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THE FERMI SURFACE OF IRIDIUM

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The transverse magnetoresistance (anisotropy and field dependences) and Hall effect in an iridium single crystal are investigated at low temperatures and magnetic fields up to 45 kOe. The measurement results indicate that iridium is an "uncompensated" metal and apparently possesses a closed Fermi surface consisting of electron and hole sheets. The results are compared with the theoretical model of the Fermi surface of this metal.

IRIDIUM is among the least investigated transition metals. There have been no experimental investigations whatever of its Fermi surface, insofar as we know.

In this paper we report measurements of the transverse magnetoresistance and of the Hall effect in single-crystal iridium in the region of helium and hydrogen temperatures in magnetic fields up to 45 kOe, aimed at obtaining possible information concerning the topology of its Fermi surface.

A specimen in the form of a bar measuring 0.95 × 0.95 × 28 mm was cut by the electric-spark method from a single crystal prepared by crucible-free zone melting with heating of the zone by electron bombardment. The axis of the specimen made an angle of 40° with the crystallographic direction [100], 18° with $[1\bar{1}0]$, and 20° with $[1\bar{1}1]$. The ratio of the resistivities of the specimen at room and helium temperatures was $\rho(298°\mathrm{K})/\rho(4.2°\mathrm{K}) = 150$.

1. **Magnetoresistance.** The anisotropy of the magnetoresistance of single-crystal iridium (for the given orientation of the specimen axis), is shown in Fig. 1a. In the plots of the electric resistance against the magnetic field, measured both at the maxima and at the minima of the angle diagram, there is observed a tendency to saturation of the magnetoresistance with increasing magnetic field (Fig. 1b). According to the theory of galvanomagnetic phenomena[1], these results indicate that iridium is an "uncompensated" metal and on its Fermi surface, no open orbits are produced at the given orientation of the specimen axis relative to the plane of rotation of the magnetic field.

From the results of measurements of the magnetoresistance, with allowance for the criterion of "compensation" of metal[2], we can expect the Hall coefficient in iridium to approach asymptotically, with the increasing magnetic field, the value corresponding to an odd number of carriers per atom. It is also of interest to determine the sign of the carriers that predominate in iridium. To this end, measurements were made of the Hall effect.

2. **Hall effect.** A typical dependence of the Hall "constant" on the magnetic field, measured in the direction of the maximum of the angle diagram $\Delta\rho/\rho$ (Fig. 1a), is shown in Fig. 1b. In sufficiently weak magnetic fields (i.e., when $\omega\tau \ll 1$) at T = 4.2°K, the Hall coefficient R is positive. With increasing magnetic field, R reverses sign and tends to a value corresponding to one electron per atom. This shows also that the Hall coefficient depends on the reciprocal of the effective field ($1/H_{\mathrm{eff}}$) as $H_{\mathrm{eff}} \to \infty$ (Fig. 2).

As to the positive sign of the Hall coefficient in iridium in weak effective fields (Fig. 2), this fact is apparently connected with the existence of hole sheets of the Fermi surface, the carriers of which have larger mobilities as a result of the small effective masses. By virtue of this, in sufficiently weak fields, where $\omega\tau \ll 1$, the contribution of the whole carriers to the Hall effect

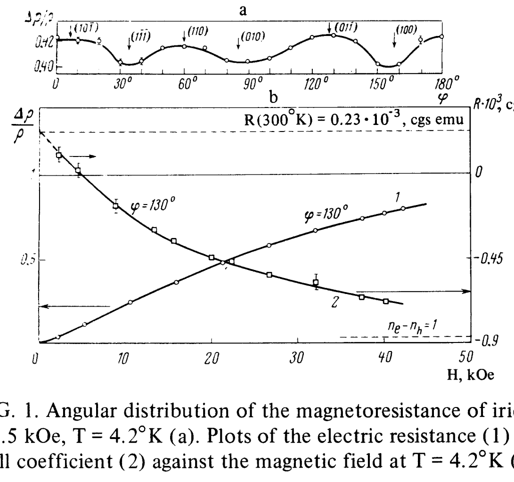

FIG. 1. Angular distribution of the magnetoresistance of iridium; H = 18.5 kOe, T = 4.2°K (a). Plots of the electric resistance (1) and of the Hall coefficient (2) against the magnetic field at T = 4.2°K (b).

