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Electrical and Galvanomagnetic Properties of Chromium Sulfides

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As regards values of specific electrical resistance, the chromium sulfides occupy an intermediate place between metals and semiconductors; their electrical and magnetic properties depend considerably on changes in structure. By varying the composition of the compounds and the conditions of heat treatment, we may obtain paramagnetic or ferromagnetic compounds with electrical conductivity of the semiconducting or metallic type. A characteristic feature of the electrical properties of these compounds is a change in the sign of the temperature coefficient of electrical conductivity /1/, similar to PbS /2/ and solid solutions of Te-Se. In order to understand the mechanism underlying the electrical conductivity of chromium-sulfur compounds, we must study not only their electrical but also their galvanomagnetic properties. It is particularly interesting to study the electrical conductivity at low temperatures since the present principle of separating substances into metals and semiconductors is based on determining their resistance as a function of temperature at low temperatures.

In this paper we set out the results of a study of the electrical resistance of chromium sulfides at low temperatures and their galvanomagnetic properties.

1. Electrical Resistance of Chromium-Sulfur Compounds at Low Temperatures. We measured the resistances of various chromium-sulfur compositions at temperatures of ____. The results are shown graphically in Fig. 1, which indicated the relative change in resistance R/R_o, where R_o is the resistance at 273^oK. We see from the graphs that the resistance of the

chromium sulfides with sulfur contents of 50 to 51 at. % tends to a low residual value at low temperatures, as in the case of metals, and not semiconductors; chromium-sulfur compounds with a greater excess of sulfur (58 to 59 at. %) become insulators at low temperatures.

2. Hall Effect. We tried to determine the Hall effect in chromium-sulfur samples by means of a compensator. Despite the high sensitivity of our apparatus and the use of magnetic fields up to 22,000 Oe, we were unable to measure the Hall effect in any of the chromium sulfide samples studied. We can only assert that the Hall constant was smaller than 10^{-4} cm^3/C, which corresponds to an electron concentration larger than that obtained from electrical-conductivity data. The electrical conductivity....is of the order of 10 to $10^3 \Omega^{-1} cm^{-1}$; on the basis of this value, and also assuming an electron mobility for semiconductors of 10 to $10^2 cm^2/V$ sec, we obtain an electron concentration of 10^{16} to 10^{20}. For such carrier concentrations we ought easily to have been able to determine the Hall constant, since for magnetic fields of H = 22,000 Oe and a current of 1 A in a sample 0.1 cm thick the Hall emf $E = 1.4 \cdot 10^{-2}$V, since for....the Hall constant $R = 6.3$ cm^3/C. We could easily have measured a value of $E = 1.4 \cdot 10^{-2}$V, since our apparatus had a sensitivity of $2 \cdot 10^{-8}$V.

Fig. 1.

Fig. 2.

(1) Oe

3. Effect of a Magnetic Field on the Electrical Resistance of Chromium Sulfides. Measurements of this effect showed that, for compositions of 50 to 56

at. % S, R/R had an extremely small value, beyond the sensitivity of our apparatus. Exceptions were the chromium sulfides with sulfur excess (58 to 59 at. %), for which we were able to measure the change of resistance in a magnetic field; however, ...had a negative sign, i.e., it behaved anomalously (see Fig. 2).

The only previous example of a fall in resistance in a magnetic field was tellurium (a semimetal), as indicated by R. A. Chentsov /3/.

The immeasurably small values of the Hall effect in chromium sulfides with sulfur contents of .... at. % and also the absence of any influence of magnetic field on the electrical resistance of these compounds may indicate the existence of mixed conductivity (electron and hole). If we start from energy-band considerations relating to the energy states of the electrons in semiconductors, we must conclude that in the present case the mixed conductivity is a result of the very small width of the forbidden band. This is also suggested by the fact that the temperature coefficient of the resistance of chromium sulfide changes its sign at comparatively low temperatures.

In conclusion we wish to thank Active Member of the Academy of Sciences of the Ukranian SSR B. G. Lazarev for enabling us to conduct the measurements in the Low-Temperature Laboratory of the Physico-Technical Institute of the Academy of Sciences of the Ukranian SSR and for help in these measurements.

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