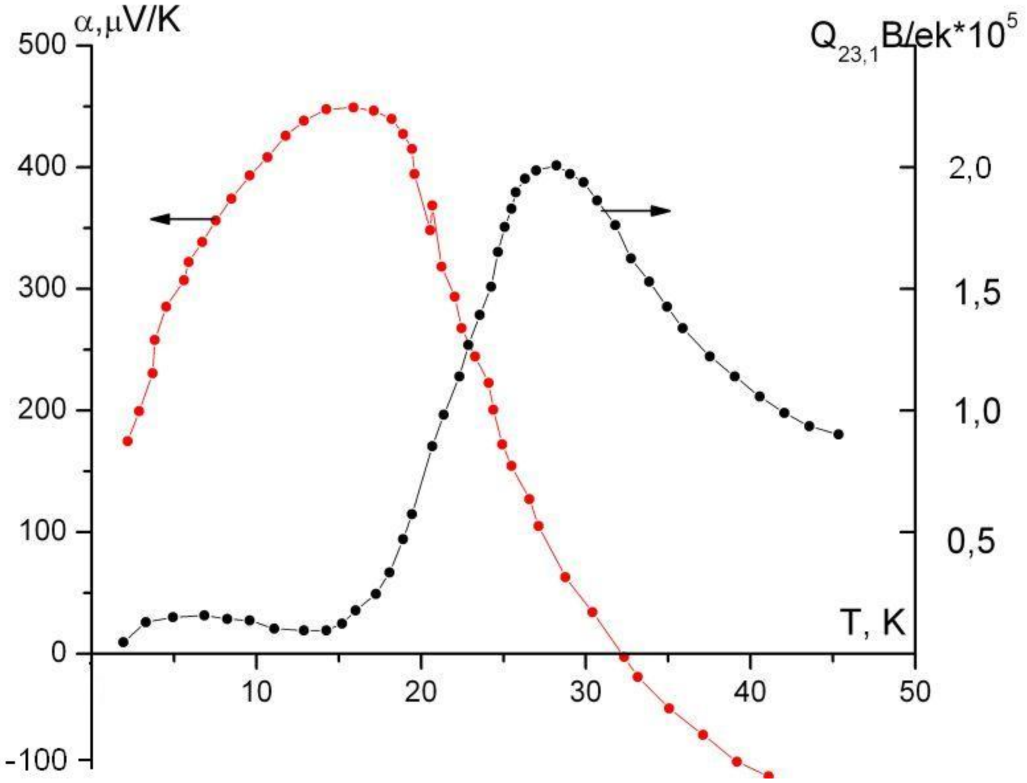

Fig. 1. Temperature dependences of thermopower α_{22} and Nernst coefficient $Q_{23,1}$

$(H=0)$ of $Bi_{0.88}Sb_{0,12}$ *alons*

Let us note that the UQL condition was realized in the whole region of the impurity conductivity in sufficiently small magnetic fields (H≤1 kOe for all the directions of the magnetic field). The fields and temperature dependences of the phonon thermopower were analyzed for the case of not very strong fields, i.e. for the fields whereat the carriers interact with the long-wave phonons.

Let us estimate the scale of magnetic fields in our case. The pulse of the carriers in the plane perpendicular to the magnetic field, $P_e \sim h/\lambda$, where $\lambda=(ch/lH)^{1/2}$ is the magnetic length. The pulse boundary value for the long-wave phonons is P*~0,15 KoT/S, where S is the sound velocity. For T=10 K $P_e \sim P^*_{Ph}$ at H~10 kOe. Thus, in the magnetic fields being weak in the above stated sense, in the interval (3÷10) K, $\alpha_{Ph} \sim H^{1,4\div1,5}$ at H||C_3, what corresponds to the linear frequency dependence of the inverse relaxation time of the long-wave phonons [2]. According to Herring, the sum of indices in the frequency and temperature dependences of the inverse relaxation time is equal to five. Then, $\tau_N^{-1} \approx \omega T^4$, what must give the temperature dependence of the phonon thermopower $\alpha_{Ph} \sim T^{-5,5}$. In the interval (6÷10) K $\alpha_{Ph} \sim T^{-4,8}$. The understated value of the degree index is connected to the influence of the phonon boundary scattering fig.2.

