MAGNETIC CHANGE OF THE RESISTANCE OF FERROMAGNETS

I. K. KIKOIN and T. N. IGOSHEVA

Submitted to JETP editor March 9, 1964

J. Exptl. Theoret. Phys. (U.S.S.R.) 46, 1923-1925 (May, 1964)

It has been shown[1] that the ferromagnetic ("anomalous") Hall coefficient is related simply to the magnetic resistance ρ_M. The value of the magnetic resistance itself is given in terms of the spontaneous magnetization by the equation

$$\rho_M = a\,(J_{s0}^2 - J_s^2), \qquad (1)$$

where J_{s0} and J_s are the values of the spontaneous magnetization at 0°K and at a given temperature, respectively; the coefficient a is practically independent of temperature and is constant for a given material. This means that the observed temperature dependence of the Hall coefficient is determined by the temperature dependence of the spontaneous magnetization J_s.

We shall attempt to find a similar relationship for the other galvanomagnetic effect in ferromagnets: the change of resistance in an external magnetic field (magnetoresistance). We shall restrict ourselves to the range of fields and temperatures in which intrinsic magnetization occurs.

It is natural to assume that the change of resistance $\Delta\rho$ of a ferromagnet in a magnetic field should be equal to the change of its magnetic resistance $\Delta\rho_M$ in this field, i.e.,

$$\Delta\rho = \Delta\rho_M = \rho_{MH} - \rho_M, \qquad (2)$$

where ρ_{MH} is the value of the magnetic resistance of a sample in a magnetic field. We can also assume that the magnetic resistance ρ_{MH}, like the Hall effect, is governed by the total magnetization J. This means that to calculate ρ_{MH} it is necessary to replace in Eq. (1) the spontaneous magnetization J_s by the total magnetization J:

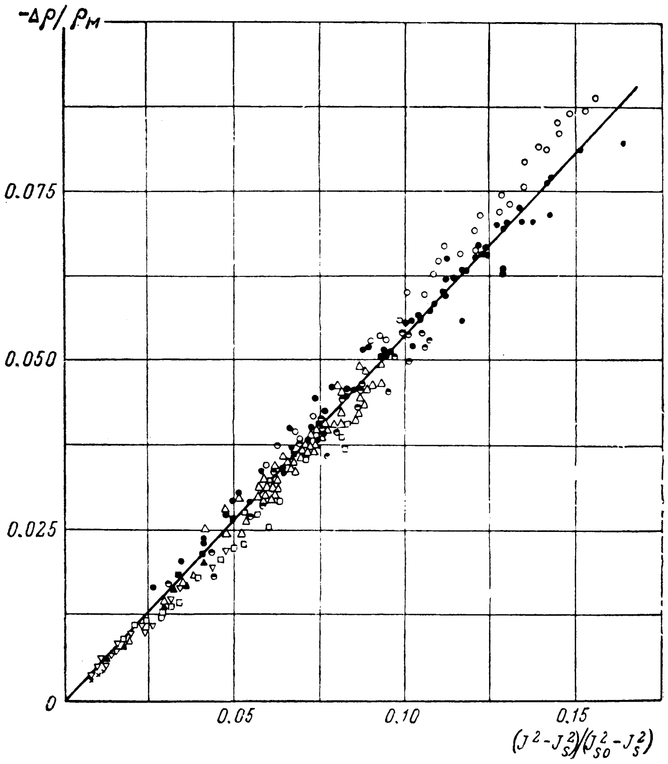
$$\rho_{MH} = a\,(J_{s0}^2 - J^2). \qquad (3)$$

From Eqs. (1)—(3), we obtain the required relationship in the form

$$-\Delta\rho / \rho_M = (J^2 - J_s^2) / (J_{s0}^2 - J_s^2). \qquad (4)$$

Within the limitations of the assumptions made here, the above expression is universal, i.e., it should not depend on the substance.

To check the relationship (4), we analyzed the data on the change of the resistance, $\Delta\rho$, of several ferromagnets in a magnetic field. The values of the change of the resistance and magnetization for nickel—copper, manganese—antimony, and chromium—tellurium alloys were obtained in our laboratory,[2,3] and those for nickel and iron were taken from the published data.[4-6] The magnetic resistance ρ_M was determined by a method used in earlier work.[1]



Dependence of $\Delta\rho/\rho_M$ on $(J^2 - J_s^2)/(J_{s0}^2 - J_s^2)$ for ferromagnetic nickel–copper alloys containing the following atomic percentages of copper: □ – 23.4; △ – 28; ◒ – 31.6; ● – 36.8; ○ – 42.4. ▲ – MnSb; ■ – CrTe; × – Fe.

The figure shows the dependence of $\Delta\rho/\rho_M$ on $(J^2 - J_s^2)/(J_{s0}^2 - J_s^2)$ for the ferromagnets just listed; this dependence was plotted from the experimental data. It was found that the function of interest to us was indeed "universal" for the samples considered. In judging the validity of this conclusion, one must bear in mind that the values given in the figure lie within a range whose upper and lower limits differ by a factor of 30.

