Spin Sensitive Dynamics of a Charged Exciton in Magnetic Fields

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Recently, it became possible to realize two-dimensional electron gas having high density and mobility in dilute magnetic semiconductor (DMS) quantum structures. There have been a large number of reports on charged excitons in samples with a low electron density. There are, however, a few studies for those at high electron density. Charged exciton is composed of two electron1s (hole) and one hole (electron). Therefore photoluminescence of charged excitons in semiconductor strongly depends on spin states of the electron and the hole, and also on Landau level splittings. We have observed continuous wave (cw)-photoluminescence (PL) and time-resolved photoluminescence spectra of modulation n-doped $Cd_{1-x}Mn_xTe/Cd_{1-y}Mg_yTe$ (x = 0.018, y=0.147) single quantum wells (electron concentration $n=2\times10^{11}$ /cm^2) [1]. We could have shown that the time decay of the PL spectra have an important information identifying the origin of the charged exciton spin characteristics.

Figure 1 shows peak energies of PL obtained by cw-light excitation. In the absence of magnetic field, the main PL arises from spin-singlet charged excitons (X_s^-). On increase of the field, PL of X_s^- showed a red shift in σ^+ component, while the σ^- component vanished. Above 1.6 T a new peak appeared as spin-triplet charged excitons (X_{t1}^-) at low energy side of X_s^-. Further increasing of magnetic field lead to vanishing of X_s^-, and the another peaks appeared due to landau level transitions (L_2, L_1, L_0) and triplet charged excitons (X_{t0}^-) at high energy side of X_{t1}^-. Here, X_{t1}^- and X_{t0}^- are transitions from the spin-triplet charged exciton state to the conduction Landau level 0 and 1, respectively. Figure 2 shows a transition diagram of charged excitons summarizing present data.

The time-resolved spectra is shown Figure 3 at various magnetic fields. At 0 T the decay time of X_s^- is 130 ps, whereas at 2T the decay time of X_s^- and X_{t1}^- are respectively 150 ps and 140 ps. The observed fast decay time of X_{t1}^- is well explained by the fact that the PL comes from the recombination of a charged exciton of the bright triplet, which are described by a transition from electrons of the spin –1/2 to the hole of the spin -3/2. At 7 T the decay time of Xt_0^-, Xt_1^-, are 110 ps and 150 ps, respectively. Whereas, L_0 and L_1 are respectively 100 ps and 30 ps. The recombination of inter-landau level transitions are considered to show faster decay time than that of charged excitons. The decay time of n=0 inter-Landau transition (L_0) could be exceptionally longer than those of high Landau numbers.

Figure 4 shows the time decay of charged exciton PL at 0 T. We have observed striking change of the decay profile depending on the exciting energy. High energy excitation (400 nm) gives rise to a longer decay time of about 500 ps in comparison to the case for low energy resonant excitation (730 nm). This is probably because more efficient formation of the charged excitons with dark and bright spin triplet type when excited by a higher energy and causing increased number of the spin flip scattering event during the energy relaxation into the band bottom.

[1] S Takeyama, *et. al.*, *Proc. of 26th International Conference on the Physics of Semiconductors*, 29 July - 2 August 2002, Edinburgh, Scotland, U.K.

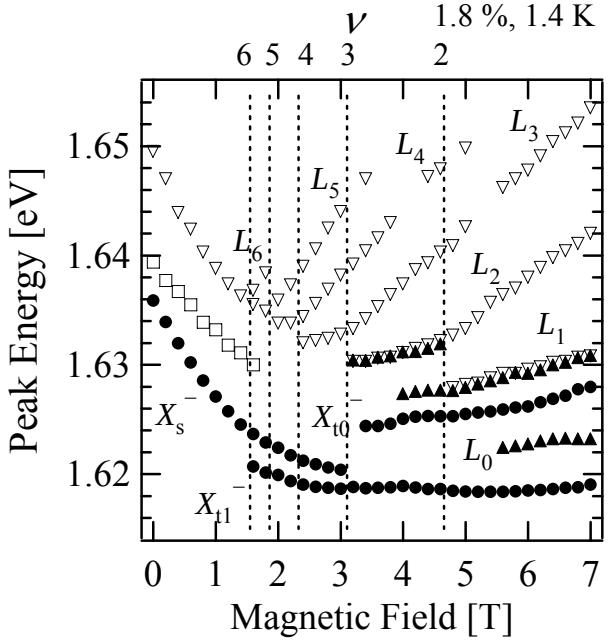

Fig. 1. Peak energies of σ^+ PL are denoted by solid marks. Absorption peaks are indicated by open marks. PL of X_s^- and X_t^- arise from charged excitons. The peak marked by L_n is from inter-landau level transitions.

