Kinetic properties of a single crystal of samarium

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The dependences $\rho(T)$ and $[\Delta\rho(H)/\rho_{||}]_T$ for a single crystal of samarium with a resistance ratio $\rho_{273} = 54$, 56, and 60 for the a, b, and c axes, respectively, are investigated in the temperature range 4.2–400 K and in magnetic fields up to 50 kOe. Anomalies accompanying magnetic phase transitions at temperatures of 14 and 106 K are investigated. The quantities ρ_{mag}, α_{ph}, m^*/m, and G are determined for different crystallographic orientations. It is shown that the properties investigated are anisotropic.

In this work, we investigate the temperature dependence of the resistance and longitudinal magnetoresistance of a single crystal of samarium in the temperature range 4.2–400 K and in magnetic fields up to 50 kOe.

The Sm single crystal was grown by the method of recrystallization annealing with preliminary deformation. We determined the crystallographic directions with the help of the DRON-2 x-ray diffractometer. The specimens were cut out by the electric spark method. The maximum error in the determination of the crystallographic orientations was $\sim 3°$. To eliminate the deformed layer and to protect the specimens from further oxidation, ionic etching (discharge in argon) was performed.

The specimens were prepared from Sm with 99.99% purity with resistance ratios $\rho_{273} = 54$, 56, and 60 for the a, b, and c axes, respectively, and had the shape of parallelepipeds with dimensions $4 \times 1 \times 1$ mm. The contacts were welded by the electrical spark method.

The measurements were performed by the potentiometric method. The setup[1]

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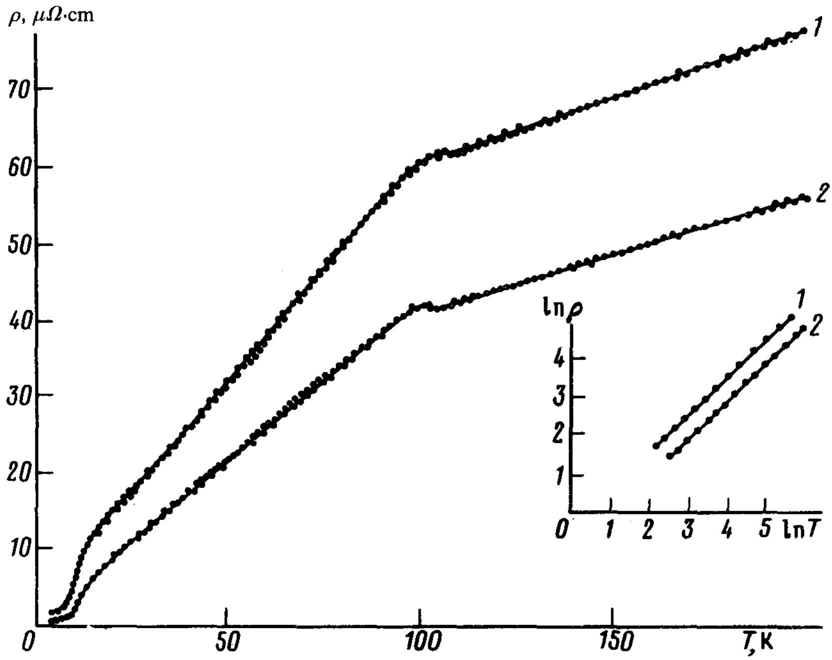

FIG. 1. Temperature dependence of the electrical resistance with the magnetic field oriented along different crystallographic axes. c (1) and a, b (2).

permitted recording automatically all effects investigated as a function of temperature and magnetic field. The temperature was measured to within 0.2 K. The current was stabilized and varied by not more than 1×10^{-6} A/h during the measurements. The error of the measurements did not exceed 3%. The maximum sensitivity with automatic recording amounted to 10^{-10} V/mm.

