Magnetic breakdown in vanadium

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The magnetoresistance of vanadium single crystal is investigated in fields up to 170 kOe. Magnetic breakdown that leads to the change of open trajectories into closed ones is observed.

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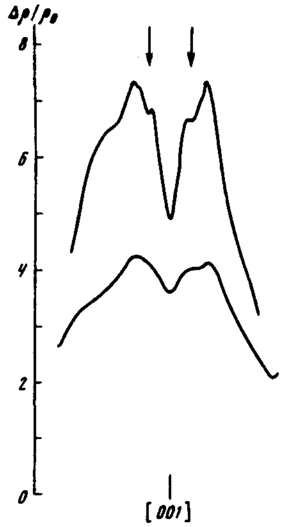
We have reported in[1] anomalies in the angular and field dependences of the magnetoresistance of superpure niobium, which were observed by us in fields stronger than 100 kOe for magnetic-field directions lying inside the two-dimensional regions of open trajectories around fourfold axes on the stereographic projection. Since the formation of elongated trajectories is impossible for these magnetic-field directions, it was concluded that magnetic breakdown took place. In weak fields, the motion of an electron along on open trajectories in a multiply-connected surface of the third band leads to a quadratic dependence of the magnetoresistance on the field; in strong magnetic field, as a result of magnetic breakdown through the spin-orbit gap between the second and third bands the trajectory becomes closed, and the magnetoresistance exhibits saturation. An analysis of the experimental dependences of the magnetoresistance on the field, within the framework of the coherent model of magnetic breakdown, has made it possible to determine the value of the spin-orbit interaction in metallic niobium. This value (0.09 eV) practically coincided with the spin-orbit interaction energy obtained spectroscopically for the Nb^{3+} ions. Since the spin-orbit interaction depends on the atomic number, it was possible to assume that the magnetic breakdown in vanadium, whose Fermi surface is similar to the Fermi surface of niobium,[2] should occur in much weaker fields.

The magnetoresistance of vanadium was measured in the helium temperature region for single-crystal samples having a room-to-residual resistivity ratio close to 700. The magnetic field was produced by the water-cooled solenoid E-105 of our Laboratory. Permendur concentrators were used to increase the magnetic field.

The figure shows characteristic angular dependences of the magnetoresistance of vanadium in the two-dimensional region of open trajectories around the fourfold axes. These dependences are perfectly analogous to those obtained earlier for niobium. With increasing



Angular dependences of the magnetoresistance of a vanadium sample with axis close to the [100] direction. The upper curve is for $H = 162.1$ kOe, and the lower for $H = 108$ kOe.

magnetic field, additional minima appear on the angular dependence of the magnetoresistance of vanadium, located 10° away from the [001] direction. Just as in the case of niobium, the appearance of such minima offers evidence of the onset of magnetic breakdown. It should be noted that the depth of these magnetic-breakdown minima is smaller than for niobium. This circumstance can apparently be attributed to the fact that the magnetic breakdown in niobium was investigated by us for much purer sample (the resistivity ratio reached 62 000).

If the estimate of the breakdown field from the value of the spin-orbit interaction is correct, then magnetic breakdown in tantalum, the Fermi surface of which is similar to the Fermi surface of niobium and vanadium, should occur in the megagauss region.

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