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GIANT EXCITON FARADAY ROTATION IN $Cd_{1-x}Mn_xTe$ MIXED CRYSTALS

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New semiconductor compound $Cd_{1-x}Mn_xTe$ exhibits strong Faraday rotation in the interband region. It is shown by measurements of magneto-optical Kerr effect and reflection in magnetic field that unusually large exciton Zeeman splitting plays an essential role in the observed Faraday rotation. A possible explanation of the observed splitting (corresponding to a "g factor" value up to 100) by exchange interaction of excitons with manganese d states is suggested.

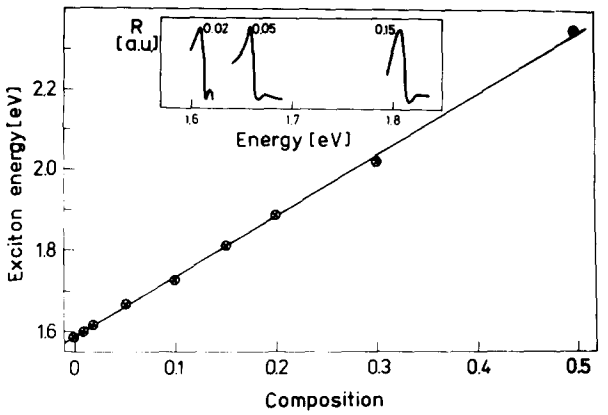

Fig. 1. Exciton energy vs manganese mole fraction x in $Cd_{1-x}Mn_xTe$ at 77 K. Some of the reflection curves, from which exciton energy was determined, shown in the insert (values of x given for each curve).

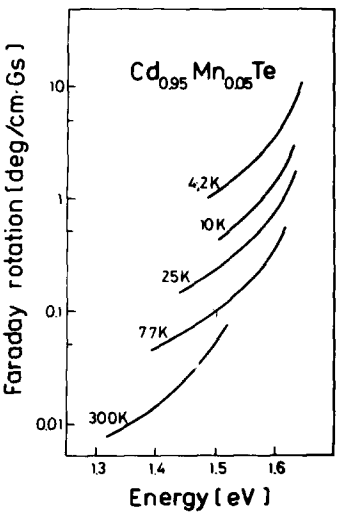

Fig. 2. Faraday rotation spectra of $Cd_{0.95}Mn_{0.05}Te$ measured at various temperatures.

SOLID SOLUTION $Cd_{1-x}Mn_xTe$ was grown using the modified Bridgman method. Single crystals of zinc-blende structure were obtained, having composition x up to 0.5. In order to determine dependence of the energy gap on composition, exciton reflection measurements were performed at liquid nitrogen temperature. The results are shown in Fig. 1. Understandably, the exciton reflection structure broadens with increasing manganese contents x. The exciton energy, determined as the point of maximum slope on reflection curve, varies linearly with composition according to the following equation

$$E_{ex} = 1.585\,\text{eV} + x \cdot 1.51\,\text{eV}.$$

Faraday rotation spectra were measured in the fundamental absorption edge region. The results are shown in Figs. 2 and 3. The observed effect is totally different than that of II–VI or III–V semiconductor compounds: it is greater by orders of magnitude, strongly temperature dependent and its spectral dependence definitely differs from interband Faraday rotation spectra of

Table 1. Relative values of coefficient A *and characteristic energy* $\hbar\omega_0$ *[equation* (2)*] obtained from displacing Faraday rotation spectra in log–log scales (see Fig.* (4) *for different temperatures and compositions. For* x = 0.05 and T = 77 K, $\hbar\omega_0$ = A = 1 *was assumed. Dependence of accordingly normalized exciton energy on composition shown for comparison*

		Relative values		
x	T [K]	A	$h\omega_0$	E_{exc}
0.02	77	0.25	0.97	0.97
0.05	77	1.00	1.00	1.00
0.15	77	2.0	1.10	1.09
0.20	77	3.6	1.14	1.14
0.30	77	4.5	1.22	1.22
0.50	77	5.15	1.41	1.41
0.05	4.2	11.6	1.01	
0.05	10	4.4	1.00	
0.05	25	2.6	1.01	
0.05	77	1.00	1.00	
0.05	120	0.69	0.99	
0.05	300	0.19	0.95	

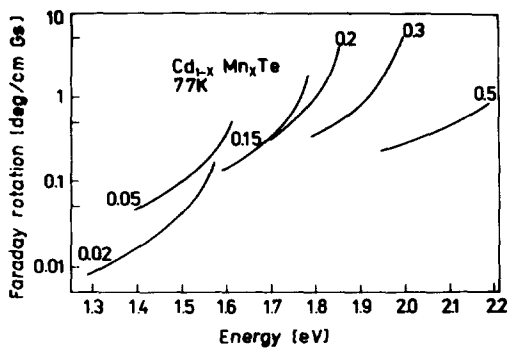

Fig. 3. Faraday rotation spectra of $Cd_{1-x}Mn_xTe$ measured at 77 K. Composition values given for each curve.

