# *EVEN GALVANOMAGNETIC EFFECT IN ANTIFERROMAGNETIC* $MnAu_2$ *IN THE PARAMAGNETIC TEMPERATURE REGION*

V. G. LOGINOV and V. I. NIKOLAEV

Submitted August 8, 1969

Zh. Eksp. Teor. Fiz. 58, 747–750 (February, 1970)

Results of investigation of the even galvanomagnetic effect in the antiferromagnetic compound $MnAu_2$ at paramagnetic temperatures are reported. It is shown that when $T > T_N$ the magnetoresistance of $MnAu_2$ depends on the magnetic moment in the same way as in ferromagnetic substances. The results show that in the paramagnetic temperature region the even galvanomagnetic regularities previously established for ferromagnetic substances are also applicable to antiferromagnetic compounds.

A method was suggested recently for determining the laws governing galvanomagnetic effects in ferromagnets. It was found, in particular[1], that in a large number of ferromagnetic compounds and alloys, the magnetic change of the electric resistance (the even galvanomagnetic effect) in the region of the paraprocess is well described by the equation

$$-\frac{\Delta\rho}{\rho_M} = A\frac{J^2 - J_s^2}{J_{s0}^2 - J_s^2}. \qquad (1)$$

Here $\Delta\rho$ is the change of the resistance of the sample, $\rho_M$ is the magnetic part of the resistance in the absence of a field, J is the magnetization of the sample in a magnetic field, $J_{s0}$ and $J_C$ are respectively the magnetization at absolute zero and at the given temperature T. The coefficient A turns out in this case to be equal to approximately 0.5, regardless of the field and of the temperature.

It is important to carry out similar investigations of galvanomagnetic effects in substances having a different character of magnetic ordering, for example in antiferromagnets. Such an investigation would make it possible to determine the limits of applicability of the laws obtained in experiments with ferromagnets, a particularly important factor for the understanding of the causes of the indicated phenomena.

Common to all the substances with ordered magnetic structure is the fact that they contain localized magnetic moments. We can therefore expect in the paramagnetic temperature region, where the features of the character of the magnetic ordering practically disappear, the main laws governing the galvanomagnetic phenomena to be the same in these substances.

In this connection, we undertook an investigation of the even galvanomagnetic effect in the antiferromagnetic compound $MnAu_2$[2] in the paramagnetic region of temperatures. The choice of this intermetallic compound as the object of investigation was dictated by the following considerations: 1) one of the galvanomagnetic effects in $MnAu_2$, an odd one (the Hall effect), is described by the same equation as in ordinary ferromagnets[3]; 2) the character of the temperature dependence of the resistance in $MnAu_2$ in the absence of an external field is the same as for ferromagnets[4]; 3) the magnetic properties of $MnAu_2$ (which is an helicoidal antiferromagnet[5]) have been thoroughly investigated.

The Neel point for $MnAu_2$, according to[2], is 363°K (according to[3], $T_N$ = 373°K).

## EXPERIMENTAL PROCEDURE

The investigations of the galvanomagnetic effect were carried out with a sample of rectangular shape, measuring 10 × 0.6 × 0.2 mm (temperature x-ray investigations were performed earlier on the same sample[6]). Two pairs of contacts were arc-welded to the ends of the sample. During the course of the experiments, the sample was in an atmosphere of helium. The measurements were performed with direct current by a null method. In the experiments we used an electromagnet that produced fields up to 15 kOe.

In the investigation of the even galvanomagnetic effect as a function of the field intensity and of the temperature, it is necessary to know the value of the magnetic part $\rho_M$ of the total resistance of the sample $\rho$[1]. To determine $\rho_M$, one usually employs the Matthiessen rule, according to which the resistance $\rho$, besides $\rho_M$, contains additively terms due to other carrier scattering mechanisms, namely the resistance $\rho_d$ due to the presence of crystal-lattice defects, and a phonon part $\rho_{ph}$:

$$\rho = \rho_d + \rho_{ph} + \rho_M$$

To determine the magnetic part of the resistance $\rho_M$, we measured the resistance of the $MnAu_2$ sample at temperatures from 12 to 720°K. $\rho_d$ was taken to be the residual resistance of the sample at low temperatures. The phonon part of the resistance was determined with the aid of the temperature coefficient of resistivity in the paramagnetic region of temperatures, where $\rho(T)$ was a linear function (starting with approximately 520°K). The temperature coefficient $\rho^{-1}\partial\rho/\partial T$ turned out to be $3.02 \times 10^{-6}$ deg$^{-1}$. It was assumed that at $T > T_N$ the increase of $\rho$ with increasing T is due to a change of only $\rho_{ph}$.

