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GALVANOMAGNETIC PHENOMENA IN INDIUM AND ALUMINUM

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THE existing data on galvanomagnetic phenomena in indium and aluminum[1-7] refer to specimens in which the resistivity decreases less than a thousand-fold between room temperature and 4.2° K. We had at our disposal metals of appreciably greater purity which enabled us to reach a region of larger effective fields[8] than in previous investigations. Besides increasing the range, a study of aluminum in large effective fields is of interest in connection with the results of Lüthi and Olsen.[7]

The indium specimen was a single crystal, 1.84 mm in diameter and 12.55 mm between the potential leads. The aluminum specimen was a polycrystalline strip, 0.27 mm thick, 3 mm broad, and 36 mm between the leads. The temperature dependence of resistivity is shown in the table.

The measurements were made with the current normal to the magnetic field. A rotation diagram was taken for indium of the resistance change and Hall effect, and the measurements showed that the Hall constant is isotropic and is independent of field in the range $10 - 28 \times 10^3$ oe; its value is

T, °K	$[r_0(T)/r_0(273)] \cdot 10^4$	
	In	Al
20.4 4.2 2.2	0.8	9.6 4.3 4.3

$R = 1.5 \times 10^{-3}$ cgs magnetic units. The ratio of Hall field, E_y, to the field in the current direction, E_x, increases linearly with magnetic field, as is shown in Fig. 1 (curve 1). The Hall field is nearly 20 times greater than the field in the current direction at the largest magnetic fields.

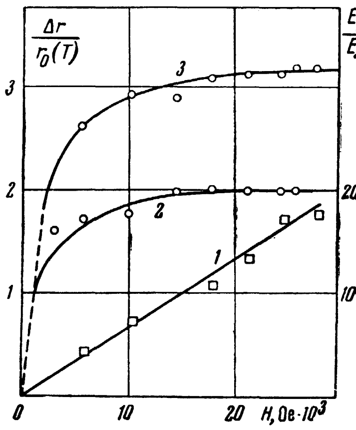

FIG. 1. Hall effect and magnetoresistance in In, T = 4.2°K. Curve 1 – E_y/E_x; Curve 2 – $\Delta r/r$ for the direction corresponding to the minimum effect; Curve 3 – $\Delta r/r$ for the direction for maximum effect.

The anisotropy of the relative change of resistance was found to be small, the greatest difference from the mean value not exceeding 25%. Curves 2 and 3 of Fig. 1 show the resistance change in a magnetic field for directions which show the maximum and minimum effects. It can be seen that in high fields the resistance tends to a limiting value. The results agree with those of other authors.[2,3,4]

The results for aluminum are shown in Fig. 2.

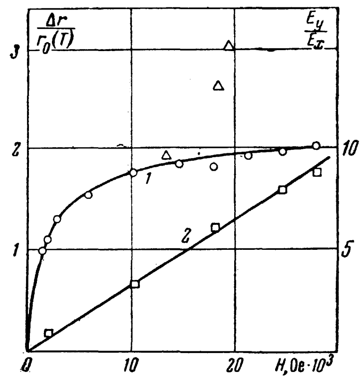

FIG. 2. Hall effect and magnetoresistance in Al, T = 4.2°K. Curve 1 – $\Delta r/r$; Curve 2 – E_y/E_x; Δ – data of Lüthi and Olsen.

Here again we have a linear increase of E_y/E_x (curve 2) with increasing magnetic field and the resistance (curve 1) tends to a limiting value.

The Hall constant in high fields is constant and equal to 9.4×10^{-4}. This agrees with the results of E. S. Borovik.[5] (We should point out that in this paper the value given for R was incorrectly an order of magnitude greater).

The data of Lüthi and Olsen[7] are represented by the triangles in Fig. 2. Köhler's rule has been used to reduce the effective fields to our scale. Clearly, there is disagreement for large fields and we are inclined to regard Olsen's results as in error. The source of error could be the incorrect neglect of the Hall field on the results for the resistance change. It can be seen from Fig. 2 (curve 2) that the Hall field is nearly 10 times greater than the field in the current direction. We found an upward trend to the curve, as in Lüthi and Olsen's work, when the potential leads for the measurement of resistance were not mounted on the same current line. The effect we found was weaker and started in larger fields (21,000 oe). The source of the error found for such a disposition of potential leads has been elucidated by Alekseevskiĭ, Brandt, and Kostina.[10]

The results obtained for indium — the absence of anisotropy in the Hall coefficient and the small anisotropy of magnetoresistance — enable us to state that indium belongs to the group of metals with closed Fermi surfaces.[11] The form of the dependence of resistance and E_y/E_x on field shows that indium is a metal with unequal numbers of holes and electrons.[8]

From the relations obtained for the Hall effect and magnetoresistance in high fields, ignoring Olsen's results, we may suppose that aluminum also belongs to the same type of metals, but measurements on a single crystal would be necessary to make sure of this.

As has been shown by Lifshitz, Azbel', and Kaganov,[11] the difference between the concentrations of electrons and holes can be derived rigorously from the Hall constant in high fields by the formula $R = 1/nec$ (where n is the concentration difference). We have derived this from the data given above. For indium $n = 4.2 \times 10^{22}$ and for aluminum $n = 6.7 \times 10^{22}$. These values are in agreement with earlier determinations.[8]

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POSSIBLE MODE OF OSCILLATION FOR A CHARGE IN CROSSED FIELDS

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We consider the motion of a charge in mutually perpendicular uniform electric and magnetic fields. It is assumed that a damping force $m\gamma(v)\mathbf{v}$ acts on the charge. The z axis is taken in the direction of the magnetic field, the y axis is in the direction of the electric field, and we assume that $v_z \equiv 0$. We convert from the variables v_x and v_y to the new variables a and ψ, using the relations

$$v_x = v_x^0 + a\cos\psi, \quad v_y = v_y^0 - a\sin\psi,$$

$$v_x^0 = \frac{cE/H}{1+\gamma^2(v_0)/\omega_H^2}, \quad v_y^0 = \frac{\gamma(v_0)/\omega_H}{1+\gamma^2(v_0)/\omega_H^2}\frac{cE}{H}. \quad (1)$$

It is apparent that $\mathbf{v}^0(v_x^0, v_y^0)$ is the drift velocity while a and ψ are the amplitude and phase of the Larmor rotation of the charge. If the damping is linear (γ independent of v) the Larmor rotation disappears in the course of time and only the drift motion remains.

The situation is changed, however, if the damping is nonlinear. Here we have the analog of a self-oscillating system of the Thomson type, with the Larmor rotation of the charge acting as the "tank circuit." The amplitude of this rotation does not vanish in the course of time, but approaches a