DEPENDENCE OF THE ELECTRIC AND MAGNETIC PROPERTIES OF CHROMIUM ON THE MAGNETIC FIELD STRENGTH AND TEMPERATURE

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The dependence of the magnetic susceptibility and electric resistance of chromium iodide samples on the temperature and the external magnetic field is investigated. Two transition temperatures are observed at temperatures of the order of 150° and 310°K. In the temperature range 150—310°K a critical field strength exists, for which the magnetization increases and the electric resistance decreases. The experimental results can be explained by assuming the existence in chromium of a helicoidal structure in the temperature region 150—310°K.

THE experimental research on different properties of chromium still has not yet yielded enough data to explain the nature of magnetic transformations in chromium. Furthermore, frequently the results of individual investigations cannot be compared because of the differences in the samples. We therefore deemed it of interest to investigate as completely as possible the electric and magnetic properties of chromium in identical samples.

The dependence of the magnetic susceptibility and the electric resistivity on the temperature and the external magnetic field were investigated in samples of chromium iodide[1)] of different purity. The purity of the specimens was estimated from the ratio $\rho = r(290°K)/r(4.2°K)$ of the electric resistivity at 290°K to the resistivity at 4.2°K. The electric measurements were made on samples of chromium with $\rho < 90$, cut in the form of parallelepipeds measuring $12 \times 2 \times 0.5$ mm from pieces of vacuum-remelted chromium. The chromium samples with $\rho > 90$ were crystals measuring 2—5 mm.

The thinnest and longest samples were used for the electric measurements, while the magnetic measurements were made on powdered samples.

To investigate the magnetic susceptibility, an instrument was built, employing the principle of the spring balance and comprising a variant of the instrument described by Brandt[1] but adapted for measurements over a broad temperature interval. The sensitivity of this instrument was 2×10^{-5} g/mm-m. The electric resistivity was measured with an ordinary potentiometer circuit using an FÉOU-18 photoelectric amplifier. The sensitivity of the circuit was 3×10^{-9} V/mm. The current and potential electrodes were copper wires 0.1—0.05 mm in diameter welded to the specimen by the capacitor-discharge method.

Figure 1 shows the dependence of the electric resistivity on the temperature for a chromium sample with $\rho = 6.4$. The $r(T)$ curve has a kink in the vicinity of 310°K. This is the temperature of the chromium transition from the paramagnetic to the antiferromagnetic state, previously noted by several investigators[2-4]. The anomaly of the resistivity near the magnetic transformation tem-

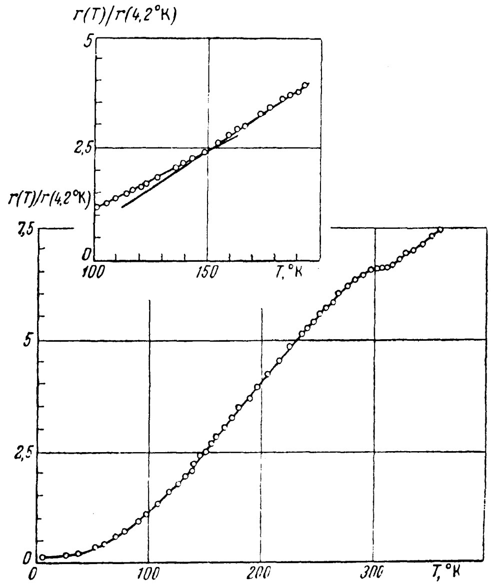

FIG. 1. Temperature dependence of electric resistivity of a chromium sample with ratio $\rho = 6.4$.

1)All the chromium samples were obtained from the Moscow Engineering Physics Institute (Metallurgy and Metal Research Department). The authors take this opportunity to thank the members of that department for graciously supplying the samples for the measurements.

perature can be attributed to the scattering of the electrons by the inhomogeneities of the magnetic moment, while the change in the slope of the r(T) curve on going through this point may be due to the influence of the magnetic order. A second kink is observed on the r(T) curve at 145—150°K.

Figure 2 shows a plot of r(T) for a chromium sample with ρ = 130. It follows from Figs. 1 and 2 that in spite of the great difference in the residual resistivities (6.4 and 130), the Néel temperatures for both samples coincide within 2—3°K. Both samples were obtained by the iodide method from the same chromium, and apparently differ in the content of dissolved gas.

The Néel temperature of the sample of electrolytic chromium with residual resistivity 14 is noticeably shifted towards the lower temperatures (T_N = 270°K).

At low temperatures (~ 150°K), no anomalies were observed, within the accuracy of our measurements, for the sample with ρ = 130.

Figure 3 shows the temperature dependence of the magnetic susceptibility for chromium samples with ρ = 6.4 and 130. Maxima appear on the χ(T) curves at the temperatures (145—150 and 310°K) of the kinks on r(T) curve. At lower temperatures (down to 20°K), the susceptibility of the samples with ρ < 100 increases, apparently owing to the presence of paramagnetic impurities.

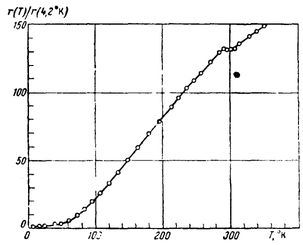

FIG. 2. Temperature dependence of electric resistivity of a chromium sample with ratio ρ = 130.

