DEVIATION FROM KOHLER'S RULE IN PURE ALUMINUM

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The dependence of the resistance on the magnetic field was investigated for very pure aluminum samples at $T = 20.4°K$. A comparison was made with data for less pure aluminum ($R_{273}/R_{4.2} \leq 2000$). The results of the measurements are given in Kohler coordinates. An appreciable deviation from Kohler's rule is noted for high-purity aluminum samples ($R_{273}/R_{4.2} \approx 10{,}000$).

MOST metals obey a semiempirical rule established by Kohler,[1] which states that if the relative change of the resistance $\Delta R/R$ is represented as a function of the product HR_{273}/R_T (where R_{273} is the resistance at 273°K) a single curve is obtained approximately, for all temperatures and samples of various purities, with a deviation not exceeding 30%. This is a natural consequence of the fact that the quantity HR_{273}/R_T is to a certain extent a measure of the effective value of the magnetic field.[2]

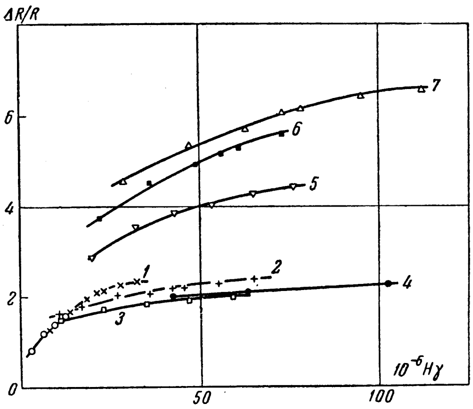
In an investigation of aluminum samples for which $R_{273}/R_{4.2} < 2000$ the deviations from Kohler's rule did not exceed those usually observed for other metals. However, as will be shown below, large deviations from Kohler's rule are observed in studies of high-purity aluminum ($R_{273}/R_{4.2} \geq 10{,}000$). The purpose of the present work is to illustrate this effect.

Measurements were carried out on single-crystal samples of aluminum with rectangular cross section; the samples had the following properties:

	Al-1	Al-2	Al-3	Al-4
R_{273}/R_{20}:	3230	2500	2000	930
$R_{273}/R_{4,2}$:	22200	10000	6250	1850

The measurements were carried out at temperatures of 20 and 4.2°K in fields up to 35,000 Oe. At the temperature of liquid hydrogen rotation diagrams were obtained for the resistance of all samples in a magnetic field. The deviation of the resistance from its average value did not exceed 15%.

The magnetic-field dependence of the resistance in Kohler coordinates is given in the figure for all the samples. The same figure shows the results of measurements on less pure aluminum. The curves do not diverge very greatly from one another but it should be noted that even the curve



Dependence of the resistance on the magnetic field in Kohler coordinates for Al ($\gamma = R_{273}/R_T$). Curve 1: o – according to [3], × – Al-4, T = 20.4°K; curve 2: Al-4, T = 4.2°K; curve 3: according to [4], T = 4.2°K; curve 4: Al-3, T = 4.2°K; curve 5: Al-3, T = 20.4°K; curve 6: Al-2, T = 20.4°K; curve 7: Al-1, T = 20.4°K.

for sample Al-4 at T = 20.4°K lies slightly above the curve for the helium temperature. On further increase of the sample purity this difference becomes greater. Thus, as shown by curves 4 and 5, which represent the results of measurements on sample Al-3 at T = 4.2°K and T = 20.4°K, the relative change of the resistance in a magnetic field at 20°K is more than twice the relative change of the resistance at 4.2°K. The relative change of the resistance in a magnetic field at 20.4°K becomes even greater on further increase of the sample purity (curves 6 and 7).

Since measurements were carried out on single crystals and the crystallographic orientations of the samples were not identical, the differences in the value of $\Delta R/R$ could have been due to the anisotropy of the properties. However, as pointed out above, the anisotropy in the region of hydrogen temperatures is small.

One could also assume that the difference in the behavior of the resistance at temperatures of 4.2 and 20.4°K in the case of pure samples was related to the sample dimensions being comparable with the mean free path. However, using Aleksandrov's estimates[5] it was found that the mean free path even for our purest sample was about 0.03 cm, while the average transverse dimension of the samples was 2 mm.

At the temperature T = 4.2°K a strong anisotropy of the resistance in a magnetic field was found for all the "pure" samples ($R_{273}/R_{4.2} \geq 10{,}000$), and the dependence of the resistance on the magnetic field was somewhat unusual. A detailed communication on this point will be published separately.

In the case of aluminum not only the behavior of this resistance in a magnetic field but also the temperature dependence of this resistance is anomalous. A strong deviation from Mathiessen's rule is found in aluminum. This may be illustrated by the following figures. Had Mathiessen's rule been observed, the difference between the values of the relative change of the resistance on cooling from 20 to 4.2°K, $\Delta = (R_{20} - R_{4.2})/R_{273}$, should have remained constant. This is obeyed well by such metals as In, Sn, Cd, Zn and others. Thus, for example, for In, which is similar in its galvanomagnetic properties to aluminum, when the purity is altered by one order of magnitude the value of Δ alters by several per cent:

$\Delta = 1.83 \cdot 10^{-2}$ when $R_{273}/R_{4.2} = 590$ [6],
$\Delta = 2 \cdot 10^{-2}$ when $R_{273}/R_{4.2} = 12300$ (our measurements).

For aluminum Δ changes by a factor greater than 2. Thus, for example,

$\Delta = 6.4 \cdot 10^{-4}$ when $R_{273}/R_{4.2} = 625$ [3],
$\Delta = 2.6 \cdot 10^{-4}$ when $R_{273}/R_{4.2} = 22200$ (Al-1).

The reason for these anomalies in the behavior of aluminum is not clear. Attention should be drawn to the fact that the Debye temperature of aluminum is considerably higher than that of other metals. Therefore it is possible that such anomalies will be discovered in other metals at lower temperatures.

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