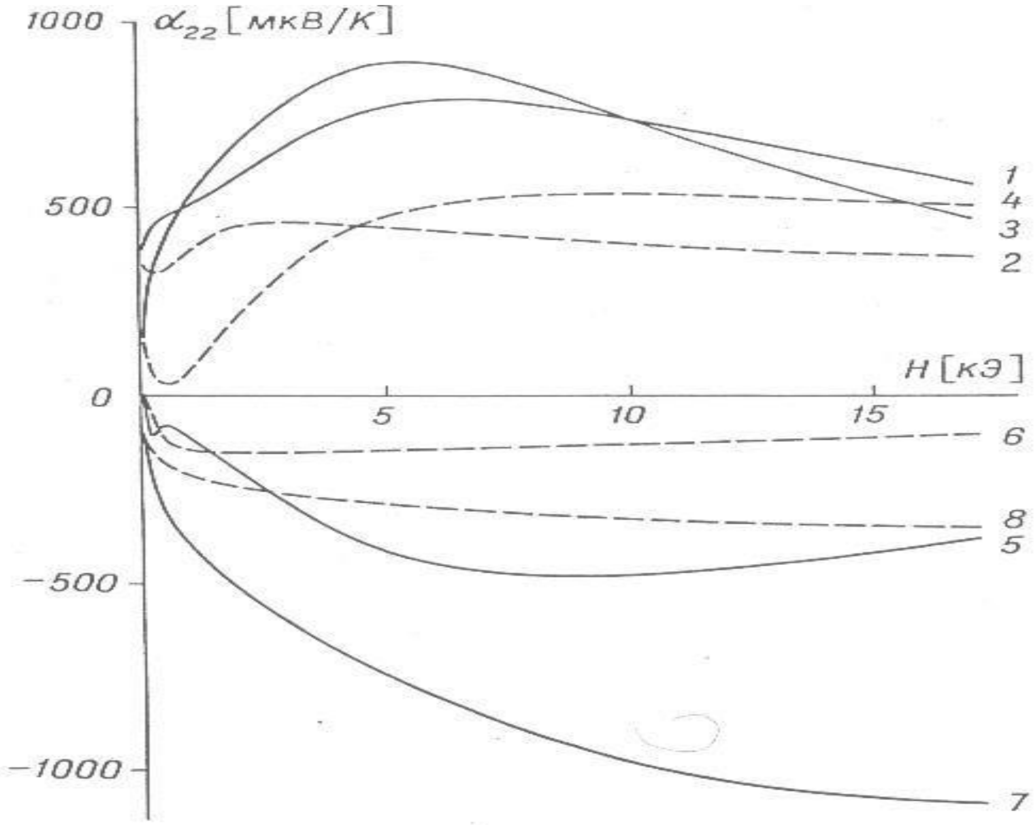

Fig.2. Field dependens of thermopower of $Bi_{0.88}Sb_{0.12}$ alloy at different orientations of the magnetic field, T, K: 1,2-20,4 K; 3,4-25,7K; 5,6-33,4K; 7,8-42,6.

The boundary scattering completely determines the phonon thermopower behaviour at T<3 K. In this temperature range a quadratic dependence of the phonon thermopower on the magnetic field is observed. The dependence $\tau_N^{-1} \approx \omega T^4$ corresponds to the Saiman mechanism of the phonon relaxation, and as it follows from the above-said, it is probably realized in alloys bismuth-stibium at helium temperatures.

Let us note that the Herring mechanism of relaxation of long-wave phonons for rhombohedral crystals $\tau_N^{-1} \approx \omega^3 T^2$ must give the dependence $\alpha_{Ph} \sim H^{0,5}T^{-3,5}$ significantly differing from the experimental one. The phonon thermopower temperature dependence similar to the one observed by us may be given by two-step drag of carriers with participation of impurities [3]. However, it is practically impossible to determine the two-step drag contribution in the alloys bismuth-stibium due to strong compensation of the alloys and electric inactivity of many impurities.

2. Measurements of heat conductivity of the same series of $Bi_{0.88}Sb_{0.12}$ alloy samples have revealed a considerable size effect at T<15 K. The magnetic field with the strength up to 18 kOe did not influence the heat conductivity value at T<20 K, this confirming its purely lattice character. Since long-wave phonons can not participate in the processes of overthrow at the temperatures below the Debye one, the temperature dependence of normal relaxation processes determines the temperature dependence of size-sensitive part of heat conductivity. In the interval (6÷15) K it is obtained that $\Delta\kappa \sim T^4$, what corresponds to $\tau_N^{-1} \approx \omega T^4$, and is in a good agreement with the temperature dependence of the relaxation time obtained from the analysis of the phonon thermopower.

REFERENCES:

1. Zhukov A.A., Karavaev V.G., Kudryashov A.A., Skrbek L., Chudinov S.M., PTT, 1982, v.24, N10, p.2963-2971.
2. Zyryanov P.S., Klinger M.I. Quantum theory of electron transport phenomena in crystal semiconductors, M., Nauka, 1976.
3. Kozlov V.A. PTP, 1984, v.18, N2, p.295-299.