Proc. XIX International School of Semiconducting Compounds, Jaszowiec 1990

MAGNETIC SUSCEPTIBILITY OF $Pb_{1-x-y}Sn_yMn_xSe$*

M. GÓRSKA[a], J.R. ANDERSON[b] AND L. KOWALCZYK[a]

[a])Institute of Physics, Polish Academy of Sciences, Al. Lotników 32/46, 02-668 Warszawa, Poland

[b])Department of Physics, University of Maryland, College Park, MD 20742, USA

(Received August 8, 1990)

Magnetic susceptibility has been measured in $Pb_{1-x-y}Sn_yMn_xSe$ with x values up to 0.02 and y values up to 0.05. The measurements were carried out using a SQUID system over a temperature range from 5 to 250 K. The susceptibility followed the Curie–Weiss relation with a small paramagnetic Curie temperature that indicated a weak antiferromagnetic exchange interaction between Mn ions. We analyzed the results together with our previously published data on high-field magnetization in this material. A reasonable agreement of the exchange parameters obtained from the low-field susceptibility and high-field magnetization data was obtained.

PACS numbers: 75.20.Ck, 75.30.Et

1. Introduction

Studies of magnetization and magnetic susceptibility of IV–VI diluted magnetic semiconductors (DMS) showed, that there is a very weak antiferromagnetic exchange coupling among magnetic ions [1]. Recently, we have measured the high-field magnetization in a series of IV–VI DMS, including the quaternary $Pb_{1-x-y}Sn_yMn_xSe$, and compared the results with those from the low-field measurements [2]. For $Pb_{1-x-y}Sn_yMn_xSe$ the low-field susceptibility data were lacking. Therefore, we have measured the magnetic susceptibility of this system for $x < 0.02$ from 5 to 250 K.

*This work was supported in part by the U.S. DARPA and the U.S. ARO under Grant No DAAG 29-85-K-0052 and by the Polish Project CPBP 01.04.

2. Experiment

The samples of $Pb_{1-x-y}Sn_yMn_xSe$ were cut from larger boules grown by the Bridgman technique. The nominal values of x and y were chosen to keep the energy gap constant at approximately the value for PbSe (0.145 eV at 4.2 K) [3]. The x and y values determined by electron microprobe analysis are given in the Table. The crystals were p-type with carrier concentrations ranging from 5×10^{18} to 1×10^{19} cm^{-3}.

The magnetic susceptibility of $Pb_{1-x-y}Sn_yMn_xSe$ was measured by using a SQUID detection system at temperatures from 5 to 250 K and at magnetic fields from 50 to 200 Oe. The experimental method and arrangement were described previously [4, 5].

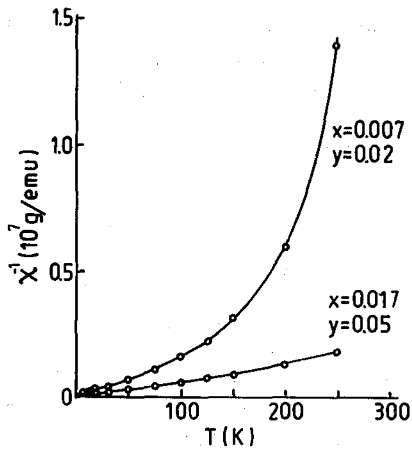

Fig. 1. Inverse susceptibility vs. temperature for $Pb_{1-x-y}Sn_yMn_xSe$. The solid lines are fits to the Curie–Weiss law.

3. Results and discussion

The susceptibility data have been fitted over the temperature range from 20 to 250 K to the Curie–Weiss law:

$$\chi = \frac{P_1}{T+\theta} + \chi_0, \tag{1}$$

where T is the absolute temperature, P_1 is the Curie constant, θ is the Curie temperature, and χ_0 is the diamagnetic susceptibility of the host lattice. P_1, θ, and χ_0 were the fitting parameters. The effective content of Mn ions, $\bar{x}$, and the nearest neighbor exchange parameter, J/k_B (where k_B is the Boltzmann constant), were determined from P_1 and θ as described in [5].

The results of fits are shown in Fig. 1 as solid lines. The apparent deviation from a straight line in the sample with the lowest Mn-content is a result of the host diamagnetic contribution. The fitting parameter values are given in the Table.

The fits were not very sensitive to the parameter θ and there is a large uncertainty in this parameter value. However, we see that the exchange interaction is antiferromagnetic and comparable to that in other IV–VI DMS. From the high-field magnetization data we obtained a value $J_P/k_B = 0.97 \pm 0.3$ [2], a value higher than the values presented here, though the values agree within experimental accuracy. This effect may indicate a ferromagnetic interaction between the next nearest neighbors, since the J/k_B value determined from the susceptibility vs. temperature data as an average of all exchange interactions would then appear lower.

In our analyses of the susceptibility data in other IV–VI DMS we kept the χ_0 parameter constant and equal to that in the nonmagnetic host lattice. For $Pb_{1-x-y}Sn_yMn_xSe$ we do not know the χ_0 of $Pb_{1-y}Sn_ySe$ with different y values, and it was impossible to obtain good fits to the experimental data using the diamagnetic susceptibility of PbSe, $\chi_0 = -3.6 \times 10^{-7}$ emu/g. Therefore, χ_0 was also a fitting parameter, and turned out to be smaller than χ_0 in PbSe.

We are grateful for the use of the SQUID facilities at the National Magnet Laboratory and to Dr. S. Foner for his help. We wish to thank Dr. A. Szczerbakow for the $Pb_{1-x-y}Sn_yMn_xSe$ samples.

TABLE

Susceptibility parameters for $Pb_{1-x-y}Sn_yMn_xSe$

x	y	$\bar{x}$	θ(K)	χ_0(emu/g)	J/k_B(K)
0.007	0.02	0.006±0.001	0.27±0.4	$(-3.1 \pm 0.2) \times 10^{-7}$	0.63
0.017	0.05	0.014±0.001	0.54±0.5	$(-3.1 \pm 0.2) \times 10^{-7}$	0.55

References

[1] M. Górska, J.R. Anderson, *Phys. Rev. B* **38**, 9120 (1988).

[2] J.R. Anderson, G. Kido, Y. Nishina, M. Górska, L. Kowalczyk, Z. Gołacki, *Phys. Rev. B* **41**, 1014 (1990).

[3] L. Kowalczyk, I.I. Zasavitsky, *Acta Phys. Pol.* **A75**, 285 (1989).

[4] J.R. Anderson, M. Górska, L. Azevedo, E. Venturini, *Phys. Rev. B* **33**, 4706 (1986).

[5] M. Górska, J.R. Anderson, *Solid State Commun.* **63**, 1055 (1987).