Specific heat of ZnCoSe semimagnetic semiconductor

Vol. A77 (1990) ACTA PHYSICA POLONICA No 1

SPECIFIC HEAT OF ZnCoSe SEMIMAGNETIC SEMICONDUCTOR*

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(Received June 20, 1989)

The magnetic specific heat of ZnCoSe data are reported in the temperature range $1.5 < T < 50$ K and magnetic field $B < 3$ T. The experimental data are interpreted in the Extended Nearest Neighbour Pair Approximation taking into account short and long ranged *d-d* exchange interaction.

PACS numbers: 75.50.Pp, 75.50.Kj

Semimagnetic Semiconductors (SMSC), studied intensively during recent years, contained mainly manganese or iron ions as magnetic substitutes for nonmagnetic cations. Very recently a new class of SMSC containing cobalt Co^{++} has been synthesized (ZnCoSe and ZnCoS) [1, 2]. The Co^{++} ions in these systems have magnetic ground state ($^4A_2$) with quenched orbital momentum ($L = 0$, $S = 3/2$) and thus magnetic properties of Co-based SMSC are expected to be analogous to that of Mn-type SMSC.

In this paper we report results of specific heat study of $Zn_{0.958}Co_{0.042}Se$ ($x = 0.042 \pm 0.009$) in the temperature range 1.5–50 K and magnetic field up to 2.8 T. The magnetic contribution to the specific heat (c_m) was obtained from the total specific heat by subtraction of ZnSe lattice heat capacity (it should be noticed that the lattice specific heat is dominant in the measured heat capacity of ZnCoSe above 10 K: it is comparable to c_m at $T = 7$ K

* Proc. XVIII School on Physics of Semiconducting Compounds, Jaszowiec 1989.

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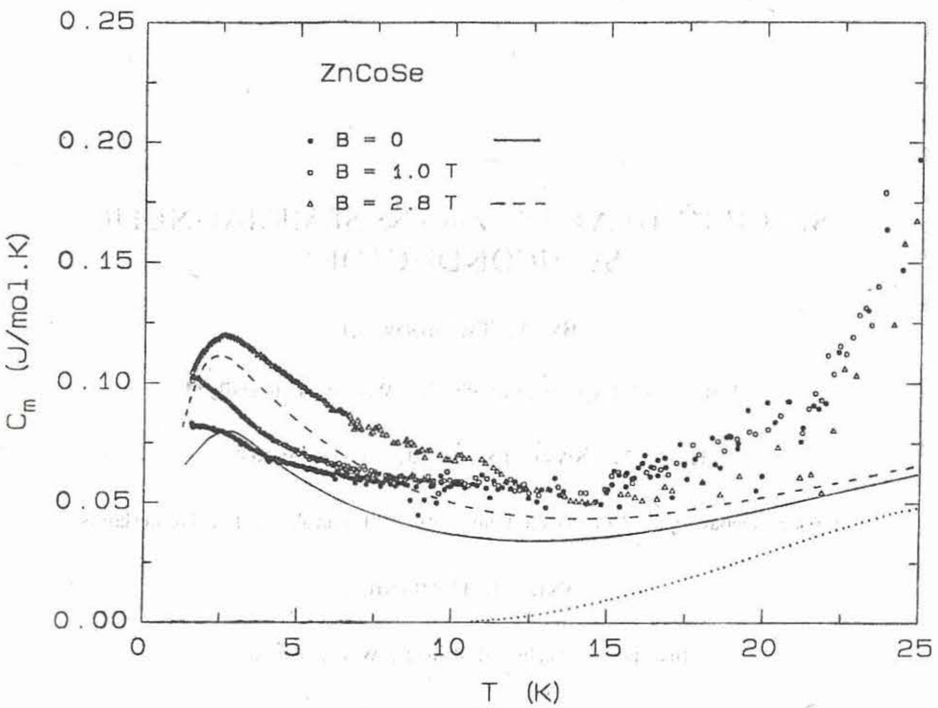

Fig. 1. Magnetic contribution to the specific heat of $Zn_{0.958}Co_{0.042}Se$ versus temperature at magnetic fields $B = 0$, 1 and 2.8 T. The lines show calculated specific heat (ENNPA): solid line — $B = 0$, $J_{NN} = -50$ K, $J_{LR} = -50$ K/$R^{6.8}$, dashed line — $B = 2.8$ T, $J_{NN} = -50$ K, $J_{LR} = -50$ K/$R^{6.8}$, dotted line — $B = 0$, $J_{NN} = -50$ K, $J_{LR} = 0$

and exceeds 20 times c_m at 17 K). The results are shown in Fig. 1 for $B = 0$, 1 and 2.8 T. In the absence of magnetic field c_m decreases with increasing temperature down to at 12 K and then monotonically increases with increasing temperature up to 50 K. Magnetic field influences specific heat significantly: at low temperatures a maximum of c_m is well pronounced. The absolute values of c_m increases with applied magnetic field. This situation is similar to that found for Mn-type SMSC [3, 4] and is characteristic for "spin-only" magnetic ions. The existence of zero-field specific heat evidences (in the spin-only case) *d-d* interaction between Co ions. On the other hand this interaction must be Long Ranged (LR) as revealed by low temperature increase of c_m with decreasing temperature (at $B = 0$).

We interpret the specific heat data in the Extended Nearest Neighbour Pair Approximation (ENNPA) [3, 4] assuming totally quenched orbital momentum of Co ions ($L = 0$). and spin $S = 3/2$. The Nearest Neighbour (NN) interaction is provided from neutron scattering experiment [2] and high temperature susceptibility [5]: $J_{NN} = -50$ K. This interaction is responsible for high temperature c_m; the low temperature specific heat must result from the interaction with more distant neighbours (see calculations for $J_{LR} = 0$ in Fig. 1). We assumed LR interaction in the form similar to that obtained for ZnMnSe [4]: $J_{LR} = J/R^{6.8}$ with $J = J_{NN}$. The results of ENNPA calculations are shown in Fig. 1.

We notice qualitative agreement between experimental and calculated specific heat in the low temperature range although it is apparent that the interaction range is shorter than assumed by us (as revealed by the discrepancy between calculated low temperature maximum of c_m and the experimental data). Adjustment of further neighbour interaction would result in better fit, however we believe that at the present stage such a fitting procedure would not necessary be physically meaningful. At high temperatures ($T > 25$ K) calculated c_m is much smaller than experimental one. The available data do not allow to conclude about this discrepancy.

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