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INVESTIGATION OF THE THERMOELECTROMOTIVE FORCE AND THERMOMAGNETIC EFFECT IN DYSPROSIUM

E. I. KONDORSKIĬ, O. S. GALKINA, P. A. MARKOV, and Yu. M. BOROVIKOV

Moscow State University

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The thermoelectromotive force and thermomagnetic effect in dysprosium are investigated as a function of magnetic field strength up to 38.5 kOe at temperatures between 90 and 190°K. It is found that in strong magnetic fields and at the indicated temperatures the thermal e.m.f. is a weak function of the temperature. The critical fields for which a sharp change of the thermoelectromotive force occurs are the same as those in which magnetization increases as a result of transition from the antiferromagnetic to ferromagnetic state.

WE report in this paper results obtained in the study of the thermal emf and the thermomagnetic effect of Dy in the temperature interval 90–190°K. The thermomagnetic effect $Q_H - Q$ is characterized by the difference between the thermal emf Q_H when the sample is magnetized in a magnetic field H, and the thermal emf Q in a magnetic field H = 0, in the absence of residual magnetization. The thermomagnetic effects were never investigated before in this temperature region.

The thermomagnetic effect and the thermal emf of Dy were measured by us by an ordinary potentiometric method, using a photoelectrooptical amplifier FÉOU-18. The sample was in the form of a cylinder 50 mm long and 3 mm in diameter. The heating devices were placed on the ends of the sample and made it possible to obtain a temperature gradient 2–6° along the sample. To measure the temperature we used two copper-constantan thermocouples. The emf of the thermocouple was measured with a R-306 potentiometer and a galvanometer (M21/4). The temperature gradient was measured accurate to 0.1°. The sample temperature was defined as the average of the readings of the first and second thermocouples. The sample was placed in a glass tube, which was evacuated to 10^{-2} mm Hg. The glass tube was lowered into a Dewar with liquid helium. The magnetic field was produced by a superconducting solenoid. The measurements were made in fields up to 38.5 kOe.

Our investigations were performed on a Dy sample supplied by GIREDMET (State Institute for Rare Metals). According to the chemical-analysis data, the composition of the sample was Ho–0.07, Er–0.025, Y–0.05; Tb–not observed, Cu < 0.01, Fe < 0.01.

Figure 1 shows plots of the thermomagnetic effect as a function of the magnetic field H for different temperatures. In weak fields, a slight growth of the thermomagnetic effect is observed, and then, at a definite value of the field, a sharp increase, different for each temperature, occurs. This "jump" is connected with the transition of Dy from the antiferromagnetic state into the ferromagnetic state. With increasing temperature, the magnitude of the "jump" first increases (to temperatures of approximately 130°K), and then decreases. The field in which the transition from the antiferromagnetic state into the ferromagnetic state takes place

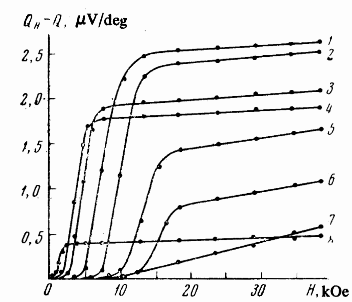

FIG. 1. Plots of the thermomagnetic effects (degrees K): 1–129.8; 2–141.7; 3–109.0; 4–104.3; 5–164.2; 6–173.5; 7–189.3; 8–90.3.

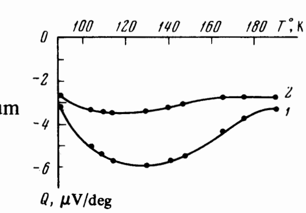

FIG. 2. Thermal emf of dysprosium • 1–H = 0, 2–H = 35 kOe.

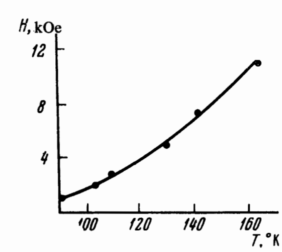

FIG. 3.

increases with increasing temperature. At 190°K, no "jump" of the thermomagnetic effect is observed, since Dy at this temperature is in the paramagnetic state.

Figure 2 (curve 1) shows values of thermal emf Q for Dy. In the temperature region 90–190°K, the thermal emf has a diffuse maximum. The curve and the value of the thermal emf are close to those obtained earlier in[1]. As is well known, Dy is in the antiferromagnetic state in the temperature interval $\Theta_1 > 85°K$ and $\Theta_2 > 179°K$ in a zero magnetic field[2].

Curve 2 of Fig. 1 shows the values of the thermal emf Q_H in a magnetic field H = 35 kOe. For all temperatures of the interval $\Theta_1 - \Theta_2$, the value of the thermomagnetic effect $Q_H - Q$ has approximately the same magnitude and is approximately equal to the value Q of the thermal emf of Dy in the ferromagnetic state at a temperature 85°K.

Figure 3 shows the dependence of the critical field (the field at which a sharp increase in the thermal emf is observed) on the temperature. The value of the critical field was previously determined from magnetic measurements, and from measurements of the magnetostriction and of the galvanomagnetic effect[2]. The values of the critical fields obtained from these measurements and from the thermomagnetic effect coincide.

[1]H. J. Born, S. Legvold, and F. H. Spedding, J. Appl. Phys. 32, 2543 (1961).

[2]K. P. Belov, M. A. Belyanchikova, R. Z. Levitin, and S. A. Nikitin, Redkozemel'nye ferro- i antiferromagnetiki (Rare Earth Ferro- and Antiferromagnets), Nauka, 1965.

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