TEMPERATURE DEPENDENCE OF THE HALL EFFECT IN MnAu₂

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It is shown that the ordinary Hall effect in MnAu₂ is supplemented by an additional effect in the antiferromagnetic temperature range. It is suggested that this additional effect is caused by the presence of a high magnetic susceptibility.

MANY substances are known to exhibit more than one form of spin ordering. The magnetic properties of these substances have been investigated thoroughly, but their electrical properties have been studied fully only in the case of ferromagnets. It therefore appeared interesting to investigate the galvomagnetic properties of antiferromagnets in order to determine those parts of the observed effects that are directly associated with antiferromagnetism.

We have investigated the Hall effect in the intermetallic compound MnAu₂, which is antiferromagnetic but becomes ferromagnetic in magnetic fields above a certain threshold ($H > H_{th}$).[1,2] Our specimen exhibited the Néel temperature T_N = 92° C and H_{th} = 8000 oersteds. In earlier work[3] we showed that the Hall emf for MnAu₂ in the region $0 < H < H_{th}$ depends linearly on the magnetic field strength H. In the present work we investigated the temperature dependence of the Hall emf in the same specimen, using magnetic fields in which MnAu₂ remains antiferromagnetic. An abrasive disk was used to saw the specimen from an ingot, thus excluding large residual deformations. The emf and magnetic susceptibility were measured as in reference 3.

The figure shows the temperature dependence of the Hall emf for an internal magnetic field H = 5000 oe. Curve 1 exhibits a peak located near the Néel temperature T_N, which was determined from the temperature dependence of the magnetic susceptibility. In this respect MnAu₂ can be contrasted with manganese telluride, where the Hall emf falls off rapidly around the Néel temperature.[4]

Let us consider the portion of the curve that lies in the paramagnetic region. It has been shown by Kikoin and others[5-7] that in strongly paramagnetic substances and in ferromagnetics above the Curie point the Hall emf can be represented by

$$E_x = [R_0 H + R_1 \chi H] I/d = R_0 [1 + 4\pi\alpha\chi] HI/d, \tag{1}$$
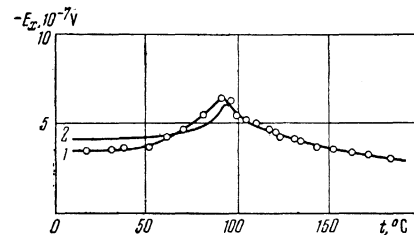
Temperature dependence of the Hall emf for MnAu₂ with an internal magnetic field H = 5000 oe. 1 – experimental curve; 2 – curve calculated from Eq. (1).

where H is the magnetic field, I is the current flowing through the specimen, d is the thickness of the specimen, R_0 is the magnetic susceptibility, R is the Hall constant for the ordinary effect, and R_1 is the Hall constant for the part of the effect that is associated with magnetization. Since it was shown in the same investigation that R_1 is independent of temperature, we have assumed that (1) is also valid in antiferromagnetics above the Néel temperature. The figure shows that the experimental curve 1 can be closely approximated by (1) when the following numerical constants are used:

$$R_0 = -2.19 \times 10^{-12} \text{ v-cm/amp-oe}$$
$$R_1 = -2.42 \times 10^{-10} \text{ v-cm/amp-gauss}$$
$$\alpha = 8.8. \tag{2}$$

These values were determined by the method of least squares from the experimental results in the paramagnetic temperature region. It should be noted that α = 8.8 is small compared with the value for ferromagnetics; e.g. for very pure nickel near the Curie point we have $\alpha \sim 10^2$.

It therefore follows from the high magnetic susceptibility of MnAu₂ ($\chi \approx 5 \times 10^{-3}$ cm⁻³) that a considerable fraction of the Hall effect depends on magnetization. Since it can hardly be supposed that at temperatures below T_N the parameter α is immediately reduced to the order of unity, a

Hall effect resulting from a paramagnetic process must evidently exist in the antiferromagnetic region.

Curve 2, which represents Eq. (1) with the values of R_0 and R_1 given in Eq. (2), is seen to agree well with the experimental curve 1 above the Néel temperature, but to differ considerably below that temperature. The temperature dependence of the Hall emf can therefore not be represented by (1) in the antiferromagnetic region if R_0 and R_1 are assumed to be temperature-independent. Since MnAu$_2$ has the electrical properties of a metal, its conduction-electron concentration is temperature-independent, and this must also apply to R_0. We can therefore assume that either R_1 or α is temperature-dependent below the Néel temperature.

It should be noted that when α is of the order of a few tens the magnetization-induced part of the Hall effect can be appreciable only in substances where the susceptibility exceeds 10^{-4} cm^{-3}. In antiferromagnets with low susceptibility, such as MnTe, the additional magnetization-induced Hall emf can therefore be imperceptible.

However, the anomalous Hall effect in manganese telluride around the Néel temperature is evidence that antiferromagnetism results in an additional Hall emf, which is apparently produced by a different mechanism than in MnAu$_2$.

[1] A. J. Meyer and P. Taglang, J. Phys. Radium 17, 457 (1956).

[2] A. Herpin and P. Meriel, Compt. rend. 250, 1450 (1960).

[3] I. G. Fakidov and V. N. Novogrudskiĭ, Физика металлов и металловедение (Physics of Metals and Metallography) 10, 158 (1960).

[4] Uchida, Kondoh, and Fukuoka, J. Phys. Soc. Japan 11, 27 (1956).

[5] I. K. Kikoin, J. Phys. (U.S.S.R.) 9, 1 (1936).

[6] Kevane, Legvold, and Spedding, Phys. Rev. 91, 1372 (1953).

[7] Kikoin, Buryak, and Muromkin, Doklady Akad. Nauk SSSR 125, 1011 (1959), Soviet Phys.-Doklady 4, 386 (1959).

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