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CORRELATION OF EXCITATION SPECTROSCOPY OF EDGE LUMINESCENCE AND PERSISTENT PHOTOCONDUCTIVITY IN CDS

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Simultaneous excitation spectra of time-resolved luminescence and persistent photoconductivity are investigated in near-zero stored-charge states at temperatures 1 - 4K and magnetic fields up to 4 Tesla.

INTRODUCTION

The phenomenon of persistent photoconductivity (PPC) has been observed in many materials[1,2], and several models have been put forward to account for the long lifetimes of electrons (holes) which give rise to the effects. Of greatest current interest among these are the macroscopic potential barrier, inhomogeneous potential barrier islands, and lattice relaxation models[3] in which recombination is forbidden as a result of configuration- coordinate shifts. The spatial distribution of the stored charges varies significantly for these models. For CdS, former work suggests a principal role of natural defect donors and acceptors both in luminescence and persistent photoconductivity[4,5]. Furthermore, constraints on donor-acceptor (D-A) pair luminescence emission regions[6,7] have been reported. Thus, a detailed correlation of PPC with D-A pair luminescence, carried out by excitation spectroscopy over a range of incident photon energies for which the absorption coefficients vary greatly, can be expected to elucidate the applicable PPC model for CdS, and the technique may similarly be profitably employed for other semiconductors.

EXPERIMENTAL

The sample (EP-A) is a high purity, almost fully compensated, CdS single crystal, 0.5 mm thick, etched on the front (excitation) surface and polished on the rear (luminescence detection) surface. PPC is observable at temperatures below 240K. The flashlamp pumped dye laser excitation and time-resolved detection system used for luminescence measurements are the same as those described in another paper at this conference[7]. The sample is orientated with the c axis parallel to the incident light direction, and plated indium contacts on the front surface permit PPC measurements. A magnetic field of up to 4 Tesla can be applied parallel to the c axis. Upon absorption of excitation light, persistent current builds up. The resultant non-zero stored charge state can be returned to zero by bringing the stored charge state up to some threshold and applying a field of about 80 V/cm between the contacts. This momentarily heats the sample to several hundred degrees Kelvin, and empties the stored charge sites. Excitation spectra are taken both in the near-zero stored charge states and in the near-saturation stored charge state.

RESULTS AND DISCUSSION

The excitation spectra of D-A time-resolved low energy series (LES) luminescence and PPC for three successively incremented (starting at zero) near-zero stored charge states are shown for 4K in Fig. 1. The luminescence intensity is integrated over delay times from excitation, t_D, of 400 - 900 ns. We note growth of both Δi_{PPC} and I_{LES}, the emission intensity at 518 nm, with successive excitation pulses. The relative growth is largest for long λ_{EXC} (>490 nm). For λ_{EXC} < 489 nm, I_{LES} does not appreciably change after the second pulse. Since the luminescence and PPC excitation spectroscopic features are very similar, the implication is drawn that the dynamics of D^0-A^0 formation and PPC charge storage are closely associated in the early stored-charge accumulation process. One may also conclude from the small responses to the first pulse, especially at the longer excitation wavelengths, that precursor photo-reactions must occur in the empty stored-charge state, near the surface, before either i_{PPC} or I_{LES} can be observed. From the increasing peaks in Fig 1a at the I_2 (487 nm) and I_1 (489 nm) (respectively $[D^0,X]$ and $[A^0,X]$) positions, the role of D^0 and A^0 formation in the near-surface

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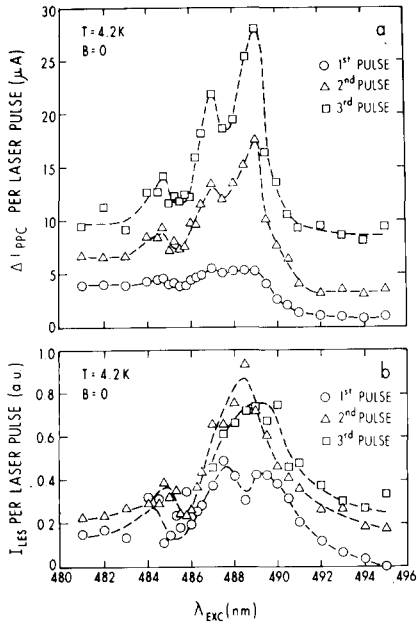

FIG. 1. Simultaneous excitation spectra of Δi_{PPC} and I_{LES} starting from zero stored-charge state. a. E = 6 V/cm. b. I_{LES} delay time integration is 400 - 900 ns.

depletion region produced by surface states is further illustrated. The near-surface depletion region may be constituted as inhomogeneous islands, allowing in the low electric field regions relatively unperturbed exciton production, evidenced by the dips in Fig 1 at the position of the free $A_{n=1}$ exciton. The fairly high efficiency of excitation at λ_{EXC} near 495 nm, where the photogenerated carrier density is orders of magnitude lower than for λ_{EXC} < 485 nm, suggests low quantum efficiency at high generation densities for distant D^0-A^0 pair formation and stored-charge states. The continued growth by several orders of magnitude of i_{PPC} with successive pulses implies either spatial growth of storage charge into the interior, or denser filling of storage sites in the near-surface (10^{-4} cm) region. Fig 2b illustrates the magnetic field quenching of luminescence, particularly in the region of the I_1 excitation. This quenching is probably dependent on magnetic field dynamics rather than explicitly on spin-polarization[8], since the quenching at 1.1K is of approximately the same magnitude. No comparable quench effect is seen in Fig 2a, but at 1.1K, a 3.5 Tesla field reduces Δi_{PPC} by about 10%. which may

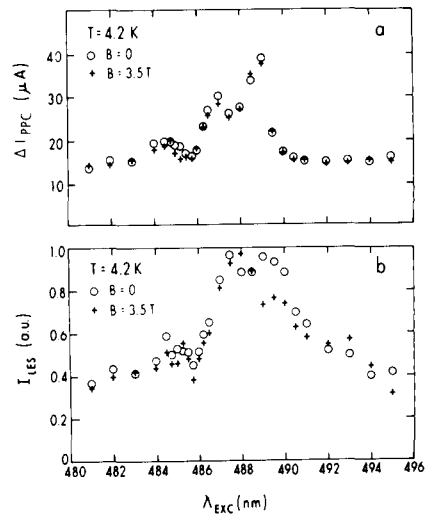

FIG. 2. Simultaneous excitation spectra of Δi_{PPC} and I_{LES} averaged over excitation pulses 3 - 6, for magnetic field 0 and 3.5 Tesla.

be a manifestation of spin-polarization dependent dynamics[9]. These experiments give useful information on aspects of PPC not usually probed, but they do not at this stage yield an unequivocal answer as to the nature and conduction mechanism of the stored charge. Spectrally-sensitive PPC decay and magnetoresistance experiments at various stored-charge states should clarify the roles of surface barrier and D^- complexes in the PPC process, and are now in progress.

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