SOME FEATURES OF THE TEMPERATURE DEPENDENCE OF THE ELECTRICAL RESISTANCE OF GADOLINIUM AND YTTERBIUM AT LOW TEMPERATURES[1)]

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The electrical resistance of gadolinium and ytterbium was measured in the temperature range 1.5—20.3°K. In the expression for the temperature dependence of the electrical resistance, we separated the terms due to electron-electron interaction and those due to the scattering of conduction electrons on phonons. For gadolinium (in the ferromagnetic state), the term representing the scattering of conduction electrons on spin waves was found. The results obtained are in good agreement with the theoretical conclusions in [3,4].

VONSOVSKIĬ[1,2] showed that the presence of the spontaneous moment in ferromagnets cannot lead to a special form of the scattering of conduction electrons, while Turov[3] and Yudin[4] calculated theoretically the temperature dependence of the electrical resistance for ferromagnets on the basis of the s–d exchange model and showed that the scattering of conduction electrons on spin waves leads to the appearance of a linear term in the temperature dependence of the electrical resistance. This term was found experimentally in the electrical resistance of nickel and iron in the temperature range from 0.4 to 4.2°K.[5,6]

Precision measurements carried out on platinum, which is a nonferromagnetic transition metal, showed that the linear term was absent in the electrical resistance.

It was of interest to carry out precision measurements on rare-earth metals and to find how their special electron structure affects the nature of the temperature dependence of the electrical resistance. For this purpose, we measured the electrical resistance of gadolinium, in the magnetically ordered state, and, for the sake of comparison, on ytterbium, which did not undergo a magnetic-ordering transition over the whole investigated range of temperatures.

The measurements were carried out on samples of 99.9% purity in the form of strips 50 mm long, 1.5—2.0 mm wide and 0.25 mm thick, annealed in a stream of liquid helium vapor for 1.5 hours at 650°C in the case of gadolinium and 550°C in the case of ytterbium.

During the measurements, the samples—in a Dewar flask with helium—were placed between two pairs of Helmholtz coils, compensating the vertical and horizontal components of the magnetic field of the earth. In the ranges 1.5—4.2 and 14—20°K, the temperature was found from the vapor pressure of liquid helium and hydrogen, respectively; and between 4.2 and 14°K, it was measured with a double thermocouple and a carbon thermometer.

The results of the measurements of the electrical resistance of gadolinium in the temperature range from 1.5 to 20°K are given in Fig. 1. The temperature dependence of the electrical resistance of gadolinium between 1.5 and 4.2°K is described well by the law obtained for ferromagnetic metals by Sudovtsev and Semenenko[5] and by Kondorskiĭ et al.[6]:

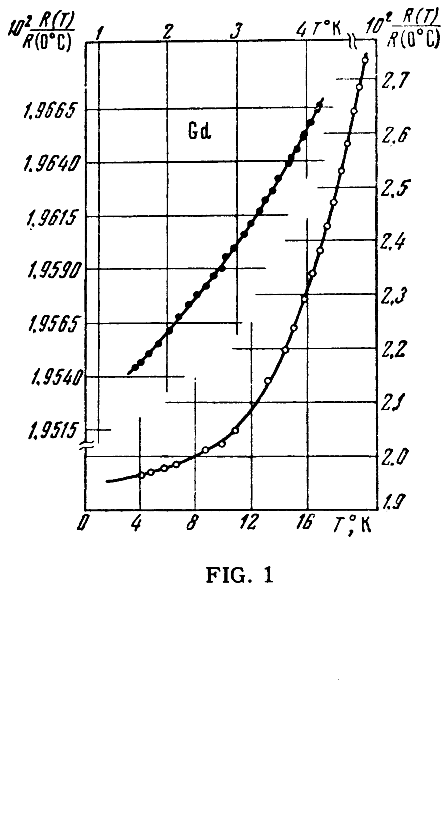

FIG. 1

[1)]The paper was presented at the Tenth All-union Conference on the Physics of Low Temperatures, Moscow, 1963.

$$R(T)/R(0^\circ\mathrm{C}) = R_0/R(0^\circ\mathrm{C}) + AT + BT^2,$$
$$R_0/R(0^\circ\mathrm{C}) = 1.9495\cdot 10^{-2},$$
$$A = 21.8\cdot 10^{-6}\,\mathrm{deg}^{-1},$$
$$B = 5.1\cdot 10^{-6}\,\mathrm{deg}^{-2}.$$

The term proportional to T^5 is negligibly small in this temperature range. Physically, this indicates two mechanisms of conduction electron scattering in gadolinium at low temperatures: scattering on spin waves and electron-electron interaction.

At temperatures between 12 and 20.3°K, a considerable contribution to the temperature dependence of the resistance comes from the scattering of conduction electrons by phonons, and in this temperature range the variation of the resistance is given by the formula

$$R(T)/R(0^\circ\mathrm{C}) = R_0/R(0^\circ\mathrm{C}) + aT^2 + bT^5,$$
$$R_0/R(0^\circ\mathrm{C}) = 1.9495\cdot 10^{-2}, \quad a = 8.6\cdot 10^{-6}\,\mathrm{deg}^{-2},$$
$$b = 1.3\cdot 10^{-9}\,\mathrm{deg}^{-5}.$$

At these temperatures, the linear term is very small.

Figure 2 shows the results of similar measurements for ytterbium. In the temperature range from 1.5 to 4.2°K, the resistance of ytterbium quite well satisfies the law

$$R(T)/R(0^\circ\mathrm{C}) = R_0/R(0^\circ\mathrm{C}) + BT^2 + CT^5,$$
$$R_0/R(0^\circ\mathrm{C}) = 13.7967\cdot 10^{-2}, \quad B = 8.7\cdot 10^{-6}\,\mathrm{deg}^{-2},$$
$$C = 3.6\cdot 10^{-8}\,\mathrm{deg}^{-5},$$

and in the temperature range 12—20.3°K, it varies as

$$R(T)/R(0^\circ\mathrm{C}) = R_0/R(0^\circ\mathrm{C}) + aT^2 + bT^5,$$
$$R_0/R(0^\circ\mathrm{C}) = 13.7967\cdot 10^{-2},$$
$$a = 2.3\cdot 10^{-5}\,\mathrm{deg}^{-2},\ b = 6.8\cdot 10^{-10}\,\mathrm{deg}^{-5}.$$

The linear term is absent in the whole investigated range of temperatures.

Thus, in ferromagnetic gadolinium at helium temperatures, conduction electrons are scattered on spin waves. In nonferromagnetic ytterbium, this type of scattering of the conduction electrons

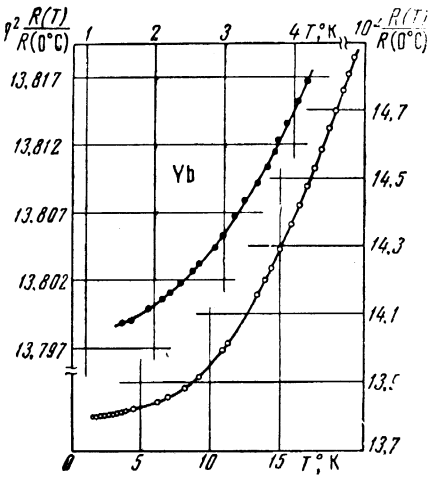

FIG. 2

is absent. The results obtained are in qualitative agreement with the conclusions of the theoretical work of Turov.[3]

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