Figure 1 shows the curves of the temperature dependence of the resistance $\rho(T)$ along the c axis (curve 1) and in the basal plane (curve 2). It is evident from the figure that there are anomalies in the curve $\rho(T)$ near the temperatures 14 and 106 K: rapid growth at 14 K and a local minimum at 106 K. The appearance of a minimum of the resistance near the Néel temperature can be related to the existence of short-range order in the magnetic structure of Sm. In addition, the slope of the curve $\rho(T)$ changes at the temperatures 14 and 106 K. In the temperature range 14–106 K, the electrical resistance increases linearly in all crystallographic directions (see the inset in Fig. 1), although in other rare-earth metals $\rho(T)$ increases proportionally to either T^2 or T^4 in the region of existence of magnetic ordering. In the paramagnetic region the electrical resistance increases linearly in all directions. This is apparently related to the fact that here localized moments of Sm are completely disordered and the magnitude of the magnetic contribution to $\rho(T)$ does not change with temperature.

Figure 2 shows the isotherms of the longitudinal magnetoresistance $[\Delta\rho(H)/\rho_{\parallel}]_T$ for the c axis. In the temperature range 4.2–8.5 K the magnetoresistance $[\Delta\rho(H)/\rho]_T$ is

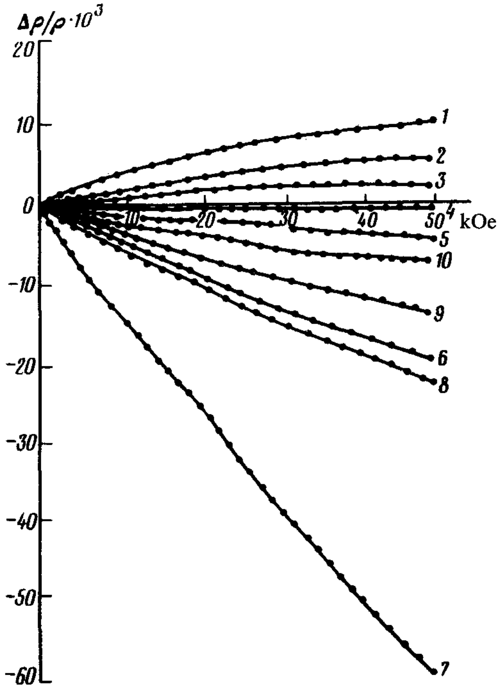

FIG. 2. Isotherms of the longitudinal magnetoresistance at different temperatures T, K. 4.2 (1); 6.3 (2); 8.5 (3); 9.0 (4); 10.2 (5); 13.5 (6); 16.0 (7); 19.0 (8); 25.5 (9); 44.0 (10); 51.1 (11).

positive and increases slightly in a magnetic field, whereas above 8.5 K its sign changes and it decreases with increasing temperature. Near 14 K, the values of $[\Delta\rho(H)/\rho_{\|}]_T$ in a magnetic field increases sharply and then decreases with increasing temperature and approaches zero at $T = 60$ K.

We found the maximum contribution of scattering by magnetic inhomogeneities by extrapolating the rectilinear sections of $\rho(T)$ above 106 K to 0 K. For the axis, $\rho_{\rm mag} = 45\ \mu\Omega\cdot$cm and in the basal plane $\rho_{\rm mag} = 37.5\ \mu\Omega\cdot$cm. For the values of $\rho_{\rm mag}$ we estimated the ratio of the effective mass of current carriers to the mass of a free electron m^*/m and the exchange parameter G (the value of θ_p is taken from Ref. 2). For the c axis $m^* = 3.8$ and $G = 2.6$ eV·Å^3, and in the basal plane $m^* = 3.2$ and $G = 2.8$ eV·Å^3.

Comparing these magnitudes with the corresponding values of m^* and G for transition rare-earth metals, we see that they all have the same order of magnitude.

We calculated the photon coefficient $\alpha_{\rm ph}$ for $T \gg T_n$. For the c axis $\alpha_{\rm ph} = 1.7\times 10^{-7}\ \Omega\cdot$cm and for the basal plane $\alpha_{\rm ph} = 1.5\times 10^{-7}\ \Omega\cdot$cm. The dependence of $\alpha_{\rm ph}$ on the direction of the measurements shows that this contribution has a crystallographic anisotropy.

