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ELECTROREFLECTANCE IN $Mn_xCd_{1-x}Te$

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In this paper we report on electroreflectance and derivative photoresponse measurements done on nine different compositions of $Mn_xCd_{1-x}Te$ single crystals ($0.001 \leq x \leq 0.60$) in the temperature range from 9K to 300K. Using three-point-fit method the energy gap was determined. The observed variation of energy gap with temperature is linear in the range 100-300K in all investigated samples. The temperature coefficient of energy gap is negative and strongly depends on composition.

I. Introduction

The ternary compound such as $Mn_xCd_{1-x}Te$ exhibits some interesting optical, magneto-optical and electrical properties. It forms uniform solid solution with the zince-blende structure in the wide range of Mn concentration ($0 \leq x \leq 0.72$). In the absence of magnetic field the $Mn_xCd_{1-x}Te$ mixed crystals show the typical characteristics of a semiconductor alloy. However, when magnetic field is present, the spin exchange interaction between localized magnetic moments of 3d electrons and charge carriers becomes important. This interaction modifies the band structure and gives rise to a very strong magneto-optic phenomena [1,2].

In the present study, we report on recent results of electroreflectance (ER) and derivative photoresponse (DPR) measurements done on $Mn_xCd_{1-x}Te$ single crystals with nine different compositions ($0.001 \leq x \leq 0.6$) for the wide range of temperature. Specifically, these measurements allow us to obtain the temperature and compositional dependences of the fundamental energy gap of $Mn_xCd_{1-x}Te$ and to draw some conclusions concerning the physical nature of the excitons in these alloys.

II. Experiment

$Mn_xCd_{1-x}Te$ single crystals were grown using a modified Bridgman method. High purity elements were used; Te and Cd twice vacuum distilled and zone refined, Mn- vacuum distilled. The composition of the samples was checked by EDAX, density and photoluminescence measurements. In all cases x agreed with the technological composition within experimental error (~3%). Since most of the as-grown crystals were semi-insulating, a simple transverse electrode configuration (two strips of gold contacts separated usually by 0.5 mm) was used in applying the electric field to the sample. The samples were cleaved prior to contact disposition. The ER data were obtained with the conventional electric field modulating technique. We used Spex 1702 monochromator, a halogen lamp as a source, a near-normal

incidence reflectometer, a Si detector and a PAR 124A lock-in for detection. The ER measurements were performed in the temperature range 9-300K using Heli-Tran LT-3-110 as a sample dewar. The photoresponse (PR) and DPR measurements were made on the same samples and in the same experimental configuration as those of ER. Both the PR and DPR measurements were performed to complement the ER data.

III. Results and Discussion

Fig. (1) shows typical ER structure of the Γ_8-Γ_6 transition in $Mn_xCd_{1-x}Te$ for x=0.15 at four different temperatures. The observed

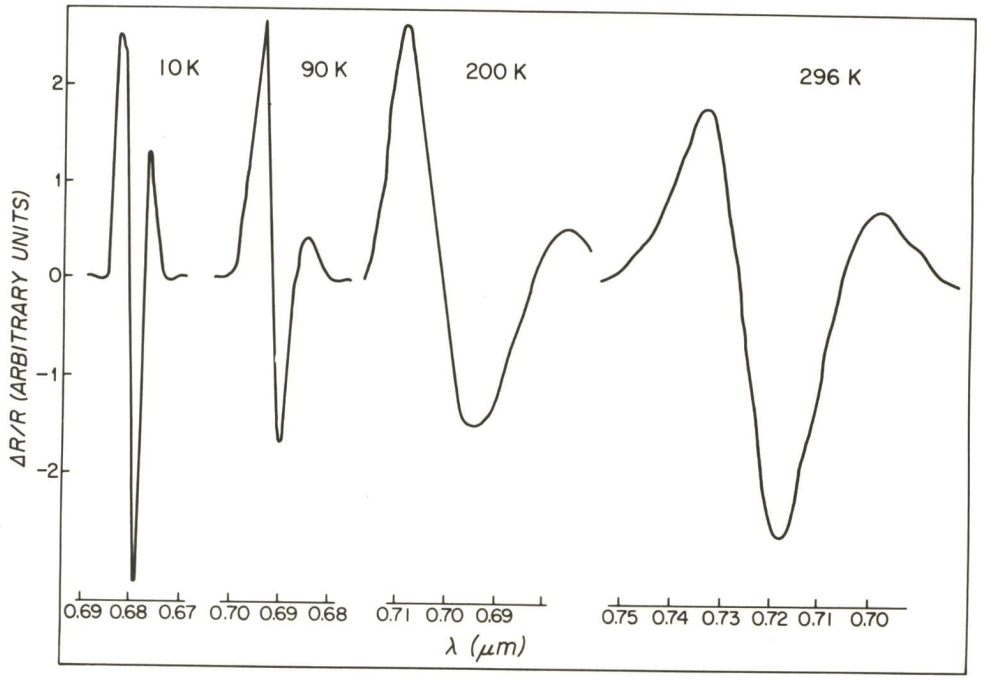

Fig. 1 Electroreflectance spectra at different temperatures obtained for $Mn_{0.15}Cd_{0.85}Te$

room temperature ER spectra are typical of a three-dimensional critical point transition. The lifetime broadening parameter changes from 35 to 50 meV throughout the composition and probably is due to the presence of impurities (or vacancies) in the lattice and/or to small fluctuations in the composition. As temperature decreases, the Coulomb interaction between electron-hole pair becomes evident by narrowing of peaks (~200K). Below 100K we have modulation of a discrete exciton structure. The observed broadening of ER line shape indicates that in $Mn_xCd_{1-x}Te$ the excitons are Wannier-like.