non-magnetic semiconductors, resembling rather atomic-like single oscillator dependence

$$\vartheta(\omega) \sim \frac{\omega^2}{(\omega_0^2 - \omega^2)^2}. \tag{1}$$

A detailed analysis of the shape of these spectra will be reported later. The best way of presenting the obtained results is to plot log ϑ vs log ω, as was done by Ebina *et al.* [1]. Since both equation (1) and typical expressions for interband Faraday effect are of the form

$$\vartheta(\omega) = Af\left(\frac{\omega}{\omega_0}\right) \tag{2}$$

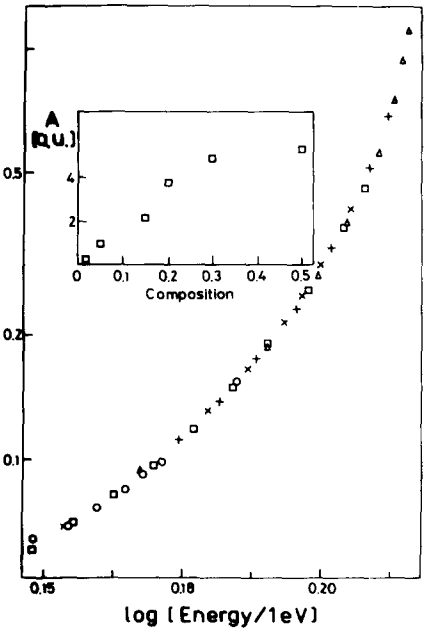

Fig. 4. Faraday rotation spectra of $Cd_{1-x}Mn_xTe$ for different compositions and temperatures, brought to identity by horizontal and vertical displacement in log–log scales. For clarity, only part of the data is shown: ○ 77 K x = 0.5; △ 77 K x = 0.2; □ 77 K x = 0.05; × 300 K x = 0.05; + 10 K x = 0.05. Scales relate to the 77 K x = 0.05 curve. Relative magnitude of the effect A (see Table 1) shown as a function of composition in the insert.

[2, 3, 4], changing parameters A and ω_0 is equivalent to displacing the curve paralelly in ϑ — or ω — axis direction. Therefore, if a set of results can be described by a common model of this type, all experimental curves can be brought to identity by vertical and horizontal displacement. This is done in Fig. 4. The scales on ϑ — and ω — axis relate to x = 0.05 rotation spectrum, measured at T = 77 K. The remaining spectra have been shifted by values shown in Table 1. The horizontal displacement of curves measured for various compositions at 77 K coincides with that of the exciton energy. Dependence of coefficient A [equation (2)] on composition x at 77 K is shown in the insert in Fig. 4. The magnitude of rotation increases approximately linearly with composition up to x = 0.3. The result for x = 0.5 is less certain because of poorer quality of the crystals of this composition.

In order to find optical transition, responsible for the observed Faraday rotation, strong circular dichroism was investigated. It was done by measuring magnetooptical Kerr effect, e.g. rotation of polarization plane in reflection under influence of magnetic field. Measurements were performed by a polarization modulation technique, similar to that described by Kessler [5]. A typical curve is shown in Fig. 5, with reflection

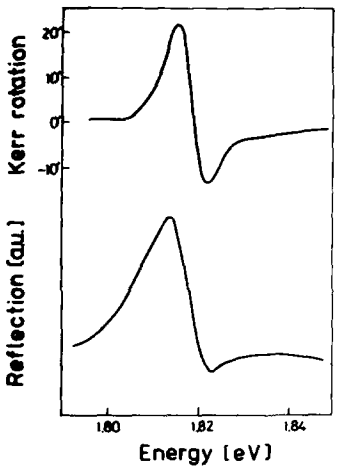

Fig. 5. Kerr rotation spectrum at 77 K and 5 kGs for $x = 0.15$. Reflection spectrum given for comparison below.

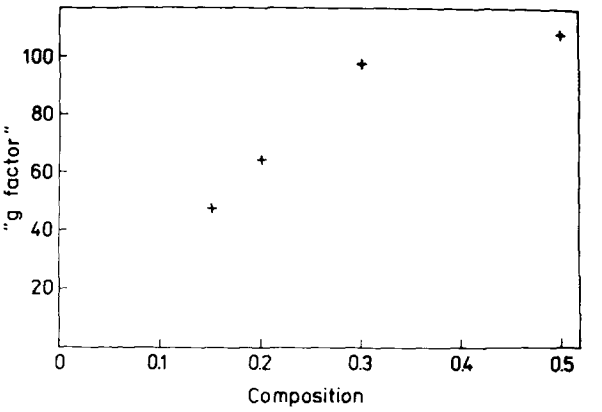

Fig. 6. Exciton splitting in magnetic field, measured as energy shift between reflection curves for opposite circular polarizations, expressed in terms of "g factor" $g = (\Delta E/\mu_B H)$.

spectrum given for comparison. The singularity in circular dichroism (predominantly responsible for magneto-optical Kerr effect) coincides exactly with exciton energy. The same was observed for other x values studied. This forms direct evidence of the essential role of excitons in the observed Faraday rotation. In order to explain the magnitude of the rotation, anomalously large exciton splitting in magnetic field should be assumed. To verify this hypothesis, reflection measurements were performed in magnetic field with circularly polarized light. Curves measured for opposite circular polarizations were shifted in energy by a value proportional to magnetic field. Figure 6 shows dependence of "g factor" proportional to that splitting on composition x. The observed splitting is up to two orders of magnitude greater than that of a free electron. The question of physical mechanism of this effect remains open. It seems possible that exciton splitting in magnetic field can be magnified due to exchange interaction with manganese ions in its neighbourhood, similarly as proposed by Bastard *et al.* for conduction band electrons in $Hg_{1-x}Mn_xTe$ [6].

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