

TIME-RESOLVED SPECTROSCOPY IN $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ FOR $x = 0.55$

W. Gebhardt, V. Gerhardt, E. Müller, F. Wünsch,
University of Regensburg, F. R. Germany,

and

W.M. Becker
Purdue University, West Lafayette, Ind., U.S.A.

The nonresonant energy transfer in the mixed semiconductor $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ is investigated by using time resolved spectra of the manganese ${}^4\text{T}_1 \rightarrow {}^6\text{A}_1$ emission.

$\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ is a semimagnetic semiconductor [1,2]. The Zinc sulfide structure of the alloy is stable up to $x = 0.70$. For $x > 0.4$ a strong red photoluminescence is observed. In a sample with $x = 0.55$ the emission has a peak at 2.01 eV (16210 cm^{-1}) and a halfwidth of 0.120 eV (970 cm^{-1}) at LHeT. The emission, which does not show a zero phonon structure, is attributed to the multiphonon band of the ${}^4\text{T}_1 \rightarrow {}^6\text{A}_1$ transition within the Mn^{2+} -ions [3]. In this paper we investigate $x = 0.55$ samples with time-resolved emission spectroscopy 1) to obtain information about the energy distribution of ${}^4\text{T}_1$ -states and 2) to discuss the mechanism of radiationless energy transfer. Single crystals were grown at Purdue University using the Czochralski technique. The emission was excited with the 514.5 nm line of a pulsed Ar-Laser. The width of the laser pulse was typically 50 μs , the repetition frequency 5 kHz. Time-resolved spectra were recorded with a 1m SPEX spectrometer and a EMI 9558 QB photomultiplier. A single wavelength decay was recorded with 64 channels using a sampling time of 1 μs for one channel. 200 channels were used to obtain a full emission spectrum with a resolution of 0.6 nm for each channel. The sampling time was in this case 3 μsec .

Fig.1 shows the decaying emission band shifted to longer wavelengths during radiative decay. This is better seen in fig.2 where all four bands are normalized to equal maximum intensity. After 48 μsec the emission band loses 140 cm^{-1} on the blue but gains 50 cm^{-1} on the red side i.e. there is not only a shift of the center of mass to the red but also a decrease in the halfwidth. It is obvious that the broad emission band covers transitions from a distribution of ${}^4\text{T}_1$ -states to the ${}^6\text{A}_1$ -groundstate. The "blue" wing which is rich in higher lying states shows a faster decay than the "red" wing of the band, containing lower lying ${}^4\text{T}_1$ -states.

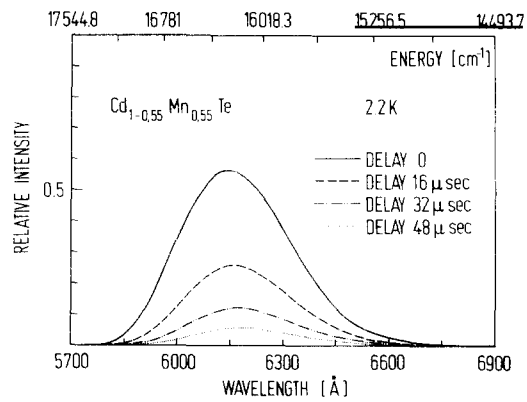


Fig.1 Emission band at 2.2 K recorded 0, 16, 32 and 48 μs after excitation.

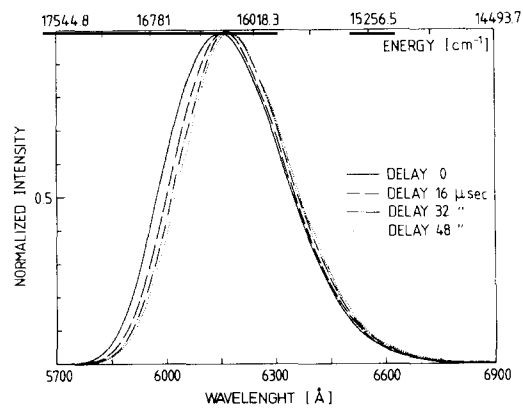


Fig.2 Emission bands from fig.1 normalized to equal maximum intensity.