Somewhat unexpected is the value of the slope of the straight line in the figure, which instead of unity is about one half, i.e.,

$$-\Delta\rho / \rho_M = A\,(J^2 - J_s^2) / (J_{s0}^2 - J_s^2), \qquad (5)$$

where A = 0.5 ± 0.1. Above the Curie point, $J_s = 0$ and Eq. (5) becomes

$$-\Delta\rho / \rho_M = J^2 / 2J_{s0}^2,$$

which is completely identical with the expression for $\Delta\rho/\rho_M$ obtained in [1] for the paramagnetic region.

It is not yet clear what determines the value of the coefficient A in Eq. (5). It is possible that the assumptions made were too rough; in particular, this applies to the assumption that it is not important whether the magnetic resistance varies due to changes of the spontaneous magnetization under the action of temperature or due to changes in the external magnetic field. Unfortunately, sufficiently accurate determination of the coefficient A meets with great experimental difficulties because a small relative error in determining J_s and J far from the Curie point leads to a large error in the coefficient A in Eq. (5).

---

[1] I. K. Kikoin and T. N. Igosheva, JETP **46**, 67 (1964), Soviet Phys. JETP **19**, 48 (1964).

[2] Kikoin, Babushkina, and Igosheva, FMM **10**, 488 (1960).

[3] Kikoin, Babushkina, and Igosheva, JETP **39**, 1172 (1960), Soviet Phys. JETP **12**, 816 (1961).

[4] K. P. Belov, Uprugie, teplovye i elektricheskie yavleniya v ferromagnetikakh (Elastic, Thermal, and Electrical Effects in Ferromagnets), Gostekhizdat, 1957, 2nd edition.

[5] P. Weiss and R. Forrer, Ann. phys. **15**, 153 (1926).

[6] H. H. Potter, Phil. Mag. 13, 233 (1932); Proc. Roy. Soc. (London) **A146**, 362 (1934).

Translated by A. Tybulewicz
286

THERMAL CONDUCTIVITY OF SOLID He^4

L. P. MEZHOV-DEGLIN

Institute for Physics Problems, Academy of Sciences, U.S.S.R.; Institute for Solid-State Physics, Academy of Sciences, U.S.S.R.,

Submitted to JETP editor March 14, 1964

J. Exptl. Theoret. Phys. (U.S.S.R.) **46**, 1926-1927 (May, 1964)

SOLID helium is the most convenient substance for investigating heat transfer processes in a dielectric crystal. Chemical impurities are absent and the high compressibility makes it possible to vary the Debye temperature by a factor of nearly 2 using relatively low pressures (up to 250 atm), thereby enabling one to check the applicability of various theoretical heat transfer models keeping the lattice symmetry fixed. The first measurements of the thermal conductivity of helium were carried out by Webb et al. [1,2] but their method did not allow control over the growth of the crystals. The defective structure of the crystals obtained by this method was confirmed, for example, by the 20-fold increase of the thermal conductivity after annealing, as observed by Fairbank et al.[3-5] Shal'nikov [6] developed a method which made it possible to observe directly the process of helium solidification. Using this method, the present author grew helium crystals in a glass ampoule at practically constant pressure. Some results of the measurements of the properties of samples prepared in this way are given below. A more detailed presentation of the results and a description of the technique will be given in a separate communication.

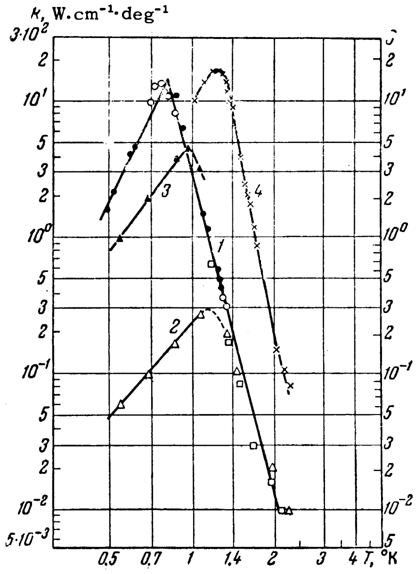


FIG. 1

Figure 1 gives values of the thermal conductivity of solid He^4 as a function of temperature. Curve 1 represents a crystal grown in 1.5 hours at a pressure of 82 atm ($\Theta_D = 33.7°K$ [7]). A series of black and open circles represents two different sets of measurements on samples ~2.5 mm in diameter; squares represent measurements on a sample 6 mm in diameter. Curves 2 and 3 illustrate the measurements of Webb and Fairbank for crystals of the same density before and after annealing. For comparison, curve 4 gives the results of the present author's measurements for a crystal grown at 185 atm ($\Theta_D = 43.5°K$ [7]).