MAGNETORESISTANCE OF RUTHENIUM IN STRONG MAGNETIC FIELDS

N. E. Alekseevskii, K.-H. Bertel 1), A. V. Dubrovin, V. I. Nizhankovskii, and L. Urai 2)
Institute of Physics Problems, USSR Academy of Sciences

Submitted 5 June 1973
ZhETF Pis. Red. 18, No. 5, 277-281 (5 September 1973)

The magnetoresistance of single-crystal ruthenium samples with different orientations is investigated in a transverse magnetic field up to 155 kOe. Magnetic breakdown in samples with axes close to the [0001] direction was observed in fields $\geq$ 90 kOe.

We present here the results of measurements of the magnetoresistance of ruthenium, performed on samples with different orientations in pulsed and stationary fields up to 155 kOe. The samples were cut by the electric spark method from ruthenium single crystals oriented by x-ray diffraction and having a resistivity ratio $\rho(300°K)/\rho(4.2°K) \simeq 150$.3) The cross section of the samples was $\sim 0.03\times0.03$ mm, and the length was 4 - 7 mm. The sample surface was electrolytically polished, and the current and potential leads were soldered with pure tin. The mounting of samples prepared in this manner in the holder and the procedure for the measurement in pulsed fields are described in [1]. For the measurements in stationary fields we used the setup described in [2]. Stationary magnetic fields were produced by two methods. In the first we used a superconducting magneti with permendur concentrators, and the maximum field was 92 kOe. In the second method we used a water-cooled copper solenoid (coil of the Bitter type) with dysprosium concentrators, and the maximum field was 155 kOe.4) All the measurements were made at a sample temperature 4.2°K.

Experimental results

Figure 1a shows typical angular dependences of the magnetoresistance of binary samples, measured in a pulsed field up to 91 kOe, and those obtained in stationary fields. The main feature of the curves in Fig. 1a is the deep minimum when the field is parallel to the hexagonal axis. As seen from Fig. 1b, almost complete saturation of the magnetoresistance sets in at the minima when the field is increased, while a quadratic growth is observed at the maxima. In addition to the deep maxima at H || [0001], a small minimum is observed in a binary sample with axis along $[10\bar{1}0]$ at H || $[1\bar{2}10]$, but in fields up to 155 kOe this minimum does not become deeper with increasing field.

The angular dependence of the magnetoresistance of a hexagonal sample, measured in a 145-kOe

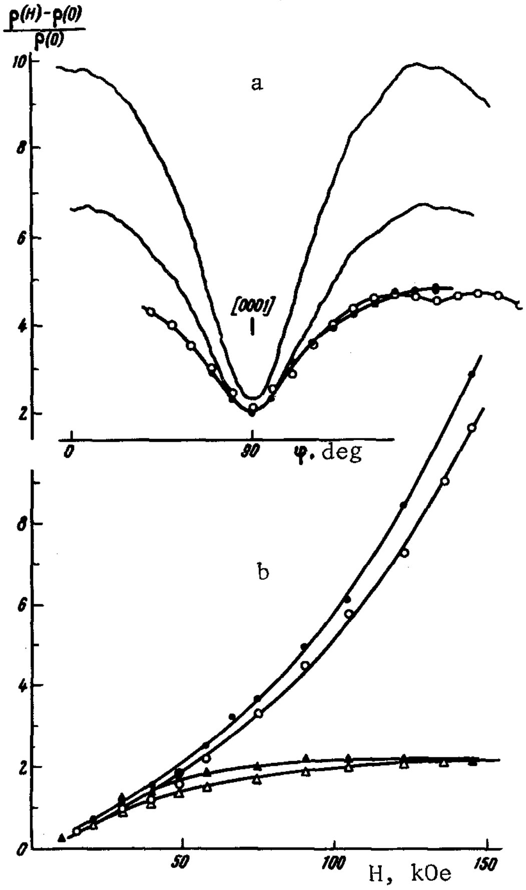

Fig. 1. a) Angular dependence of the magnetoresistance of binary samples: 1 - (o) - J || $[10\bar{1}0]$, pulsed field H = 91 kOe, 2 - (o) - J || $[1\bar{2}10]$, pulsed field H = 91 kOe, 3 - J || $[1\bar{2}10]$, stationary field H = 115 kOe, 4 - J || $[1\bar{2}10]$, stationary field H - 145 kOe. b) Field dependence of the magnetoresistance of binary samples, obtained in pulsed fields: ● - J || $[1\bar{2}10]$, H || $[10\bar{1}0]$, o - J || $[10\bar{1}0]$, H || $[1\bar{2}10]$, ▲ - J || $[1\bar{2}10]$, H || [0001], Δ - J || $[10\bar{1}0]$, H || [0001].

