MAGNETIC PROPERTIES OF THE COMPOUND Mn_3Ge_2 *IN STRONG MAGNETIC FIELDS*

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The magnetization of the compound Mn_3Ge_2 was measured in magnetic fields of up to 300 kOe intensity at temperatures from 370 to 77° K. The measurements were carried out on polycrystalline samples using a pulsed magnetic balance with a piezoelectric pick-up. The magnetization curves exhibited, at 160° K, a transition from the antiferromagnetic state to the weakly ferromagnetic state. The temperature of the transition decreased when the field intensity was increased. In the weakly ferromagnetic state, the dependence $\sigma(H)$ was linear up to 50 kOe and then an approach to saturation was observed. From the approach to saturation, it was found that, at $T > 100°$ K, the magnetic moment per atom of manganese was $1.5\,\mu_B$, while at lower temperatures a strong magnetic field caused a transition from the antiferromagnetic state to a state with a magnetic moment of $2.3\,\mu_B$ per atom of manganese. A change in the magnetic structure of Mn_3Ge_2 in a strong magnetic field at $T \approx 100°$ K was confirmed also by the temperature dependences of the magnetization and is accompanied by a change in the transition entropy by a factor of 2.4.

FAKIDOV, Grazhdankina, and Novogrudskiĭ investigated the temperature dependence of the electrical resistivity of the alloy Mn_3Ge_2[1] and discovered two magnetic transition temperatures: T_{c1} and T_{c2}. Later magnetic investigations of Mn_3Ge_2, carried out in fields of up to 2500 Oe intensity,[2,3] indicated that at $T = T_{c1}$ there is a transition of the first kind from the antiferromagnetic state to the weakly ferromagnetic state. This has been confirmed by the measurements of the magnetization in fields up to 20 kOe,[4] and by the measurements of the anisotropy of the magnetic properties of textured samples.[5] Levina[6] has shown directly that the transition in Mn_3Ge_2 observed at T_{c1} is a transition of the first kind. Investigations of the magnetization of Mn_3Ge_2 in fields of intensities greater than 20 kOe have not yet been carried out, but the shift of the transition point in fields of up to 110 kOe intensity has been investigated.[7] The purpose of the measurements reported here was to study the magnetization of Mn_3Ge_2 in fields up to 300 kOe in order to determine the magnetic moment directly from the measurements of the magnetization in the weakly ferromagnetic state.

The measurements were carried out using a pulse magnetic balance with a piezoelectric pick-up[8] on polycrystalline samples with $T_{c1} = 160$°K in the absence of a field and with the Curie point $T_{c2} = 300$°K. The results of the measurements of the magnetization of the samples under investigation in fields of up to 300 kOe intensity are given in Fig. 1. At $T < T_{c1}$ (curves 1–8), a transition from the antiferromagnetic state to the weakly ferromagnetic state is observed in the presence of a magnetic field. In strong magnetic fields, there is a tendency to saturation. At $T > 160$°K (curve 9), there is a spontaneous magnetic moment which is characteristic of the weak ferromagnetism. The linear part of the dependence $\sigma(H)$, observed in fields up to 50 kOe, is gradually replaced by an approach to saturation. At $T > T_{c2}$, an increase in the temperature makes the dependence $\sigma(H)$ approach linearity, which should be obtained in any magnetic material in the paramagnetic region.

It is evident from the $\sigma(H)$ curves that over a wide range of temperatures (curves 3–8), the magnetic moment depends weakly on temperature. However, at $T \leq 100°$ K in strong magnetic fields, a transition is observed to a state with a larger magnetic moment than that at $T > 100°$ K (curves 1 and 2). In the same temperature range, no anomalies are observed in weak fields, i.e., in the antiferromagnetic state. The transition to a new state in strong magnetic fields is illustrated more clearly by the $\sigma(T)$ curves given in Fig. 2. In weak magnetic fields (curves 1 and 2), there is a transition from the antiferromagnetic state to the weakly ferromagnetic state, accompanied by an increase in magnetization, at a temperature T_{c1},