Figure 3 shows curves of the temperature dependence of the longitudinal magne-

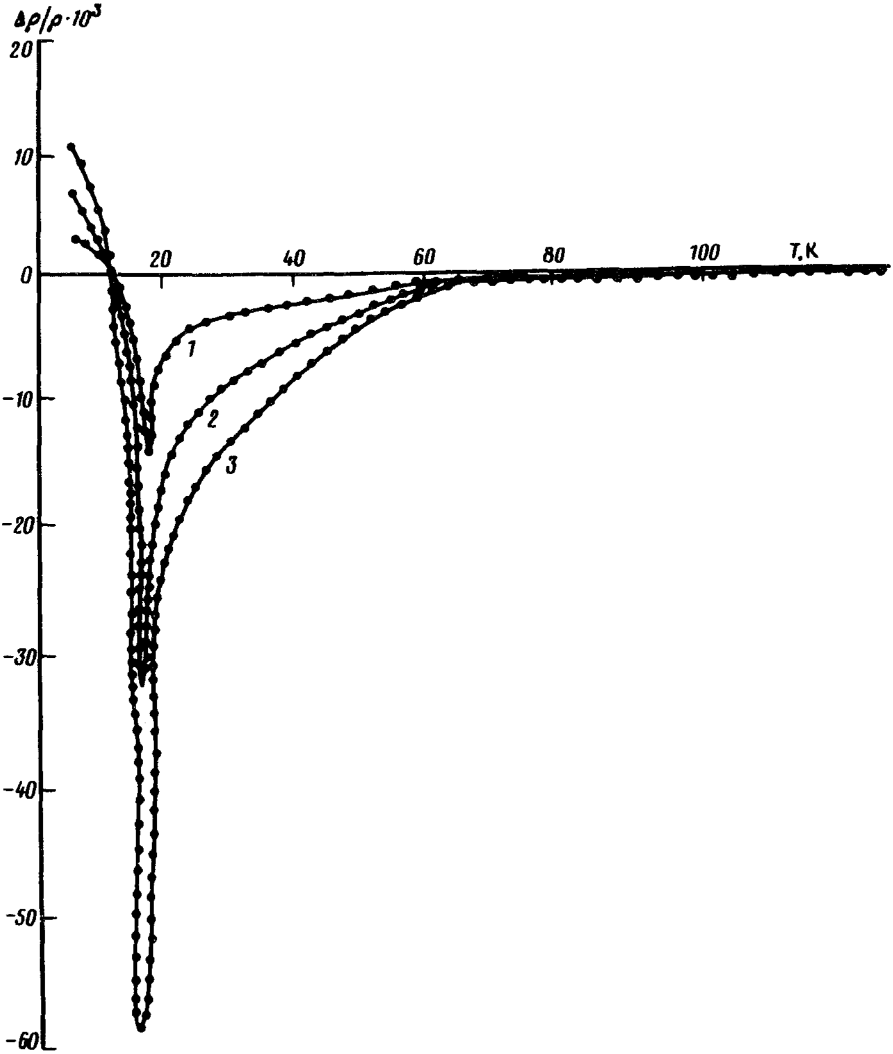

FIG. 3. Temperature dependence of the magnetoresistance for different values of the magnetic field H, kOe: 10 (1), 30 (2), and 50 (3).

toresistance in magnetic fields, $H = 10$ kOe (1), $H = 30$ kOe (2), and $H = 50$ kOe (3) for the c axis. In the temperature range 4.2–8.5 K the quantity $[\Delta\rho(H)/\rho_{\parallel}]_T$ is positive for all values of H. There is a deep, sharp minimum near $T = 14$ K, and near $T = 106$ K there is no anomaly.

The absolute magnitude of the magnetoresistance in the basal plane is aproximately 33% lower than along the c axis.

Our investigations show that the electrical and galvanomagnetic properties of samarium differ from these properties in rare-earth metals. This difference is most likely due to the characteristics of the electronic structure of samarium. It will be possible to draw final conclusions after the investigations of the thermal and magnetic properties of single crystals of samarium, which we shall report in a subsequent publication.

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