Spontaneous Hall effect in $Hg_{1-x}Mn_xTe$

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The Hall coefficient (R) of $Hg_{1-x}Mn_xTe$ crystals has been found to behave anomalously at temperatures in the range $T = 1.2$–2 K: As the temperature is lowered, the Hall coefficient decreases and changes sign. The value of R depends on the magnetization of the sample. The observed features are attributable to the spontaneous Hall effect.

The spontaneous Hall effect in ferromagnetic metals and semiconductors has been studied extensively (see Ref. 1). This effect has, to the best of our knowledge, not been detected in semimagnetic semiconductors. Phenomenologically, the coefficient of the spontaneous Hall effect R_S is given by

$$\rho_{xy} = R_0 B + R_S I, \tag{1}$$

where ρ_{xy} is the nondiagonal component of the magnetoresistance tensor, R_0 is the coefficient of the ordinary Hall effect, B is the magnetic induction, and I is the magnetization of the sample. We see from (1) that the principal peculiarity of the spontaneous Hall effect is the dependence of the Hall field on the magnetizaton of the sample.

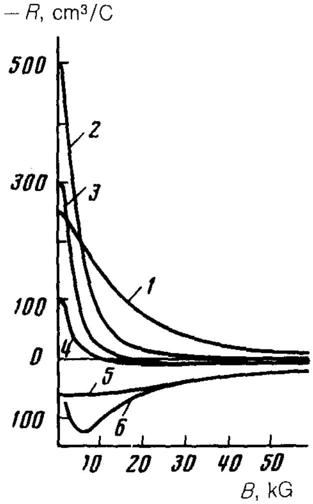

FIG. 1. The $R(B)$ dependences of the Hall coefficient. 1—240 K; 2—160 K; 3—105 K; 4—78 K; 5—4.2 K; 6—1.3 K.

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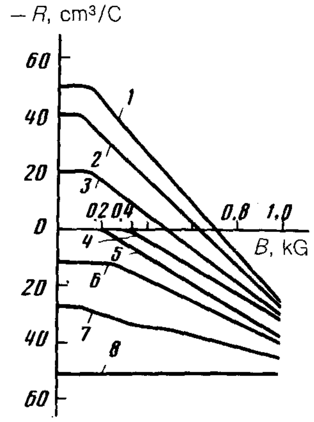

FIG. 2. The $R(B)$ dependences of the Hall coefficient. 1—1.24 K; 2—1.28 K; 3—1.48 K; 4—1.54 K; 5—1.60 K; 6—1.69 K; 7—2.0 K; 8—4.2 K.

We have investigated the Hall effect and the transverse magnetoresistance of $Hg_{0.88}$ $Mn_{0.12}$ Te samples over the temperature interval $1.24 \leqslant T \leqslant 240$ K in magnetic fields up to 60 kG. Figure 1 is a plot of the curves for the Hall coefficient $R(B)$ for a sample with $N_A - N_D \sim 10^{18}$ cm^{-3}. The resistivity of the sample $\rho_0 \approx 0.025$ Ω·cm is nearly independent of T over the temperature interval 1.3–240 K. The negative sign of the Hall coefficient is determined by the conduction-band electrons. At liquid-helium temperature we have $R > 0$, and the $R(B)$ curve is characteristic for semimagnetic semiconductors.[2] Figure 2 is a plot of the $R(B)$ curves for the same sample at $T \leqslant 4.2$ K in magnetic fields $B \leqslant 10^3$ G. It is interesting to note the behavior of the $R(B)$ curve at temperatures $T \leqslant 2$ K. In the case of a $Hg_{0.88}Mn_{0.12}Te$ crystal, a phase transition from the paramagnetic state to the spin-glass state occurs at approximately this temperature.[3] We see from Fig. 2 that $|R|$ decreases with decreasing temperature and suddenly changes its sign. This behavior of the Hall coefficient is quite extraordinary in the case of a doped semiconductor. We assume that a transition to the spin-glass

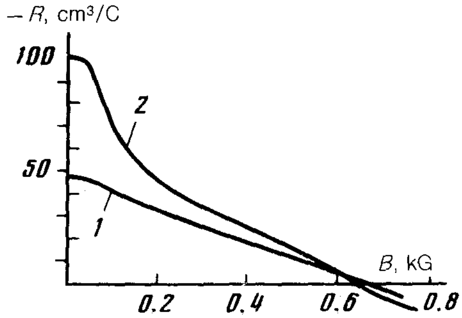

FIG. 3. The $R(B)$ dependences of the Hall coefficient at $T = 1.33$ K, using different methods of cooling the sample. 1—The sample was cooled at $B = 0$; 2—the sample was cooled at $B = 10$ kG.

phase gives rise to a negative component of the Hall field which decreases ρ_{xy} as the temperature is lowered. This component is linked with the second term, $R_S I$, in (1). If this assumption is correct, the effect must depend on the magnetization of the sample.

Figure 3 is a plot of two $R(B)$ curves: upon cooling the sample in the absence of a field (curve 1) and upon cooling the sample in a 10-kG field (curve 2). The magnetization of the sample is different in these two cases[4]: it is larger when the sample is cooled in a magnetic field. As can be seen in Fig. 3, the $R(B)$ curves differ appreciably: The Hall coefficient $R(B \to 0)$ for a sample cooled in a 10-kG field is larger than that of a sample cooled in a zero field by approximately a factor of two.

We have thus established that the nondiagonal component of the magnetoresistance ρ_{xy} with the magnetization of the sample. On this basis we can assert that the particular features of the $R(B)$ curves observed at low temperatures are attributable to the spontaneous Hall effect which occurs in the spin-glass phase.

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