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EFFECT OF PRESSURE ON THE ELECTRICAL RESISTANCE AND THE ANTIFERROMAGNETIC TRANSITION TEMPERATURE OF EUROPIUM

N. P. GRAZHDANKINA

Metal Physics Institute, Academy of Sciences, U.S.S.R.

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The electrical resistance R of europium was measured under hydrostatic pressure of up to 14,000 kg/cm^2. The R(T) curves, measured in the region of the antiferromagnetic transition temperature $\Theta_N = 90°$K, were used to determine the shift of the Néel point of europium due to isotropic compression. It was established that pressure P increased the antiferromagnetic transition temperature and that the dependence $\Theta_N(P)$ was nonlinear. The pressure coefficient of the electrical resistance of europium at room temperature was found to be negative.

INTRODUCTION

THE shifts of the magnetic transition temperatures of heavy rare-earth metals (Gd, Tb, Dy, Ho) caused by uniform compression have already been measured on many occasions. However, up to now, the group of light rare-earth metals (from Ce to Gd) has been little investigated from this point of view. Attempts have been made to determine the influence of pressure on the antiferromagnetic transition temperature of europium, but the sign and magnitudes of the derivatives $d\Theta_N/dP$, obtained from magnetic[1] and electrical[2] measurements, did not agree.

The influence of pressure on the electrical resistance of europium has been investigated on two occasions[3,4] and it has been established that the pressure coefficient of the electrical resistance of europium is positive, in contrast to all the other rare-earth metals. The cited investigations were carried out using an experimental technique in which a quasi-hydrostatic pressure was produced by isotropic compression of a sample in an elastic solid medium. In this case the sample could have been plastically deformed during compression and this could have been responsible for the observed "anomalous" positive sign of the pressure coefficient of the electrical resistance of europium. In view of this it seemed interesting to carry out a detailed investigation under hydrostatic pressure conditions.

The present paper reports the results of an experimental investigation of the influence of hydrostatic pressure on the electrical resistance and the antiferromagnetic transition temperature of europium.

MEASUREMENT RESULTS AND DISCUSSION

The electrical resistance of europium was measured using two different high-pressure chambers. The pressure coefficient of the electrical resistance was determined only at room temperature. Isotropic compression of a sample was produced in a chamber using a compressor of the L. F. Vereshchagin type together with a pressure booster, by means of which maximum pressures of 14,000 kg/cm^2 could be obtained; a mixture of transformer oil and isopentane was used to transmit the pressure. The method of measuring the electrical resistance, temperature, and pressure was similar to that described by us earlier.[5] The necessary measures were taken to prevent oxidation of europium during mounting of the sample and during measurements.

The influence of pressure on the antiferromagnetic transition temperature was determined from the measurements of the temperature dependence of the electrical resistance. The high-pressure chamber used in these measurements and the method of generating high pressures at low temperatures were similar to those described by Itskevich.[6]

The results of the measurements of the influence of pressure on the electrical resistance of europium at 17°C are given in Fig. 1, which shows that isotropic compression reduced the electrical resistance of europium. The pressure coefficient

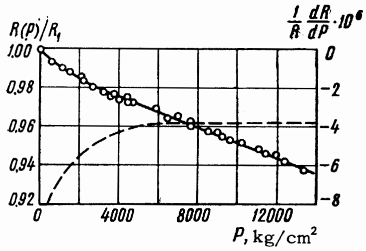

FIG. 1. Influence of pressure on the electrical resistance of europium at room temperature. The dashed curve represents $R^{-1}\, dR/dP$.

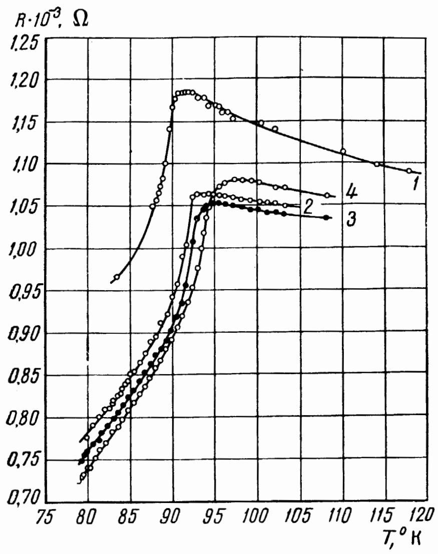

FIG. 2. Temperature dependences of the electrical resistance: 1) at atmospheric pressure ($\Theta_N = 90°K$); 2) at $P = 2700$ kg/cm² ($\Theta_N = 92.3°K$); 3) at $P = 5500$ kg/cm² ($\Theta_N = 93.3°K$); 4) at $P = 10\,400$ kg/cm² ($\Theta_N = 94.5°K$).

$\gamma = R^{-1} dR/dP$ was determined by graphical differentiation of the $R(P)/R_1$ curves, where R_1 is the electrical resistance at atmospheric pressure. Figure 1 (dashed curve) shows that at low pressures the absolute value of γ increased with increase of P, but in the range 5000–14,000 kg/cm² the value of γ remained constant and equal to 3.8×10^{-6} kg/cm². Thus, in hydrostatic compression the sign and value of the pressure coefficient of the electrical resistance of europium were the same as for all "normal" metals.

Figure 2 shows the temperature dependence of the electrical resistance of europium at four different values of pressure: atmospheric pressure, 2700, 5500, and 10,400 kg/cm².[1)] It follows from the curves in Fig. 2 that isotropic compression

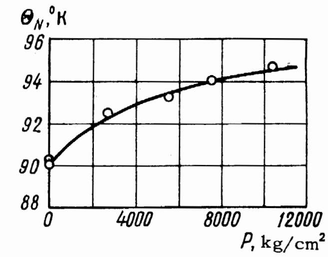

FIG. 3. Pressure dependences of the antiferromagnetic transition temperature.

shifted the R(T) curves toward higher temperatures, i.e., the Néel point rose with increase in pressure.

Figure 3 shows the pressure dependence of Θ_N. The derivative $d\Theta_N/dP$ at low pressures ($P \sim 1000$ kg/cm²) was 9×10^{-4} deg.kg^{-1}.cm² and it decreased with increase of pressure, becoming $\approx 1.5 \times 10^{-4}$ deg kg^{-1} cm² at $P = 10{,}000$ kg/cm².

The results obtained by us do not agree with those published by other authors. In a recent investigation,[2] in which the shift of Θ_N with pressure was determined from electrical measurements, carried out in the temperature range 77–200° K using quasi-hydrostatic pressures up to 90 kbar, it was found that isotropic compression in the pressure range from 40 to 90 kbar depressed the Néel point and that Θ_N was not affected by pressure in the range up to 40 kbar. Obviously, the reason for the different nature of the $\Theta_N(P)$ and R(P) dependences, determined under different isotropic compression conditions, was the plastic deformation of a sample by quasi-hydrostatic pressure.

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[1)] The temperature Θ_N given for each of these measurement cycles corresponds to the pressure P in that cycle.