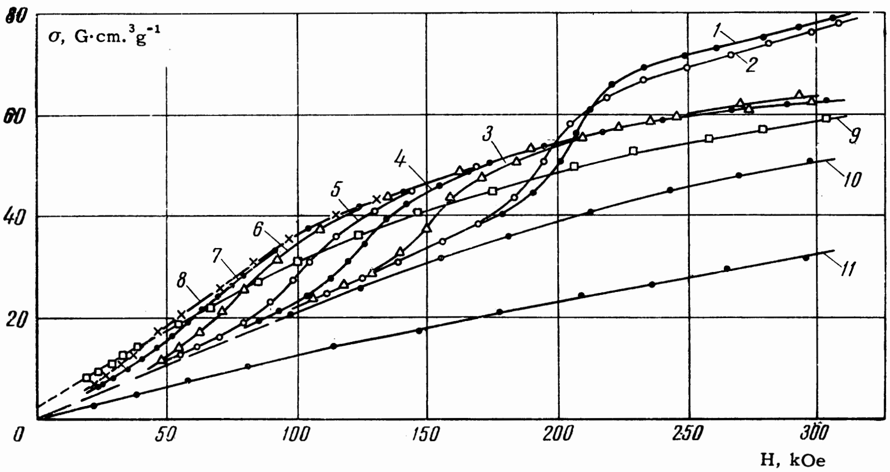

FIG. 1. Magnetization curves of Mn_3Ge_2 at various temperatures (in °K): 1) 77; 2) 82; 3) 108; 4) 118; 5) 128; 6) 137; 7) 143; 8) 152; 9) 188; 10) 290; 11) 370.

which is a function of the magnetic field intensity. In a field H = 300 kOe, there is a sharp increase in the magnetization at 100° K, indicating a change in the magnetic structure of Mn_3Ge_2.

Since a close approach to saturation was observed in strong fields, we made an attempt to estimate the saturation magnetization. Analysis of the magnetization curves showed that when the field intensity was increased, the dependences $\sigma(1/H)$ became linear. The extrapolation of the linear parts of these dependences to an infinite value of the field gave $\sigma_{\infty 1}$ = 75–80 G.cm^3/g in the temperature range 180–137°K and $\sigma_{\infty 2}$ = 123 G.cm^3/g at 77 and 82°K, which corresponded to the magnetic moments of 1.5 μ_B and 2.3 μ_B per atom of manganese.

A change in the magnetic structure in a magnetic field should be accompanied also by a shift in the magnetic transition point T_{c1}. In fact, for phase transitions of the first kind, the transition temperature should be a function of the magnetic field intensity and the dependence $H_c(T)$ should be linear. The change in the entropy in such a transition can be estimated from the slope of this dependence and there should be a kink in the dependence $H_c(T)$.[9] Using the results given in Fig. 1, we plotted the dependence $H_c(T)$ (Fig. 3). Since the transition took place in a certain range of fields, we plotted, from the $\sigma(H)$ curve, the dependence $d\sigma(H)/dH$ and from the maximum of this dependence we found the values of H_c for all the temperatures of the measurements. Figure 3 shows a kink at a temperature close to 100°K, confirming a change in the magnetic structure of Mn_3Ge_2 in strong magnetic fields at this temperature. The kink in the dependence $H_c(T)$ corresponds to a change in the transition entropy by a factor of 2.4.

Thus, the measurements of the magnetization as a function of the field intensity and temperature, as well as the change in the transition entropy, indicate that in strong magnetic fields at $T \approx 100$°K a new, and until now unobserved, change in the magnetic structure takes place in Mn_3Ge_2. Unfor-

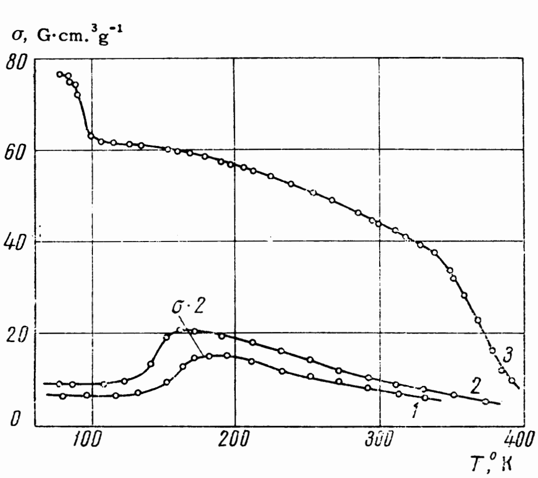

FIG. 2. Temperature dependence of the magnetization of Mn_3Ge_2. Curve 1 was recorded in a static field of 16 kOe, using the Domenicali balance, while curves 2 (H = 23 kOe) and 3 (H = 300 kOe) were recorded using a pulse magnetic balance ($\sigma \times 2$ for curves 1 and 2).

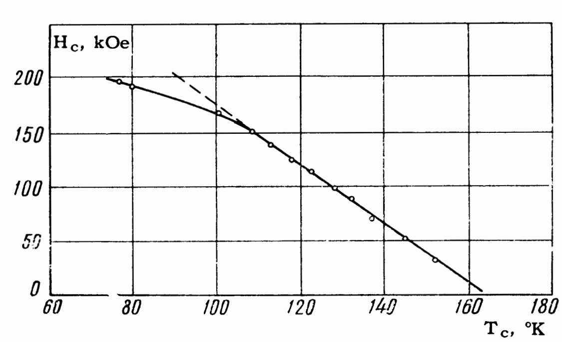

FIG. 3. Temperature dependence of the critical field of Mn_3Ge_2.

tunately, the crystal structure of Mn_3Ge_2 has not yet been investigated and, therefore, it is not possible to draw any definite conclusions about the nature of the change in the magnetic structure.

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