EFFECTIVE MASSES OF ELECTRONS CORRESPONDING TO THE DE HAAS-VAN ALPHEN EFFECT IN ALUMINUM

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The anisotropy of small effective masses of aluminum in the three principal crystallographic planes (001), (110), and (111) is studied by the cyclotron resonance method. The results obtained are in good agreement with oscillations of the de Haas–van Alphen effect and thus make it possible to identify the electron orbits responsible for the two phenomena.

As is well known, the most accurate and direct method of measurement of the effective masses of conduction electrons in metals is that of cyclotron resonance. By studying the anisotropy of this effect in the different crystallographic directions, it is possible to obtain not only data on the value of the effective masses, but also information on the peculiarities of the Fermi surface. Much interest is also attached to the comparison of experimental results obtained by various methods that are sensitive to the shape of the Fermi surface.

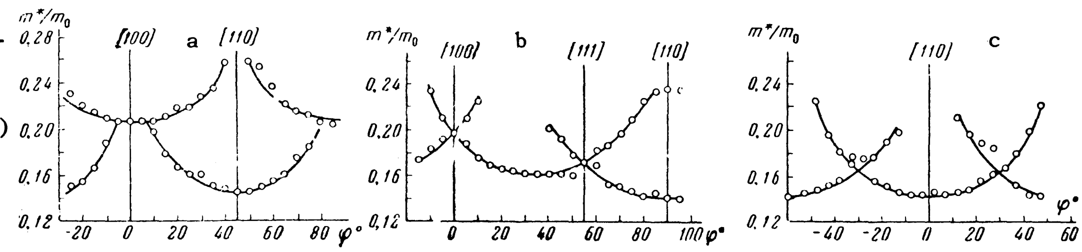
The Fermi surface in aluminum has been studied in considerable detail by Gunnersen[1] from the de Haas–van Alphen effect. Even though the anisotropy of the periods of oscillation of this effect, as Harrison has shown[2], is not single-valued, and can be interpreted by various Fermi surfaces that are completely different in shape, it is of interest to compare the results of Gunnersen with experimental data on cyclotron resonance.

The measurements of the cyclotron resonance were carried out on three monocrystalline specimens of aluminum, the surfaces of which, with accuracy to within a few degrees, lay in the (001), (110), and (111) planes. The purity of the specimens was determined from the ratio of the resistances at room and helium temperatures. This ratio amounted to $\rho_{4.2°K}/\rho_{300°K} \approx 6 \times 10^{-5}$.

The experiment was carried out by an 8 mm spectroscope of the superheterodyne type at T = 4.2°K. The angular dependence of some of the effective masses that were obtained in the three principal crystallographic planes are shown in the drawings a, b, and c. A comparison of the resultant curve with the similar dependences of the period of oscillation in the de Haas–van Alphen effect (see Figs. 7, 8, 9 in [1]) demonstrates their excellent agreement. Of course, this agreement must not be regarded as exact, inasmuch as different quantities were measured in these experiments: the period of oscillations of the de Haas–van Alphen effect yields the area $S(\epsilon)$ of the extremal cross section of the Fermi surface, while the cyclotron resonance yields the extremal mass, which is proportional to $dS(\epsilon)/d\epsilon$. However, the fact that these dependences have identical symmetry and common points of intersection allows us to think that both the de Haas–van Alphen oscillations and the cyclotron resonance take place in one and the same cross section of the Fermi surface. This conclusion is also supported by the agreement of the effective masses measured both by means of cyclotron resonance and by the temperature dependence of the de Haas–van Alphen oscillations.

In the given experiment, we succeeded in observing the maximum effective masses, corresponding to orbits for which the de Haas–van Alphen oscillations were for some reason not observed.

Dependence of the effective masses on the angle φ: a – in the (001) plane, see Fig. 7 in [1]; b – in the (110) plane, see Fig. 8 in [1]; c – in the (111) plane, see Fig. 9 in [1].



The behavior of these effective masses perhaps compels us to reconsider the Gunnersen extrapolation in the region of low periods, and consequently the Fermi surface constructed by him for aluminum.

The absence of experimental points for the maximum masses close to the [110] direction is primarily connected with the weakening of the resonance, and then with the presence of resonances from the larger masses, which makes it much more difficult to decipher the spectra in these regions of angles. The angular dependences of the effective masses that were obtained, just as in the de Haas–van Alphen oscillations, evidently cannot to date be unambiguously interpreted by one particular form of the Fermi surface. However, the presence of a series of resonances in several planes, which yield small masses, gives us a basis for believing that orbits on a multiply-connected Fermi surface, similar to what was proposed by Harrison for the third Brillouin zone, correspond to the resonances.[2-4]

In conclusion, we consider it our pleasant duty to thank Corresponding Member of the Academy of Sciences of the Ukrainian S.S.R. A. F. Prikhod'ko for kindly making possible the researches with liquid helium, and I. P. Okhrimenko for help in the experiment.

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