

THE PICOSECOND STUDY ON THE VALENCE HOLE INTER-BAND TRANSITION IN CdS SINGLE CRYSTAL

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The photoluminescence spectra and picosecond decay dynamics of highly excited CdS crystal at different polarized states have been investigated. The valence band hole inter-band relaxation has been found, and the theoretical discussions are given.

1. INTRODUCTION

The hot electron relaxation in the semiconductors has been well studied¹. The studies on the hole inter-valence-band relaxation process in the CdS single crystal will be shown in this paper.

It is well known that the valence band of the wurtzite type CdS crystal consists of A, B and C bands denoted by E_0 , E_7 and E_7 , respectively, and the conduction band has the E_7 symmetry. In the electric dipole transition, the $E_0(A)$ band to E_7 (conduction band) transition is allowed only for the $E||c$ polarized light. But the transition between the E_7 (conduction band) is allowed for the light polarized for both $E||c$ and $E\perp c$ ².

2. EXPERIMENT

We have measured the photoluminescence spectra of CdS single crystal at 70K up to 300K. The samples measured were platelet like CdS crystals with the crystal axis in the plane of the platelet. A mode locked Nd:YAG laser with the excitation intensities of the order 1MWcm^{-2} , the pulse duration of about 100ps at wavelength 355nm was used as the excitation source.

The sample was excited by the polarized incident light for $E_1||c$ as well as $E_1\perp c$, and the luminescence spectra with the polarization direction of $E||c$ and $E\perp c$ were measured.

3. RESULTS AND DISCUSSION

It is observed that the photoluminescence spectra consist of two broad bands denoted by E and E_x-2LO at room temperature³. We observed that the spectra are different for the different detected polarization direction but at the same excitation. As the results shown in Fig. 1, the energy position of the band peaks in the spectrum detected by $E||c$ polarization direction is higher than that in the spectrum detected by $E\perp c$ polarization direction, the value is 19meV. This value is independent on the excitation densities, and equals approximately the splitting energy between the valence bands A and B in CdS crystal. According to our experiments on the band edge absorption and other authors' results⁴, the splitting between A and B valence bands is about 19meV. So the luminescences corresponding to $E\perp c$ and $E||c$ are related to the recombination of the holes in the valence bands A and B, respectively.

In case $E_1||c$, only the electrons in B band are excited, while the B holes are generated. From the spectra, both the recombinations of the excited state electrons with B holes and those with A holes are observed. It can be interpreted that the presence of A holes is due to the holes relaxation from B band to A band. At the beginning of the luminescence excited by $E_1||c$, a part of the holes of B band recombine with electrons, another part of holes relax to A band. So for the $E_1||c$ excitation, the luminescence from E_7-E_0 is different to that from

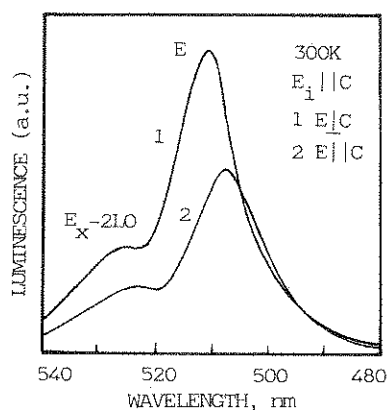


FIGURE 1

The luminescence of the highly excited CdS at room temperature.

E_7-E_7 . We have measured decay of luminescence around 500nm, where there are possibilities of E_7-E_9 and E_7-E_7 transition. The results are shown in Fig. 2 for sample excited by $E_i || C$. We have observed that the emission polarized for $E || C$ direction reached the maximum first, and decayed quickly as compared with the emission polarized for $E_i || C$.

Suppose that t_A and t_B are the lifetime of the recombination of the electrons with A holes and B holes, respectively. Considering the laser pulse has a certain width, the spectra measured were deconvoluted by a microcomputer. So $t_A=107ps$ and $t_B=65ps$ are obtained. For t_A and t_B and the B holes relaxation to A band time t_{B-A} , there is a relation of them, $1/t_B = 1/t_A + 1/t_{B-A}$. So $t_{B-A}=166ps$.

It is well known that hot electrons relax very fast by the scattering with the LO optical phonons, e.g. in CdSe the relaxation time of the electrons due to the LO phonon scattering is less than 1ps, and in GaAs less than 2ps¹. The relaxation due to the acoustic phonon scattering is relatively slower than the LO phonon process. For this reason, we have neglected the hot electron relaxation process in the discussion. We consider the hole relaxation is also

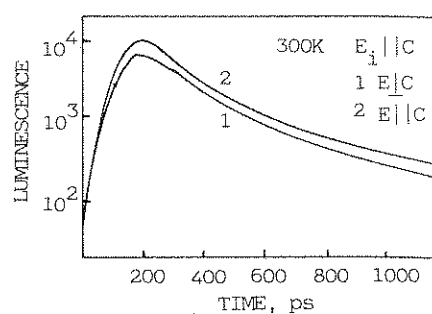


FIGURE 2

The luminescence decay around 500nm of the highly excited CdS at room temperature.

due to the phonon scattering. For CdS, the splitting between the A, B and E, C valence bands are 19, 63meV, respectively, and the LO phonon energy is 38meV⁵. Due to the LO phonon scattering, the C holes relax immediately to the B and A band, this is the reason why we can not find C holes in the experiment. As the B hole relaxes owing to the acoustic phonon scattering, the relaxation time of B hole is not much shorter than the carriers recombination time. So the B holes relaxation can be found in the experiments. We have also observed the similar hole relaxation in various temperature.

4. CONCLUSION

We have found the hole inter-band relaxation in CdS single crystal at room temperature and we attribute the process to the acoustic phonon scattering.

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1. INTRODUCTION

Secondarily, the optical excitation of luminescence has been investigated. The time of the secondarily We require polariton HL in high by picosecond

2. RESULTS

Exciton has a possibility in a picosecond polariton phonons with in the optical shows the transverse LO Raman time resolution excitation at the moment has high structural subsequent