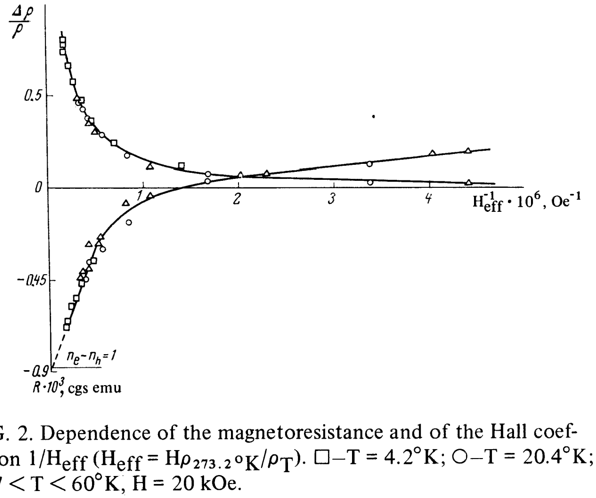

FIG. 2. Dependence of the magnetoresistance and of the Hall coefficient on $1/H_{\mathrm{eff}}$ ($H_{\mathrm{eff}} = H\rho_{273.2°\mathrm{K}}/\rho_T$). □–T = 4.2°K; ○–T = 20.4°K; △–14.7 < T < 60°K, H = 20 kOe.

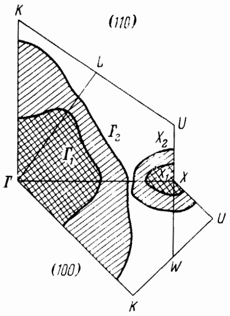

FIG. 3. Intersections of the Fermi surface of iridium with the planes (100) and (110) [3].

can be decisive. This assumption is confirmed by the fact that reversal of the sign of the Hall coefficient, measured in the temperature interval 4.2–60°K, always occurs at the same value of the effective field ($\sim 7 \times 10^5$ Oe).

The experimental results offer evidence that iridium is an ''uncompensated'' metal and apparently has a Fermi surface consisting of electron and hole sheets, and the difference between the values of these sheets amounts to one electron/atom, i.e., $n_e - n_h = 1$.

3. **Comparison of the experimental results with the theoretical model of the Fermi surface of iridium.** The model of the Fermi surface of iridium, constructed by Anderson and Mackintosh on the basis of a theoretical calculation of the electron energy spectrum by the RAPW method[3] is shown in Fig. 3. According to this calculation, the Fermi surface of iridium is closed and consists of two electron sheets (Γ_1 and Γ_2) and two hole sheets (X_1 and X_2). The volume difference between the electron and hole sheets in the Brillouin zone corresponds to one electron per atom. Indeed, iridium has carriers of the hole type with small masses, $\sim 0.2\,m_0$ (sheet X_1), which differs by approximately one order of magnitude from the masses of the electrons of sheets Γ_1 and Γ_2. It is possible that these are precisely the hole carriers which cause the positive sign of the Hall coefficient in weak effective fields.

Thus, the results of measurements of the galvanomagnetic properties of single-crystal iridium agree with the Fermi-surface model of this metal proposed by Anderson and Mackintosh.

Of course, on the basis of the measurements of the magnetoresistance at one orientation of the sample axis it is impossible to draw final conclusions that there are no open carrier trajectories in iridium. Measurements of samples of iridium with other crystallographic orientations with large ratio $\rho(300°\mathrm{K})/\rho(4.2°\mathrm{K})$ will undoubtedly make it possible to draw more convincing conclusions concerning the topology of the Fermi surface of this transition metal.

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