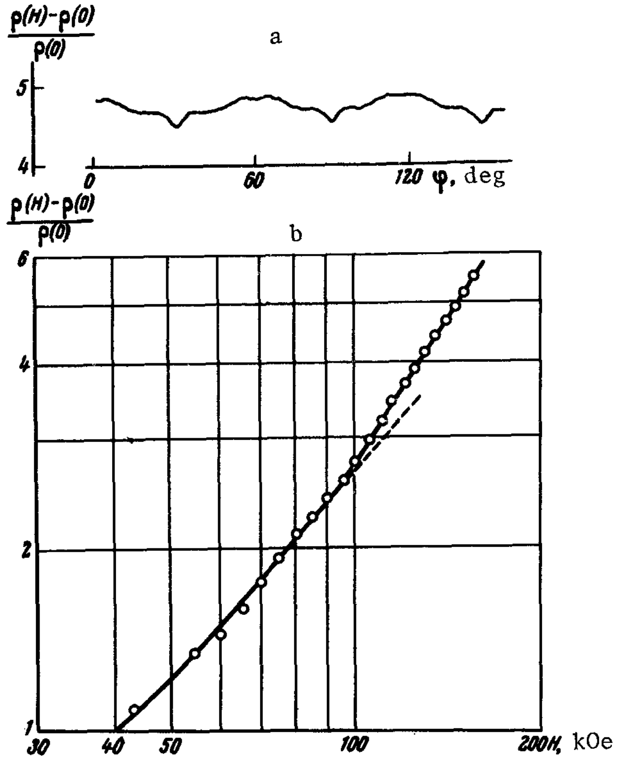

Fig. 2. Measured magnetoresistance of hexagonal sample in stationary fields: a) Angular dependence of magnetoresistance at H = 145 kOe, b) field dependence of magnetoresistance at H ∥ [1210].

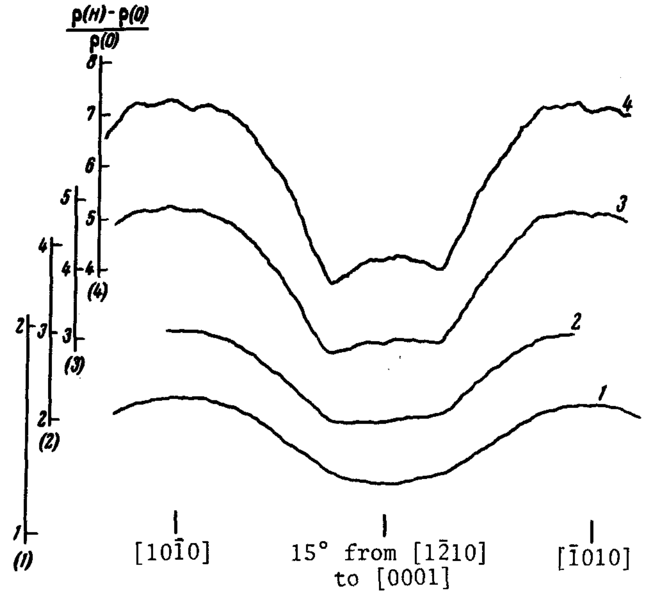

Fig. 3. Angular dependences of the magnetoresistance of a ruthenium sample with axis inclined 15° to [0001] in stationary fields: 1) H = 55 kOe, 2) H = 85 kOe, 3) H = 115 kOe, 4) H = 145 kOe.

stationary field, is shown in Fig. 2a. The magnetoresistance anomaly is small even in so strong a field. The minima correspond to magnetic-field directions perpendicular to the faces of the unit cell. The field dependences of the magnetoresistance were obtained at three directions of the magnetic field: $[10\bar{1}0]$, $[1\bar{2}10]$, and 30° from $[10\bar{1}0]$ towards $[1\bar{2}10]$. Their plots are similar in shape, and Fig. 2b shows the plot of the magnetoresistance against the field at H ∥ $[1\bar{2}10]$, measured in a stationary field. A characteristic feature of the presented dependence is the sharp kink occurring at ∿ 80 - 90 kOe. The plots of the magnetoresistance against the field obtained for pulsed fields, also show a kink in this field region.

Figure 3 shows the angular dependences of the magnetoresistance of a ruthenium sample whose axis is inclined 15° to the [0001] direction; these were obtained in stationary fields up to 145 kOe. With increasing field, a change takes place in the character of the anisotropy of the magnetoresistance and a maximum is observed at the minimum of the angular dependence.

Discussion

It follows from the general form of the angular dependences of the magnetoresistance that ruthenium is a compensated metal. The deep minimum of the magnetoresistance of binary samples at H ∥ [0001] is evidence of the presence of open trajectories in the basal plane.

The field dependence of the magnetoresistance of the nexagonal sample (Fig. 2b) can be attributed to magnetic breakdown. In weak fields, the electron moves along an open trajectory, and in strong fields the trajectory becomes closed. The change in the anisotropy of the magnetoresistance (Fig. 3) can be explained from the same point of view.

It was previously suggested [3] that the Fermi surface of ruthenium should be similar to the Fermi surface of rhenium, since ruthenium is a nonrelativistic analog of rhenium. The galvanomagnetic properties of rhenium were investigated in sufficient detail, and the results