THE ODD COMPONENT OF THE GALVANOMAGNETIC EFFECT IN THE FERRIMAGNETIC COMPOUND Mn_5Ge_2

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The magnetoresistance $\Delta R/R$ of the intermetallic compound Mn_5Ge_2 was investigated in longitudinal and transverse magnetic fields. It was found that the preliminary application of a magnetic field to a sample led to the appearance of an odd component of the magnetoresistance $\Delta R/R_\perp$ and $\Delta R/R_\parallel$, which depends linearly on the field. It is suggested that the observed odd galvanomagnetic effect in Mn_5Ge_2 is an odd function of the antiferromagnetic vector.

INTRODUCTION

INVESTIGATION of the electrical properties of uncompensated antiferromagnetics with a compensation point is of special interest for the understanding of the mechanism of electrical conduction in substances with spin ordering. In fact when the temperature is raised the long-range magnetic order and the related spontaneous magnetization are destroyed simultaneously on passing through the Curie point Θ_C. However, at the compensation point Θ_{cm} the spontaneous magnetization is zero but the long-range magnetic order is retained. Thus it is possible to separate the influence of the magnetic order and of the magnetization on the electrical conduction in substances exhibiting magnetic ordering.

Another important property of substances with a compensation point is the fact that at temperatures below and above the compensation point, because the spontaneous magnetization is $M_S \neq 0$, the antiferromagnetic vector $L = M_1 - M_2$ (where M_1 and M_2 are the magnetizations of the sublattices), may be oriented by a magnetic field in any way, since it is parallel (or antiparallel) to the resultant magnetization $M = M_1 + M_2$. Having thus fixed the antiferromagnetic axis far from the Θ_{cm} point we can then retain its direction at the compensation point itself.

Starting from these considerations, we undertook a study of the electrical and magnetic properties of the intermetallic compound Mn_5Ge_2, which is a ferrimagnetic with a compensation point at $\Theta_{cm} = 122°C$.

Earlier we showed[1] that the even transverse galvanomagnetic effect in Mn_5Ge_2 changes its sign on transition through the compensation point. During an investigation of the magnetic properties of Mn_5Ge_2[2] we discovered a shift of the hysteresis loops with respect to the coordinates if a magnetic field was applied to the sample before measurements.

The present work was undertaken in order to investigate the influence of a preliminary application of a magnetic field to a sample on the galvanomagnetic properties of the ferrimagnetic compound Mn_5Ge_2.

MEASUREMENT METHOD

A polycrystalline sample, employed in earlier work,[1,2] was used in the present measurements.

The sample resistance was measured with a low-resistance potentiometer, using a galvanometer with a sensitivity of 2×10^{-8} V per division.

The temperature was kept constant with a cryostat[3] in which ice was used as the cooling agent instead of liquid nitrogen; this made it possible to obtain stable temperatures between 0 and 200°C. The temperature was measured with a copper-constantan thermocouple. The maximum magnetic field intensity was 16,000 Oe.

Before measurements of the magnetoresistance $\Delta R/R$ at each temperature the sample was magnetized with maximum field along the direction which was later used for measurements. A special check showed that the sample temperature was not affected by the magnetic field.

A study was also made of the influence of the location of the potential electrodes with respect to the current electrodes on the magnitude of the measured effect. For this purpose the electrodes were soldered in two different ways: 1) the potential and current electrodes were soldered to the sample ends; 2) the potential electrodes were soldered to one of the sides at a distance of two sample widths from the current electrodes.

The difference in the value of the measured effect due to the different electrode locations was within the limits of the experimental error. Similarly, the values of $\Delta R/R$ obtained for different directions of the current in the sample did not differ from one another.

EXPERIMENTAL RESULTS

The magnetoresistance was investigated in longitudinal and transverse magnetic fields.

The order of measurements was as follows: first the sample was demagnetized by heating above the Curie point, then it was magnetized at room temperature by a field of definite direction which we shall denote by $\mathbf{H}_0$. Measurements of $\Delta R/R$ were carried out in fields both parallel and antiparallel to $\mathbf{H}_0$. After these measurements the sample was again magnetized with a field parallel to $\mathbf{H}_0$ and only then was it heated to the next temperature, at which measurements were carried out as before.

Thus before being heated to each successive temperature the sample was magnetized with a field parallel to $\mathbf{H}_0$.

