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N. A. BABUSHKINA

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Fig. 1

Figure 1: Fig. 1

Abstract**Full Text****N. A. BABUSHKINA****ON THE ANOMALY OF THE GALVANOMAGNETIC PROPERTIES IN GADOLINIUM***(Presented by Academician I. K. Kikoin, 13 XI 1963)*

Despite the fact that gadolinium is the first of the discovered ferromagnetic rare-earth metals, the character of its magnetic structure is still in many respects unclear. For a long time gadolinium was considered a “normal” ferromagnet with a Curie point equal to 290° K. But in recent years a number of anomalies have been found in gadolinium. Thus, for example, in a polycrystalline sample of gadolinium at a temperature of 210° K a minimum of the coercive force is observed ⁽¹⁾. In the temperature interval 210–240° K an anomaly of thermal expansion is observed ⁽²⁾, which apparently—

Fig. 1

—is connected with a change in the lattice constant of gadolinium ⁽³⁾. Measurements of magnetostriction ⁽⁴⁻⁶⁾ on polycrystalline and single-crystal samples reveal anomalous behavior at 210 and 100° K. Studies of the magnetic anisotropy of gadolinium ⁽⁷⁾ showed that the direction of easy magnetization depends sharply on temperature and that the anisotropy energy is equal to zero at a temperature of 240° K.

A very sensitive method for studying the magnetic structure of a substance is the study of galvanomagnetic properties. In the literature there are very few data on the galvanomagnetic properties of gadolinium. In this connection we undertook an investigation of the electrical resistivity of gadolinium and its change in a longitudinal magnetic field. The measurements were carried out in magnetic fields with strengths up to 17 000 oersted, in the temperature interval from 4 to 400° K.

Measurements of the magnetoresistance were made by the compensation method with a sensitive F 116-1 galvanometer on samples whose dimensions varied within the limits from $1 \times 1 \times 15 \text{ mm}^3$ to $0.2 \times 2 \times 14 \text{ mm}^3$. For measurements in the low-temperature region a cryostat was used which ensured constancy of temperature to 0.1°. Above 300° K the constancy of temperature was maintained with an accuracy of up to 0.01° by means of a special thermoregulator.

Figure 1 shows the temperature dependence of the longitudinal galvanomagnetic

Fig. 2

Figure 2: Fig. 2

Fig. 3

Figure 3: Fig. 3

effect of gadolinium. Instead of the expected maximum at the Curie point ($\theta = 290^\circ$), caused by the paraprocess, three maxima are observed. The first—the “usual” maximum at $T = 290^\circ$ K—corresponds

through the Curie point. The origin of the maximum at $T = 240^\circ$ K can apparently be connected with the fact that at this temperature the anisotropy energy assumes a minimum value. The reason for the appearance of the maximum at $T = 90^\circ$ K is still not clear.

Our experiments show that the temperature variation of the galvanomagnetic-effect curve does not depend on the purity or heat treatment of the specimens. Measurements were made on three gadolinium specimens of different purity (98.9; 99.7; and 99.9% Gd). After annealing the specimens at a temperature of 1100° C for 10 hours, the residual resistance of gadolinium decreased, but the magnitude of the galvanomagnetic effect and its temperature dependence remained the same.

Fig. 2

Fig. 3

It was of interest to check for gadolinium the regularity previously established in ⁽⁸⁾, consisting in the fact that the temperature dependence of the negative change in resistance in a magnetic field (i.e., the decrease in resistance) is determined by the temperature dependence of the square of the magnetization both in the ferromagnetic and in the paramagnetic region.

A check of this regularity on gadolinium below the Curie point does not appear possible because of the superposition of extraneous effects, manifested in the form of the additional maxima indicated above. Above the Curie point, where there are apparently no temperature anomalies, this regularity can be checked. For this purpose, on one and the same gadolinium specimen in the paramagnetic region, measurements were made both of the change in resistance in a magnetic field and of the magnetic susceptibility.

The results of the measurements are given in Fig. 2, where the abscissa is the temperature, and the ordinate gives the values of the reciprocal magnetic susceptibility $\frac{1}{\chi}$ and the values $\sqrt{\frac{\rho}{\Delta\rho}}$. From the data presented one may conclude that both quantities obey the Curie-Weiss law with the same paramagnetic Curie point ($\theta_p = 310^\circ$ K).

In addition, it is evident from the curve in Fig. 3 that at different temperatures the dependence of $\frac{\Delta\rho}{\rho}$ on the magnetic field H is determined by the relation

$$\frac{\Delta\rho}{\rho} \sim H^2.$$

This means that

$$\frac{\Delta\rho}{\rho} \sim \chi^2 H^2 = \sigma^2,$$

where σ is the magnetization of gadolinium at the given temperature. Thus the regularity mentioned above is confirmed once again for a new substance.

To elucidate the causes of the anomalous temperature behavior of the even galvanomagnetic effect in gadolinium below the Curie point, it appears necessary to study these phenomena on single-crystal samples of gadolinium.

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