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TEMPERATURE DEPENDENCE OF THE ENERGY GAP IN $Cd_{1-x}Fe_xSe$

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The energy gap and magnetic susceptibility of $Cd_{0.85}Fe_{0.15}Se$ were measured in function of temperature. Experiments showed that the magnetic contribution to the variation of the energy gap in $Cd_{1-x}Fe_xSe$ is not proportional to the product of magnetic susceptibility and temperature as it has been observed in Mn^{++}-containing semiconductors.

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1. Introduction

It has been shown [1] that magnetic contribution to the energy gap of Mn^{++}-containing semimagnetic semiconductors is negative and proportional to the product of magnetic susceptibility and temperature:

$$\Delta E_{\mathrm{g}}^{\mathrm{mag}} = bT\chi(x,T), \tag{1}$$

where b is related to wave-vector dependence of ion–carrier exchange integral J_q. Within a simple cutoff model:

$$b = -J_0^2 \frac{m_{\mathrm{h}} j(j+1) k_{\mathrm{B}}}{\hbar^2 \pi^2 N_0 N_{\mathrm{A}} (g\mu_{\mathrm{B}})^2} q_{\mathrm{c}}, \tag{2}$$

where J_0 is ion–carrier exchange constant at $q = 0$, q_{c} is its cutoff value, $j = 3/2$ is the hole momentum and m_{h} its average effective mass, N_0 denotes number of unit cells per unit volume, N_{A} is Avogadro's number, g — gyromagnetic factor and μ_{B} – Bohr magneton.

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As pointed out by J. Blinowski and P. Kacman [2] the approximations producing the above result may not be adequate in case of magnetic systems possessing internal excitations of order of $k_B T$. This is the case of Fe^{++} in CdSe. The purpose of this work is to examine the validity of the approach of Ref. [1] in the case of iron-containing semimagnetic semiconductor $Cd_{1-x}Fe_xSe$. This material is the only Fe-containing semimagnetic semiconductor where relatively high concentration of magnetic ions ($x = 0.15$) is available. Furthermore, analogous results obtained on its Mn-based counterpart CdMnSe have been published by L. Bryja and J.A. Gaj [3].

2. Experiment and discussion

Measurements of absorption in the free exciton region were performed on $Cd_{1-x}Fe_xSe$ and CdSe samples obtained from Bridgman-grown single crystals by local etching to a thickness below 1 μm. Figure 1 shows values of energy gap (free exciton absorption peak) plotted for $x = 0$ (CdSe) and $x = 0.15$ as a function of temperature. To check the validity of Eq. (1), magnetic susceptibility measure-

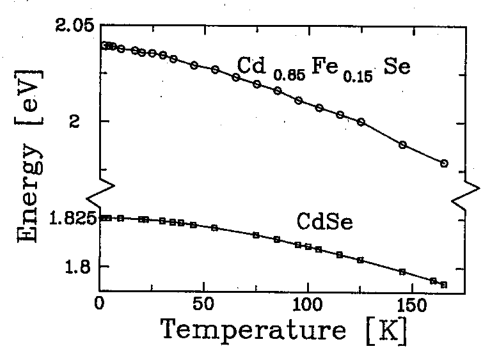

Fig. 1. Free exciton absorption peak energy plotted vs. temperature for CdSe and $Cd_{0.85}Fe_{0.15}Se$.

ments were also performed on a sample cut out of the same crystal. Figure 2b shows the results, plotted in the form χT vs. T, suitable for our purpose. The difference:

$$[E_g(x,T) - E_g(x,0)] - [E_g(0,T) - E_g(0,0)]$$

represented in Fig. 2a is rather superlinear as a function of T, whereas χT (Fig. 2b) has a completely different (sublinear) form. This confirms the conclusions of Ref. [2] and shows a need for a detailed theoretical calculation corresponding to the experimental results.

If we try to compare the values of the two curves in the high-temperature limit (where we can hope that the model of Ref. [1] can still be used as a rough approximation) we obtain $b = -0.078$ eV$\cdot$Gs$^2\cdot$ erg$^{-2}\cdot$ K^{-2}. Using available data

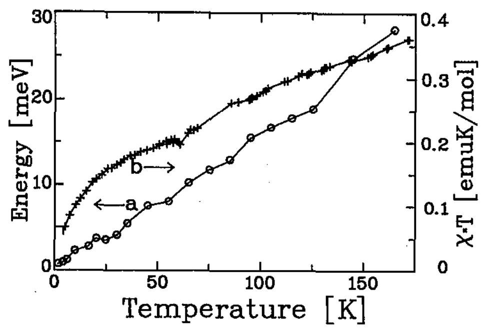

Fig. 2. Difference between temperature variation of the energy gap of $Cd_{0.85}Fe_{0.15}Se$ and that of CdSe (a) and product of magnetic susceptibility and temperature plotted versus temperature for $Cd_{0.85}Fe_{0.15}Se$ (b).

on valence band effective mass $m_h = 0.7m_0$ [3] and ion–hole exchange integral at $q = 0$, $N_0\beta = -1.53$ eV [4], we obtain from Eq. (2) $q_c = 2.56 \times 10^7$ cm^{-1}.

These values can be compared to the results obtained by L. Bryja and J.A. Gaj [3] for $Cd_{1-x}Mn_xSe$: $b = -0.085$ eV$\cdot$ Gs$^2 \cdot$ erg$^{-2} \cdot$ K^{-2} and $q_c = 3.77 \times 10^7$ cm^{-1}.

The smaller value of q_c for Fe^{++} corresponds to an intuitive idea of bigger effective size of the Fe^{++} ion compared to the Mn^{++} one.

Acknowledgment

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