Charged Excitons in Modulation n-doped $Zn_{1-x}Mg_xBe_ySe$/ZnSe/BeTe Type II Quantum Wells

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A number of studies reporting on the exciton-electron complexes, called charged excitons, in various quantum structures appeared in recent years. The charged exciton nowadays is an essential subject for understanding optical processes in such structures with intentionally or un-intentionally doped. There are, however, very few reports on charged exciton optical processes in type II quantum wells, where a two-dimensional electron and a hole are spatially separated. We have attempted to investigate possible occurrence of charged exciton transitions in a modulation n-doped ZnSe/BeTe type II quantum well.

The structures were constructed on (001)-GaAs substrates by molecular beam epitaxy. Efficient modulation doping was achieved by $ZnCl_2$ remote doping in a $Zn_{1-x}Mg_xBe_ySe$ (x=0.15, y=0.08) barrier layer. The n-doping level was controlled by the distance from the interface from the well. For the purpose of comparison, we have prepared three samples, one without doping, and the other two with different doping levels. From all the samples clear and typical type II photoluminescence spectra were observed when excited by a double frequency of Ti: Sapphire laser, 400 nm (above the ZnSe band-edge energy). The main peak around 1.87 eV is accompanied by LO-phonon replicas at its lower energy side. Doped samples exhibited a broader main peak with the peak energy at lower than those of non-doped. The main peak in non-doped one increased its intensity much more than those of doped on decreasing temperature. The behavior is very similar to the photoluminescence peak denoted as A-transition observed in ZnSe/BeTe quantum wells[1]. The transition A, which showed super-linear dependence of the intensity on the excitation laser power, is considered there as a consequence of the condensed state of excitons. In our doped samples, however, the spectra were dominated by the lower energy peak assigned as B, whilst the A-peak is suppressed. This fact is interesting in a sense that a doped electron gas resulted in substantial influence on the type II anomalous photoluminescence spectra, suggesting the B peak as charged excitonic origin.

The reflection as well as the absorption spectra have shown the heavy- and the light-hole transition discernible structures at an energy around 2.84 eV, which is a typical of a direct band edge of the ZnSe layer. At the low energy side of the heavy-hole peak there observed a shoulder only in doped samples. The absorption and the reflection measurements with right- and left- circular ($\sigma+$ and $\sigma-$) polarizations in magnetic fields showed typical negatively charged exciton characteristics for the shoulder structure. The shoulder peak became more enhanced with increasing magnetic field for the $\sigma-$ polarization, while disappeared in $\sigma+$ polarization, obeying the typical of the spin selection rule for the negatively charged excitons with a singlet spin configuration.

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

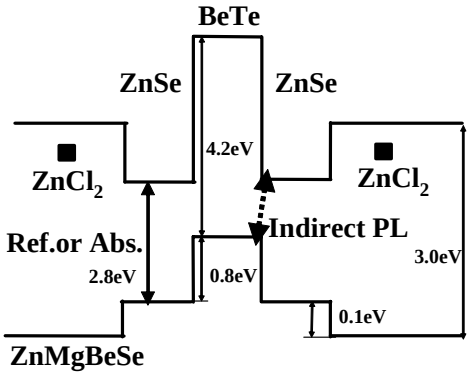

Figure 1. Quantum construction of the type II quantum well sample which was designed for efficient modulation doping. Cl was used as a dopant in the $Zn_{1-x-y}Mg_x$ Be_YSe (x=0.15, y=0.08) barrier. Two-dimensional electrons locate at ZnSe layer (L_{ZnSe}=7.9 nm), while holes in BeTe layer (L_{BeTe}=2.8 nm).

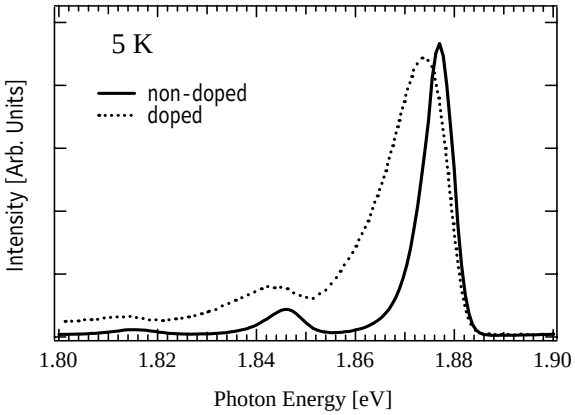

Figure 2. Type II indirect photoluminescence spectra of doped and non-doped samples.

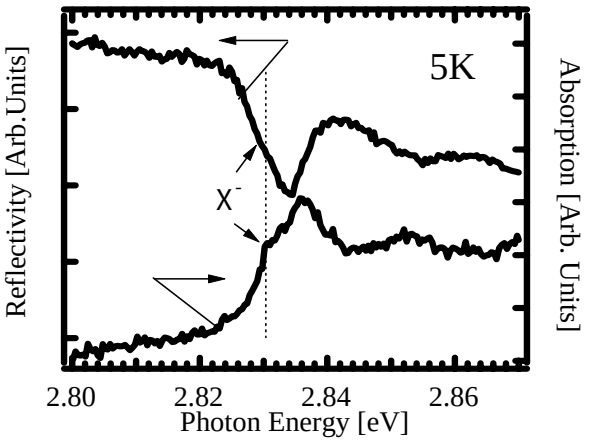

Figure 3. Absorption and reflection spectra of a n-doped quantum structure at band-edge of ZnSe layer at 5 K. Charged exciton transition X^- is indicated on both data.

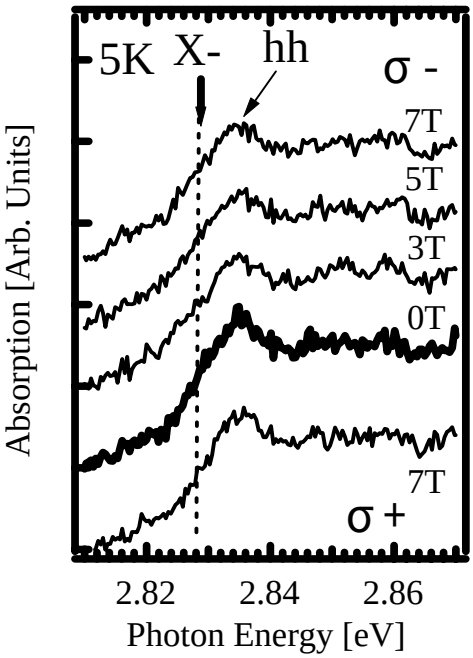

Figure 4. The absorption spectra of the doped sample in magnetic field for both polarization σ+ and σ-, respectively at 5 K. The new structure denoted by X^- is considered as a charged exciton transition, showing suppression of the shoulder peak at 7 T in σ+ polarization.