This treatment of the sample is equivalent to the application of the magnetic field at room temperature followed by heating to the temperature at which $\Delta R/R$ was measured. Indeed, measurements of $\Delta R/R$ carried out after application of

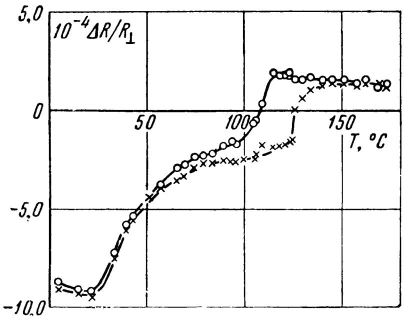

FIG. 1. Temperature dependence of the transverse galvanomagnetic effect in Mn_5Ge_2; the crosses denote measurements in a magnetic field H = 16 000 Oe parallel to the treatment field, and the circles represent measurements in a magnetic field antiparallel to the treatment field.

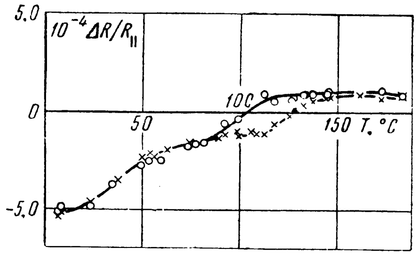

FIG. 2. Temperature dependence of the longitudinal galvanomagnetic effect in Mn_5Ge_2. The notation is the same as in Fig. 1.

the magnetic field in these two ways were identical.

Figures 1 and 2 give the temperature dependences of $\Delta R/R_{\perp}$ and $\Delta R/R_{\parallel}$ in a magnetic field of 16,000 Oe. These figures indicate that the preliminary application of the magnetic field to the sample affected the value of the magnetoresistance and this effect appeared most strongly near the Θ_{cm} point.

This influence manifested itself by the fact that the value of $\Delta R/R$ obtained by measurement in a field H parallel to the magnetic field in the preliminary treatment was different from the value measured with an antiparallel field. Hence, we may conclude that the preliminary treatment with a magnetic field at temperatures far from the compensation point gives rise to the odd component in the magnetoresistance of Mn_5Ge_2.

Thus if the total magnetoresistance is denoted by ΔR, we have $\Delta R = \Delta R_{even} + \Delta R_{odd}$, where ΔR_{even} is the even component and ΔR_{odd} is the odd component with respect to the measuring field.

It was shown experimentally that, firstly, the sign of the quantity ΔR_{odd} depends on the mutual orientation of the magnetic fields used for measurement (H) and preliminary treatment ($\mathbf{H}_0$), and, secondly, for the same orientation of the measuring field with respect to the preliminary-treatment field the sign of ΔR_{odd} depends on the temperature T_0 at which the magnetic-field treatment is carried out: above or below Θ_{cm}. All this can be generalized in the following way:

	$T_0 < \Theta_{cm}$	$T_0 > \Theta_{cm}$
1) $\mathbf{H} \uparrow\uparrow \mathbf{H}_0$,	$\Delta R_{odd} < 0$	$\Delta R_{odd} > 0$
2) $\mathbf{H} \perp \mathbf{H}_0$,	$\Delta R_{odd} = 0$	$\Delta R_{odd} = 0$
3) $\mathbf{H} \uparrow\downarrow \mathbf{H}_0$,	$\Delta R_{odd} > 0$	$\Delta R_{odd} < 0$

Measurements were carried out near the compensation point, where ΔR_{even} is small, in order to determine the dependence of the quantity ΔR_{odd} on the magnetic field. Figure 3 shows that this dependence is linear.

If a sample demagnetized by heating above the point Θ_C is then treated with a magnetic field near the point Θ_{cm}, the odd component does not appear in the variation of $\Delta R/R$.

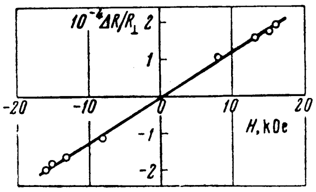

FIG. 3. Dependence of the magnetoresistance on the magnetic field intensity near the compensation point of the compound Mn_5Ge_2.

At present it is not possible to explain in detail the mechanism of the appearance of the ΔR_{odd} component on the basis of the available experimental data. However, it may be assumed that ΔR_{odd} is related to the antiferromagnetic vector **L**. It follows from the above table that this dependence is odd.

The present experimental results are in qualitative agreement with the theoretical conclusions of Shavrov and Turov,[4,5] who showed phenomenologically the possibility of the appearance of a series of new galvanomagnetic effects in magnetic crystals with two magnetic sublattices. Shavrov and Turov showed in particular that a certain component of the quantities $\Delta R/R_\perp$ and $\Delta R/R_\parallel$ is proportional to the product of the components of **L** and **H**.

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