SOVIET PHYSICS JETP VOLUME 19, NUMBER 4 OCTOBER, 1964

THE PROBLEM OF MAGNETIC BREAKDOWN IN BERYLLIUM

N. E. ALEKSEEVSKIĬ and V. S. EGOROV

Institute for Physics Problems, Academy of Sciences, U.S.S.R.

Submitted to JETP editor October 5, 1963

J. Exptl. Theoret. Phys. (U.S.S.R.) 46, 1205-1207 (April, 1964)

The results are reported of galvanomagnetic measurements on a single crystal of beryllium, carried out in various effective fields at temperatures of 4.2 and 78°K. The results obtained are interpreted in accordance with the concept of magnetic breakdown.

As reported earlier,[1] we investigated the galvanomagnetic properties of beryllium and we found that in fields of up to 50 kOe the resistance increases approximately as the square of the magnetic field for all orientations of the field with respect to the crystal axes. However, in a field stronger than 50 kOe, when the directions of the electric current in the sample and of the applied magnetic field were both perpendicular to the hexagonal axis of the crystal, a change in the law of the resistance rise with the field was observed. We suggested,[1] that the appearance of open trajectories is related to "magnetic breakdown,"[2,3] because the change in the law of the resistance rise—as in the case of rhenium—occurred in effective fields considerably stronger than those expected in the case of an open Fermi surface. Therefore, it was of interest to carry out additional experiments in various effective fields.

The single-crystal sample of beryllium was in the form of a rod 3.5 mm long and about 0.3 mm across. The hexagonal axis of the crystal was perpendicular to the sample axis. Copper wire 0.15 and 0.05 mm in diameter was used for the current and potential electrodes, respectively. The electrodes were welded to the sample by spark discharge. The distance between the potential electrodes was 2 mm.

We measured the resistance of the sample in pulsed magnetic fields. The measurement method was described by us in detail earlier.[5] The measurements were carried out both at the boiling point of liquid helium (4.2° K) and at the boiling point of liquid nitrogen (78° K). Because the Debye temperature of beryllium was low, the resistance at the nitrogen temperature was only 2.5 times greater than the resistance at the helium temperature. Thus, for this sample

$$\rho_{300}/\rho_{4.2} = 125, \qquad \rho_{300}/\rho_{78} = 50.$$

The results of our measurements are given in Figs. 1 and 2. Figure 1 shows the angular variation of the resistance of the sample at temperatures of 4.2 and 78° K, in magnetic fields of various intensities. Curves 2 and 3 are similar to the angular dependences obtained for samples with the same orientation as in the earlier work.[1] The dependence of the change of the resistance on the magnetic field intensity was recorded at the same temperatures with the field directed at right angles to the hexagonal axis of the crystal. These dependences are shown in Fig. 2.

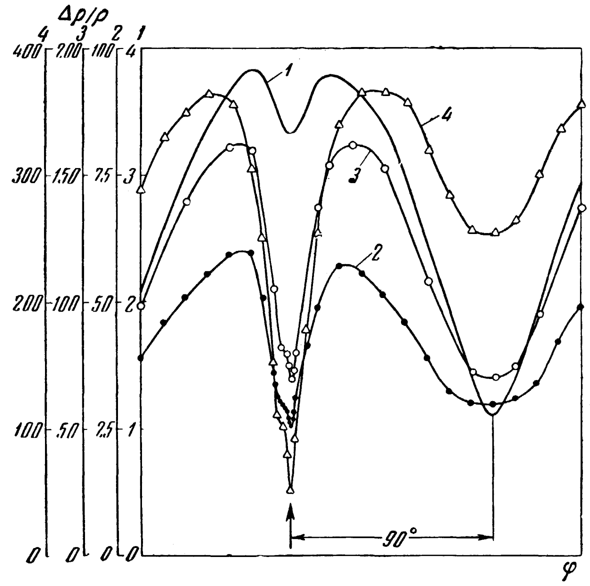

FIG. 1. Diagrams of the angular dependence of the resistance of beryllium in a transverse magnetic field. The hexagonal axis is perpendicular to the current. The field H, in the direction denoted by the arrow, is also perpendicular to the hexagonal axis. 1) T = 4.2°K, H = 5 kOe (curve 1 obtained in a steady field); 2) T = 78°K, H = 44 kOe; 3) T = 4.2°K, H = 34 kOe; 4) T = 78°K, H = 150 kOe.

