INFLUENCE OF BOUNDARIES ONTHE ELECTRIC AND GALVANOMAGNETIC PROPERTIES OF Sb

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We present here the results obtained by investigating two Sb single crystals in the temperature interval 1.6 - 20°K, in stationary fields up to 20 kOe. The samples, measuring 4 × 4 × 25 mm (Sb V) and 1.3 × 1.3 × 22 mm (Sb VI) were cut by the electric-spark method from one ingot of brand "Su-extra." The resistivity ratio R(300°K)/R(4.2°K) for Sb V and Sb VI was 1650 and 1070, respectively, and the potential contacts were placed 15 mm apart. The diagrams obtained by rotating the crystals in the bisector plane, perpendicular to their longitudinal axes, are shown in Fig. 1. It is seen (see also Fig. 2) that raising the sample temperature and increasing its transverse dimensions leads to qualitatively the same effect, namely an increase of the anisotropy of the magnetoresistance $\alpha = \Delta R(\vec{H} \parallel C_2)/\Delta R(\vec{H} \parallel C_3)$. (As usual, $\Delta R_H = R_H - R_0$, R_H is the electric resistance in a field H, R_0 is the same for H = 0, and C_2 and C_3 are the binary and trigonal crystallographic axes). Thus, below 20°K the influence of the boundaries on the anisotropy of the magnetoresistance of the customarily investigated Sb samples is decisive. When the temperature is varied, the greatest change of the magnetoresistive effect occurs when $\vec{H} \parallel C_3$. The slight change of the anisotropy α as a function of the magnetic field (Fig. 2) is due to the dependence of the exponent of the magnetoresistance on the orientation of $\vec{H}$ relative to the crystal axes. Up to 10°K (a temperature close to the effective Debye temperature θ* for the electron-phonon

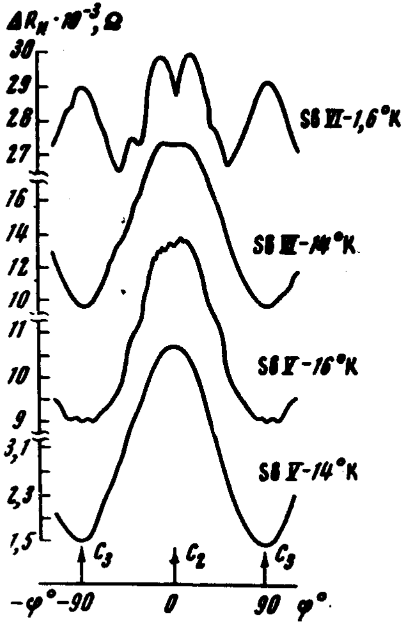

Fig. 1. Crystal rotation diagrams in a magnetic field H ≈ 15 kOe.

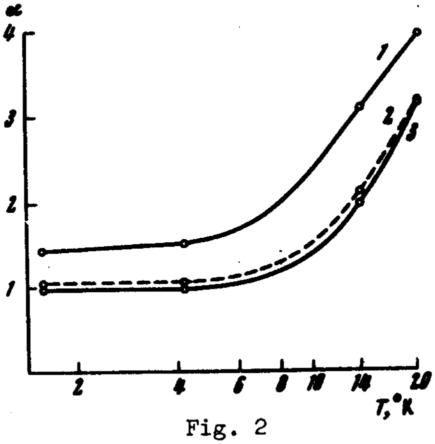

Fig. 2

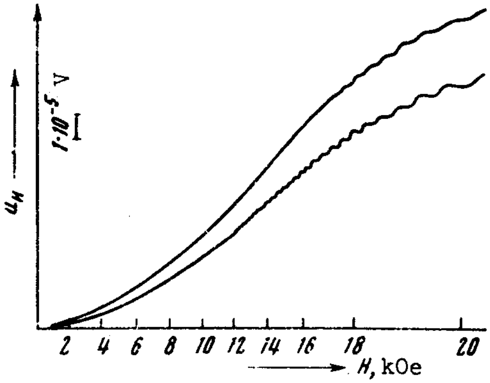

Fig. 3

Fig. 2. Temperature dependence of the magnetoresistance: 1 - Sb V, H = 20 kOe, 2 - Sb VI, H = 10 kOe, 3 - Sb VI, H = 20 kOe.

Fig. 3. Voltage drop on the samples Sb V (lower curve) and Sb VI (upper curve) as a function of the current through the electromagnet winding, $\vec{H} \parallel C_2$.

(intervalley) interaction in Sb (1, 2]), the resistance in the magnetic field increases in a non-quadratic manner (we hope to publish more detailed material on this question in the nearest future).

As seen from Fig. 3, the change of the transverse dimensions of the sample exerts a noticeable influence on the quantum effects, viz., the amplitudes of the Shubnikov-deHaas oscillations in Sb V and Sb VI differ by a factor 2.5. A similar phenomenon was observed in Bi by Tanuma and Ichizawa [3].

Besides the samples Sb V and Sb VI, we investigated Sb samples with transverse dimensions 2.3 × 2.3 and 0.5 × 0.5 mm, cut from the same ingot as Sb V and Sb VI. In the temperature interval 1.6 - 20°K, the entire set of of investigated crystals exhibits a smooth thickness dependence of the resistivity and of the magnetoresistance anisotropy. Consequently, the observed effects are connected with the dimensions of the samples, and not with differences of the defect and impurity concentrations in them. This difference, in principle, can be the results of uncontrollable factors connected with the prior history of the samples.

A rather unexpected result is obtained when the mean free path in Sb is estimated. On the one hand, the thickness dependence of the resistivity of Sb, noted already at 14°K (R(300°K)/R(14°K) equals 314 and 250 for Sb V and Sb VI, respectively) suggests that at this temperature the carrier mean free path ℓ is of the order of 1 millimeter. On the other hand, as follows from [4], the relaxation time τ of the carriers in Sb at room temperature has weak anisotropy and amounts to $(1 - 1.4) \times 10^{-13}$ sec. Then, it is assumed that the temperature dependences of the relaxation-time tensor components are of the same order of magnitude, we obtain $\tau \simeq 4 \times 10^{-11}$ sec for 14°K. Since the Fermi velocity of the electrons and holes in Sb is $v_F \simeq 2 \times 10^7$ cm/sec [5, 6], it follows that $\ell \simeq v_F\tau \simeq 10^{-3}$ cm. The disparity between the mean free paths is so large, that the possible corrections connected with the inaccuracy of v_F and also with the temperature dependences of the effective masses and carrier densities can hardly alter the situation appreciably. It is therefore little likely that the observed singularities of the electric resistance and the magnetoresistance are connected with the classical size effect [7].

We are unable as yet to present a complete explanation of the results. However, if we characterize the carrier scattering processes in Sb by means of the intervalley (τ_{int}) and intravalley (τ) relaxation times, assuming, naturally that $\tau < \tau_{int}$ when $T < \theta^*$, then we should obtain two free paths, the usual one ($\ell \simeq v_F \tau$) and the diffusion one ($L \simeq v_F \sqrt{\tau \tau_{int}}$) [8], which is quite similar to the situation observed here and yields $\tau_{int} \simeq 4 \times 10^{-7}$ sec at 14°K. The influence of phonon dragging on the size effects can likewise not be excluded [9].

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