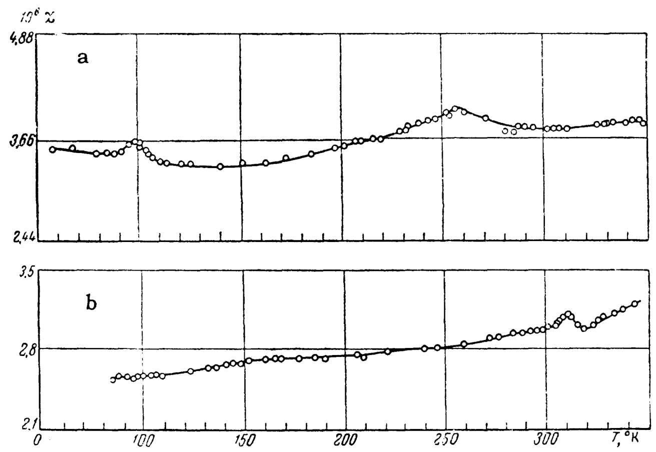

FIG. 3. Temperature dependence of the magnetic susceptibility of chromium samples with ρ = 6.4 (a) and 130 (b).

The Curie-Weiss law is not satisfied above the Néel point, and the susceptibility increases with increasing temperature for all the chromium samples. The increase in the magnetic susceptibility of chromium up to the melting point was also described by McGuire[5] and by Lingelbach[6]. It must be noted that this anomalous behavior of the magnetic susceptibility is apparently characteristic of all metallic antiferromagnets with χ on the order of 10^{-5}—10^{-6}, and of several paramagnetic metals.[7,8]

It was deemed interesting to investigate the dependence of the electric resistivity and the magnetic susceptibility on the applied magnetic field H for the chromium samples with ρ = 130, 77, 171.5, and 338°K. At 77° and 338°K there are no anomalies on the r(H) curve, in agreement with the results of Borovik and Volotskaya[9]. At 171.5°K, the resistance first increases with the magnetic field, followed by a sharp decrease with subsequent weak increase.

Figure 5 shows the dependence of the magnetization on the field for the sample with ρ = 130 and 196°K. At weak fields, the susceptibility is inde-

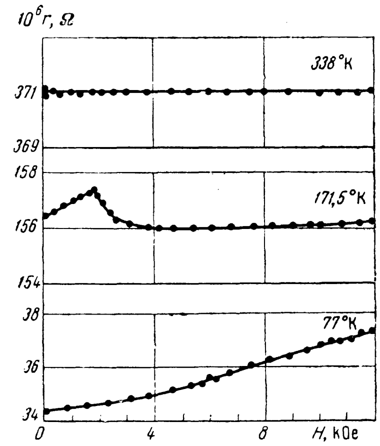

FIG. 4. Dependence of electric resistivity on the external magnetic field H for a chromium sample with ρ = 130 at different temperatures.

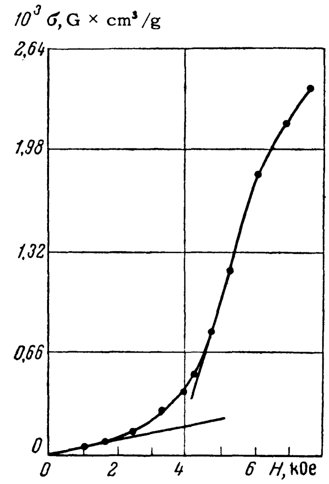

FIG. 5. Dependence of magnetization on the field for a sample with ρ = 130 at 196°K.

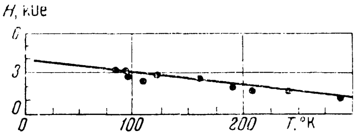

FIG. 6. Temperature dependence of the magnetic field H_{thr}.

pendent of the magnetic field. At a certain field H_{thr} the magnetization increases sharply. H_{thr} increases with decreasing temperature (Fig. 6). These values of the magnetic field coincide exactly with the field at which a decrease in resistivity is observed. It must be noted that whereas the electric resistivity displays at 77°K the usual rise with increasing magnetic field, the magnetization increases sharply at fields of the order of 4000 Oe.

In the regiőn of anomalous behavior of the resistance, a sharply pronounced hysteresis is observed. The results obtained can be interpreted from the point of view of the existence in chromium, in the temperature range 140—300°K, of a helicoidal structure[3,4,10] which is destroyed by a relatively weak external magnetic field H_{thr} ($mH_{thr} \ll kT_N$). The destruction of the helicoidal structure is accompanied by a sharp increase in the magnetic moment and by a decrease in the electric resistivity. The value of H_{thr} increases with decreasing temperature and with decreasing purity of the specimens.

In an external magnetic field, the relative increase in susceptibility at the transition point decreases with increasing magnetic field. We observed no maximum at low temperatures for the chromium sample with $\rho = 130$ on the $\chi(T)$ curve (we plotted $\chi(T)$ in a 3900-Oe field); this is apparently connected with the decrease in $\Delta\chi/\chi$ and the existence of the threshold field H_{thr}. If we plot the susceptibility $\chi(T)$ obtained by measuring by $\chi(H)$ in weak fields, the $\chi(T)$ curve displays a maximum in the 145—150°K region. There are no anomalies on the $\chi(T)$ curve obtained from measurements in strong fields.

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