OSCILLATION OF RESISTANCE AND OPEN ELECTRON TRAJECTORIES IN ZINC

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According to the Harrison model [1], the Fermi surfaces of magnesium and zinc should not have open trajectories parallel to the (0001) plane. Galvanomagnetic measurements have shown that the Fermi surfaces of these metals have open trajectories parallel to the (0001) plane [2,3]. To explain the existence of open trajectories in the (0001) plane, Stark et al. (4, 5] made use of the effect of "magnetic breakdown," which was predicted by Cohen and Falicov [6].

Another phenomenon, not yet explained theoretically, is the existence of a giant oscillation amplitude in the resistance of zinc in a magnetic field, directed along the [0001] axis. Stark [4] first called attention to the considerable disparity between the experimentally observed and theoretically prodicted values of the resistance-oscillation amplitude. Whereas the amplitude of the resistance oscillation coincides in order of magnitude with the value of the total resistance, the period of the oscillations corresponds to the so-called "needle-portion" Fermi surface. The volume of the needle-portion of the surface amounts to approximately one-millionth of the volume of the entire Fermi surface of zinc. Stark advanced the hypothesis that the observed giant oscillation in the resistance of zinc is not the usual Schubnikov - de-Haas effect, but is due to magnetic breakdown between the electronic needle-portion in the third band and the multiply connected Hall surface in the second band ("monster").

Thus, if the existence of open trajectories in the (0001) plane and the giant oscillation of the resistance in zinc are due to a single cause - magnetic breakdown - then it can be assumed that experiments will disclose a connection between these two phenomena. The present investigations were carried out with an aim of observing this connection.

For the galvanomagnetic measurements, carried out at a temperature 1.3°K in fields up to 24 kOe, we used zinc single crystals cut from a large single-crystal block. The sample dimensions were 1 x 1.5 x 20 mm. The ratio of the resistance at room temperature to the resistance at 4.2°K for these samples was ~ 18,000. The sample axes were either parallel to the (0001) plane, or made a small angle with it.

During the course of the measurements it was possible to vary the angle between the measuring current I and the magnetic field, by deflecting the cryostat from the vertical position. This made it possible to investigate two-dimensional regions of crystallographic directions in the same sample. Since the oscillation of the resistance was observed against the background of a monotonic increase in the resistance, which made quantitative determination of the oscillation amplitude difficult, the method employed provided for calculation of the monotonic component of the resistance.

Measurements were made of the amplitude of the oscillations of the resistance, as functions of the direction of the magnetic field and of the measuring current relative to the crystallographic directions.

The following main experimental facts were established:

1. The oscillation amplitude reaches a maximum for field directions parallel to the planes $\{10\bar{1}0\}$. An inclination of 3 - 4° to these directions causes the oscillation amplitude to decrease to approximately one-tenth its value (Fig. 1). At larger angles our method was not accurate enough to observe the resistance oscillations.

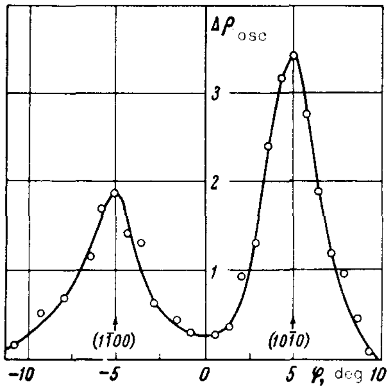

Fig. 1. Dependence of the absolute value of the resistance oscillation amplitude (in arbitrary units) on the angle between the field H = 5200 and the $\{10\bar{1}0\}$ planes. The sample axis is inclined 8° to the [0001] axis and 10° to the $(1\bar{2}10)$ plane. $I \perp \vec{H}$ $(T = 1.3^\circ K)$.

2. When the magnetic field is inclined to the [0001] axis in the $(10\bar{1}0)$ plane, the amplitude of the oscillation behaves in two ways:

a) If I is parallel to $(10\bar{1}0)$, then the oscillation amplitude depends weakly on the angle θ (the angle between the field and the [0001] axis), increasing as the angle increases up to $\sim 5^\circ$ and decreasing with further increase of the angle. Thus, at $\theta \sim 20^\circ$ the oscillation amplitude decreases by approximately one-half.

b) If the measuring current is perpendicular to $(10\bar{1}0)$, then the oscillation amplitude decreases by a factor of more than 10 at angles $\theta \sim 3^\circ$ (Fig. 2). Between these two current directions, the oscillation amplitude decreases smoothly with increasing angle between the $(10\bar{1}0)$ plane and the current.

3. When the magnetic field is inclined to the [0001] axis in any crystallographic plane passing through the [0001] axis, and I is parallel to (0001), the oscillation amplitude decreases by a factor of more than 10 at angles $\theta \sim 3 - 4^\circ$.

The results lead to the following conclusions:

1. The region of existence of giant oscillations in zinc coincides with the region of special directions of the magnetic field, for which open electron trajectories occur on the Fermi surface in the basis plane (the region of special directions of the magnetic field for zinc was first investigated in [3]).

2. Whereas the period of the oscillations is connected with the closed needle-portion of the Fermi surface, the amplitude of the oscillation of the resistance is completely determined by the electrons on open trajectories of the Fermi surface of zinc. The latter follows from the dependence of the resistance oscillation amplitude on the direction of the current

relative to the open trajectories.

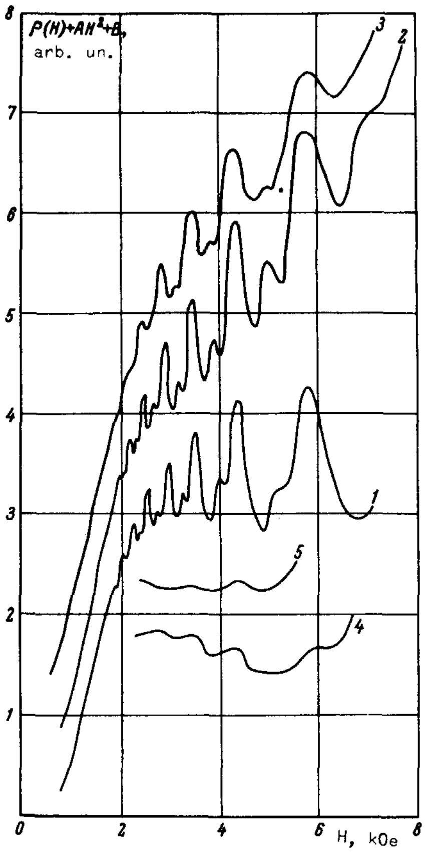

Fig. 2. Dependence of the resistance of zinc on the magnetic field (T = 1.3°K). 1 - H||[0001]; 2, 4 - $\theta = 2°$; 3, 5 - $\theta = 3°$; 2, 3 - $\vec{I} \parallel (10\bar{1}0)$; 4, 5 - $I \perp (10\bar{1}0)$. All curves are shifted along the ordinate axis by an arbitrary amount B. For curves 1, 2, and 3 the value of A is zero.

The observed singularity in the resistance oscillation, wherein the same phenomenon is connected with both a closed and an open Fermi surface, can essentially be defined as magnetic breakdown.

We hope to present a complete report of the results in the nearest future.

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