Fig.3 shows a decay of the half maximum intensities I_b and I_r at $\lambda_b = 594.3$ nm and $\lambda_r = 637.2$ nm respectively.

$I_r(t)$ decays exponentially

$$I_r = I_r^0 \exp - \frac{t}{\tau_R}$$

with $\tau_R = 24 \mu s$. $I_b(t)$ however shows a nonexponential decay [4,5,6]

$$I_b = I_b^0 f(t) \exp - \frac{t}{\tau_R}$$

From the initial slope of I_b

$$\left(\frac{d \ln I_b}{dt} \right)_{t=0} = \frac{1}{\tau_b}$$

we obtain a time constant $\tau_b = 13 \mu s$ [7].

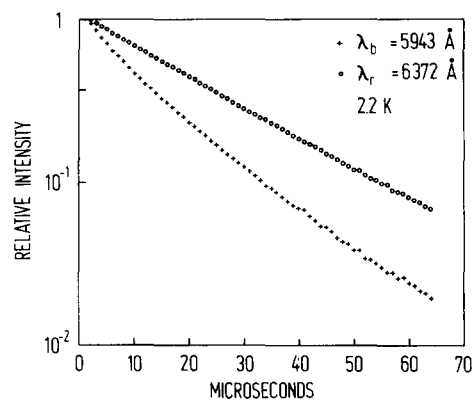


Fig.3 Decay at half maximum wavelengths $\lambda_b = 594.3$ nm and $\lambda_r = 637$ nm. Note that the decay at 594.3 nm is nonexponential.

The crystal field in the alloy $Cd_{1-x}Mn_xTe$ varies from one Mn^{2+} -site to another, which results in a random distribution of 4T_1 -states. At LHeT nonresonant energy transfer within the distribution of 4T_1 -states from high to low lying 4T_1 -states takes place. The transfer rate for these stepdown processes, $\frac{1}{\tau_t}$, is as large as

the radiative decay rate $\frac{1}{\tau_R}$. We have $\frac{1}{\tau_b} = \frac{1}{\tau_R} + \frac{1}{\tau_t}$ which yields $\tau_t \approx 14$ ns. From fig.2 we estimated 120 cm^{-1} as a lower limit of the distribution width. From the observed nonexponential decay at 594.3 nm we conclude that energy transfer between higher lying states (donor-donor-transfer) seems to be slow compared with stepdown processes (donor-acceptor-transfer) [6,8]. When the temperature is raised both stepup and stepdown processes occur which qualitatively explains the flattening of $I_p(t)$ -curves and the nonexponential behaviour of $I_r(t)$. Finally at 77 K $I_r(t)$ and $I_b(t)$ coincide. The total intensity of emission remains constant in the range of $2 < T < 60$ K. Above 60 K a steep decrease of the emission intensity is observed while no clear effect is seen in the decay times.

A part of this work was supported by the Deutsche Forschungsgemeinschaft.

References

- [1] J.A. Gaj, R.R. Galazka, M. Nawrocki; Sol.Stat.Comm. 25, 193 (1978)
- [2] R. Galazka; Inst.Phys.Conf.Ser.No. 43 (1979) p.133
- [3] W.M. Becker, M.M. Moriwaki, and W. Gebhardt; Bull.Am.Phys.Soc. March 81
- [4] W.Y. Chin, D.L. Huber, and B. Barnett; Phys.Rev. B 17, 5025 (1978)
- [5] S.K. Lyo, T. Holstein, and R. Orbach; Phys.Rev. B 18, 1637 (1978)
- [6] D.L. Huber; Phys.Rev. B 20, 2307 (1979)
- [7] D.L. Huber, D.S. Hamilton, and B. Barnett; Phys.Rev. B 16, 4642 (1977)
- [8] M. Inokuti, F. Hirayama; J.Chem.Phys. 43, 1978 (1965)