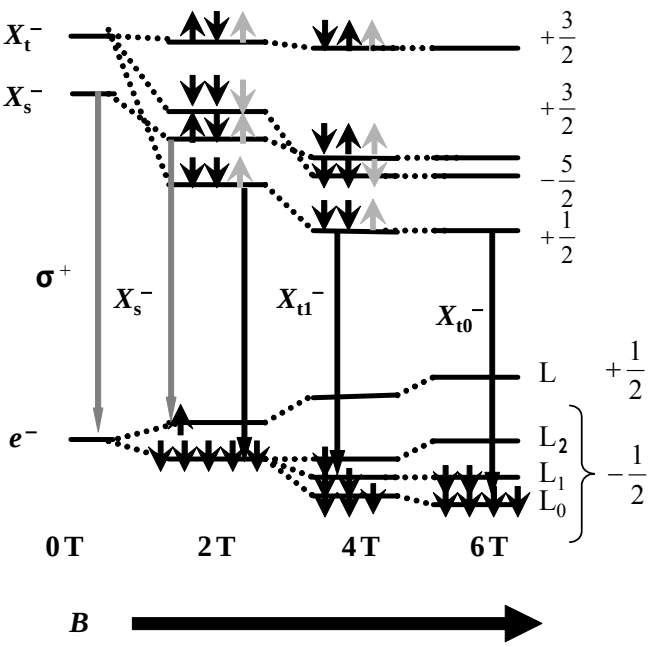

Fig. 2. Photo recombination transition diagram occurred at various magnetic fields in the present 2DEG system.

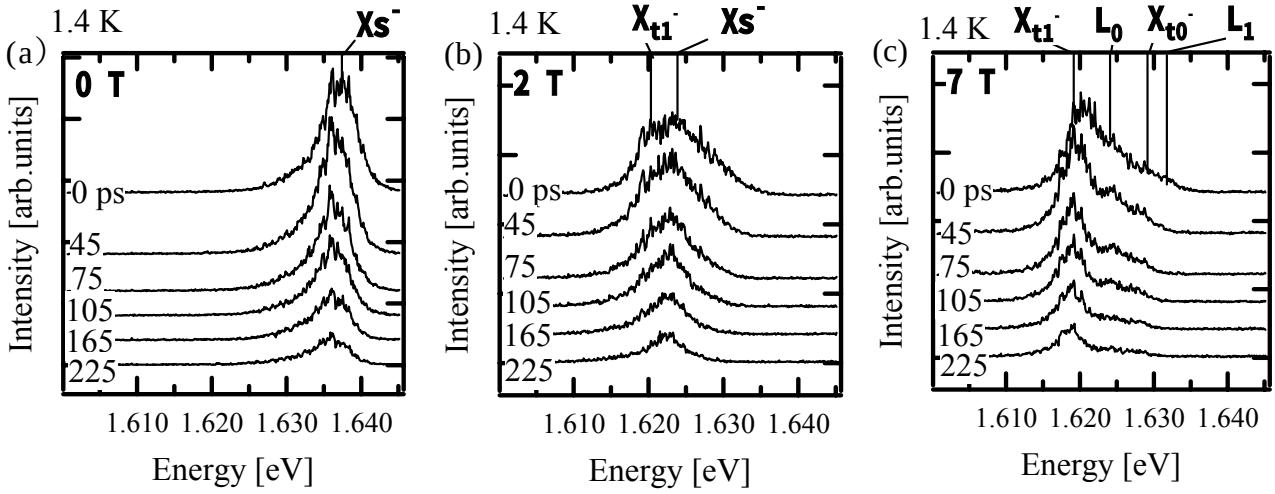

Fig. 3. Time evolution of PL spectra at magnetic field: (a) 0 T, (b) 2 T, and (c) 7 T, temperature: 1.4 K. Excitation laser power density was set to 1.0 W/cm^2 at λ = 730 nm.

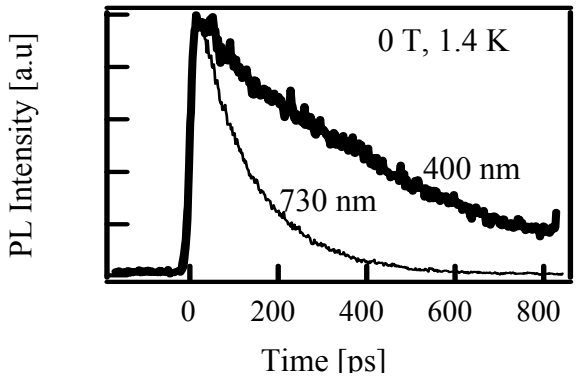

Fig. 4. Time decay of spin-singlet charged excitons observed by excitation at 730 nm and 400 nm at 0 T. Note that PL of 400 nm showed much longer decay time than that at 730 nm.