The results reported here are in good agreement with the previous results:[1] the change in the law of the resistance rise occurs at the same value of the magnetic field. It is clearly evident

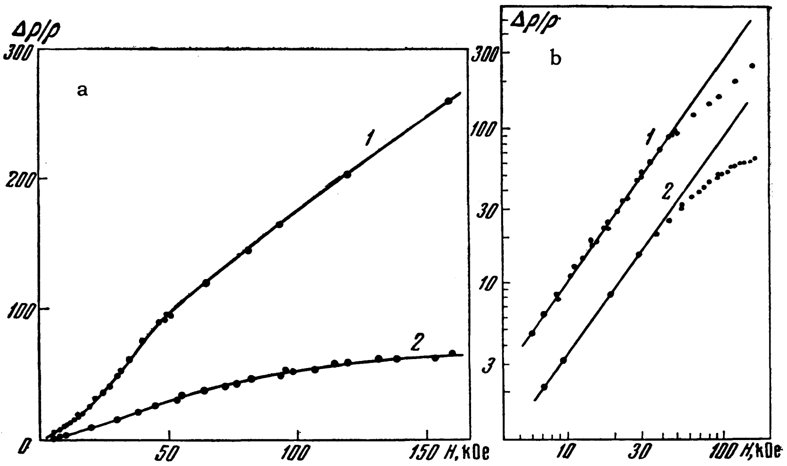

FIG. 2. Dependence of the change in the resistance on the magnetic field intensity with the field perpendicular to the [0001] axis. 1) T = 4.2°K; 2) T = 78°K; a) linear scale; b) logarithmic scale.

from Fig. 2a that at T = 4.2°K the deviation from the initial resistance rise law occurs quite sharply in a field H = 45 kOe, while at T = 78° K this transition takes place more smoothly but the inflection point still lies at approximately the same value of the magnetic field H = 40—50 kOe.

This behavior of the resistance can be interpreted as a consequence of magnetic breakdown. In fact, the change in the law of the resistance rise occurs at T = 78° K in a magnetic field H = 40—50 kOe. When the mean free path is raised by a factor of 2.5 by cooling to 4.2° K, this change occurs again at the same field H = 45 kOe, i.e., the position of the inflection point in the dependence $\rho(H)$ is determined not by the effective magnetic field but by the intensity of the external field H.

At T = 78° K, the change in $\rho(H)$ due to magnetic breakdown occurs—as previously mentioned—in a wider range of fields. This may be due to the thermal broadening of the Fermi level. As a result of this broadening, the motion of electrons along open trajectories (or along trajectories extending over several reciprocal lattice cells) appears in somewhat weaker fields. Therefore, in general, it is possible that in metals with individual parts of the Fermi surface separated by narrow energy gaps, new electron trajectories may appear on heating as a result of a special "thermal breakdown." In this case, naturally, Kohler's rule is not satisfied.

It should be noted, however, that the proposed interpretation of the results is only qualitative and can hardly be used at present for quantitative estimates.

---

[1] N. E. Alekseevskiĭ and V. S. Egorov, JETP **45**, 388 (1963), Soviet Phys. JETP **45**, 268 (1964).

[2] A. B. Pippard, Proc. Roy. Soc. (London) **270**, 1 (1962).

[3] M. H. Cohen and L. M. Falicov, Phys. Rev. Letters **7**, 231 (1961).

[4] Alekseevskiĭ, Egorov, and Kazak, JETP **44**, 1116 (1963), Soviet Phys. JETP **17**, 752 (1963).

[5] N. E. Alekseevskiĭ and V. S. Egorov, JETP **45**, 448 (1963), Soviet Phys. JETP **18**, 309 (1964).

Translated by A. Tybulewicz
171