To avoid difficulties and uncertainties in the interpretation of ER data we hold "low-field" conditions during experiment [3]. In most of the measurements the ER line shape did not vary with the applied electric field and the relative reflectivity changes, $|\Delta R/R|$, were smaller than 10^{-4}. We have interpreted our ER data using the three-point-fit method developed by Aspnes and Rowe [4]. This method

does not require optical constants or Kramers-Kronig analysis; hence, it is particularly useful for new materials. It allows determination of the interband transition energies and broadening parameters, irrespective of the physical model chosen to represent transition.

In Fig. (2), we plotted the values of the E_o, obtained using the three-point-fit method as a function of temperature for measured $Mn_xCd_{1-x}Te$ alloy composition. The observed variation of E_o (E_o is the

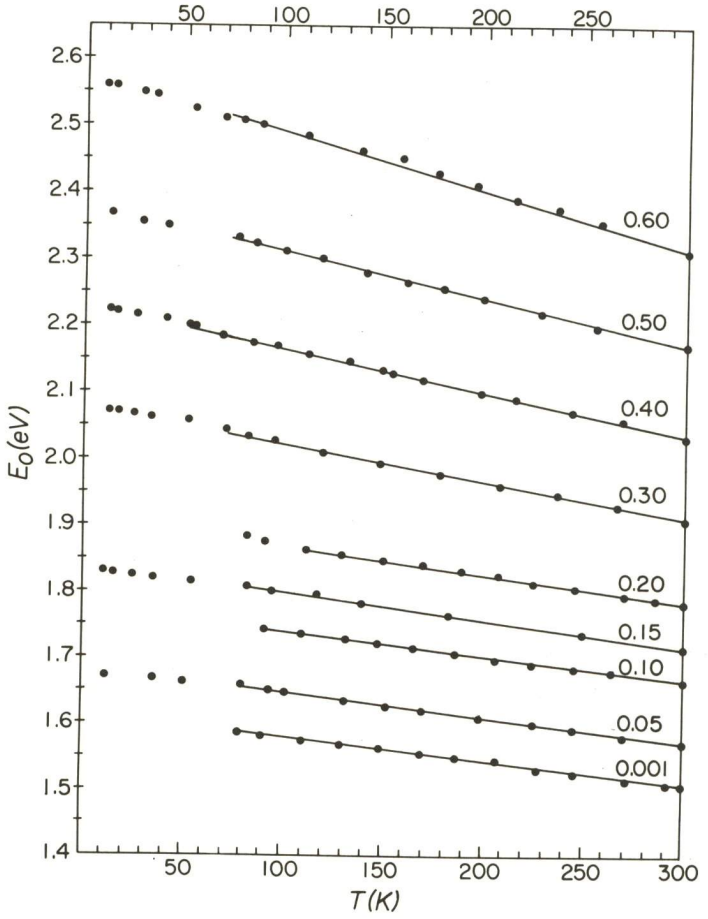

Fig. 2 Fundamental transition energy obtained from ER spectra as a function of temperature for different compositions: The value of x is given above each curve

value of energy gap modified by exciton binding energy) is linear with composition and temperature in the range 100-300K. These conclusions are confirmed by our DPR measurements and agree with existing absorption [5] and photoluminescence data at 77K [6]. In Table I the average temperature coefficient of the energy gap obtained from the least-square analysis for the range 100-300K, is given for the various alloy composition measured. It is seen that the value of the temperature coefficient depends strongly on composition for x>0.10

and it changes 2.5 times as x varies from 0.0 to 0.6.

x	0.001	0.05	0.10	0.15	0.20	0.30	0.40	0.50	0.60
α	3.7 ±0.1	3.9 ±0.2	3.6 ±0.2	4.3 ±0.2	4.6 ±0.1	5.8 ±0.2	6.6 ±0.1	7.3 ±0.1	8.9 ±0.2

Table I Dependence of $\alpha=-\frac{dE}{dT}\Big|_p$ (10^{-4}eV/K) on composition for $Mn_xCd_{1-x}Te$

The temperature dependence of the energy gap arises because the lattice vibrations of the crystal produce a temperature-dependent electronic band structure. This effect involves four terms [7], namely, the Fan intra-band and inter-band terms, the thermal expansion and the Debye-Waller factors in the Fourier expansion of the periodic part of the potential. The equivalent thermodynamic treatment of the temperature dependence of the energy gap also exists [8]. Because many of the parameters and material constants required for these calculations are not known for $Mn_xCd_{1-x}Te$ system, no attempt was made to analyze the temperature dependences of measured values of the energy gap.

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