One of the main difficulties of investigating the even galvanomagnetic effect in the paramagnetic temperature region (and in paramagnets) is the small magnitude of the measured effect. In our case, at temperatures close to 700°K, the relative change of the resistance upon application of a field of 15 kOe was only several thousandths of a per cent (Fig. 1a). Therefore

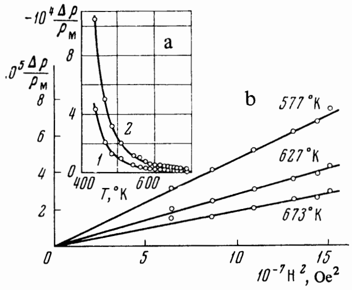

FIG. 1. Magnetic variation of the resistance of the compound $MnAu_2$ in the paramagnetic region of temperatures: a – dependence of $\Delta\rho/\rho_M$ on T at H = const (curve 1 – H = 8.0 kOe, 2 – H = 12.3 kOe); b – dependence of $\Delta\rho/\rho_M$ on $H^2$ at T = const.

the measurements of the effect were repeated (up to 15 times) at each chosen value of the field.

## RESULTS AND DISCUSSION

For the paramagnetic temperature region, relation (1), with allowance for the Curie-Weiss law $\chi = C/(T - \theta_p)$, is transformed into

$$-\Delta\rho / \rho_M = BH^2, \qquad (2)$$

where

$$B = \frac{A}{J_{s0}^2} \frac{C^2}{(T-\Theta_p)^2} \qquad (3)$$

(C is the Curie-Weiss constant, $\theta_p$ is the paramagnetic Curie point).

Our problem thus reduces to a determination of the degree to which relations (2) and (3) are valid in the case of antiferromagnets (in our case $MnAu_2$).

Figure 1b shows the dependence of $\Delta\rho/\rho_M$ on the square of the intensity of the applied field for several temperatures. It is seen from the figure that this dependence turns out to be linear and is well described by Eq. (2). In other words, the coefficient B in this equation is indeed independent of the field at a given temperature.

To clarify the character of the temperature dependence of B, we reduced the data by least squares. The results of the reduction are shown in Fig. 2.

As seen from the figure, starting with approximately 550°K, the quantity $B^{-1/2}$ depends linearly on the temperature. According to the data of[2], the Curie-Weiss law is satisfied for the compound $MnAu_2$, starting with temperatures of approximately 600°K. Thus, the relation (3) also turns out to be perfectly applicable to the compound $MnAu_2$.

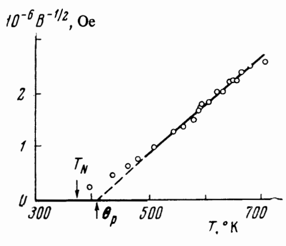

FIG. 2. Temperature dependence of the coefficient $B^{-1/2}$ for $MnAu_2$ at $T > T_N$.

From the results of the measurement of the galvanomagnetic effect it is therefore possible to obtain the paramagnetic Curie point. Extrapolation of the linear section of the curve on Fig. 2 to the temperature axis yields $\Theta_p = 406°K$. This value is in satisfactory agreement with measurements of the paramagnetic susceptibility[2], which yield $\Theta_p = 451°K$.

Finally, it is also of interest to determine the numerical value of the coefficient A for $MnAu_2$. To calculate it from data on the galvanomagnetic effect it is necessary to know the spontaneous moment at 0°K. The $MnAu_2$ sample investigated by us is quite close in its properties to that investigated in[2]. We can therefore expect that if the other data on its magnetic properties are in relatively good agreement, the values of $J_{s0}$ will also differ little. From the temperature measurements of the magnetic moment in fields above the threshold (when the $MnAu_2$ sample goes over from the antiferromagnetic state into the ferromagnetic one), $J_{s0} = 43.35$ G-cm³/g[2]. If we use this value of $J_{s0}$, the coefficient A turns out to be 0.51, in good agreement with the value 0.5 obtained in[1].

The obtained results allow us to assume that in the paramagnetic temperature region the laws governing the even galvanomagnetic effect are apparently common to ferromagnets and antiferromagnets. For a final solution of this problem, systematic investigations of galvanomagnetic phenomena in antiferromagnets are necessary.

In conclusion, we are grateful to I. K. Kikoin and T. N. Igesheva for valuable discussions.

[1] I. K. Kikoin and T. N. Igosheva, Zh. Eksp. Teor. Fiz. 46, 67 and 1923 (1964) [Sov. Phys.-JETP 19, 38 and 1296 (1964)].

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

[3] A. I. Karchevskiĭ and V. I. Nikolaev, FMM 12, 519 and 372 (1961).

[4] J. H. Smith and R. Street, Proc. Phys. Soc. 70, 1089 (1957).

[5] A. Herpin, P. Meriel, and J. Villain, Compt. rend. 249, 1334 (1959); 250, 1450 (1960).

[6] V. A. Gordienko and V. I. Nikolaev, Fiz. Tverd. Tela 9, 2820 (1967) [Sov. Phys.-Solid State 9, 2216 (1968)].

Translated by J. G. Adashko
90