Excitons and Trions in Heavily Doped QW Structures at High Magnetic Fields

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Modification of photoluminescence spectra taken from modulation doped CdTe/CdMgTe single quantum well (QW) structures have been studied in magnetic fields up to 45T as a function of 2D electron concentration in the QW.

We studied modulation-doped CdTe/($Cd_{0.7}Mg_{0.3}$)Te quantum well structures with a 2DEG of low, and moderate density (from $n_e<10^{10}$ up to 10^{12} cm^{-2}). The structures contained 100 Å single quantum well (SQW) and were δ-doped in the barriers at 100 Å distance from the QW. A special design of the structures made it possible to control the electron concentration keeping all other parameters constant with high accuracy.

The following peculiarities were found in relatively low magnetic fields for the samples with high electron concentrations when filling factors was higher than ν=2: (*i*) linear energy shift of the photoluminescence (PL) peak with increasing magnetic fields, (*ii*) periodic variation of PL intensities with maxima at even filling factors for σ^- and at odd ones for σ^+ circular polarizations, (*iii*) smooth jumps of the PL peak at integer filing factors. At high magnetic fields when filling factor becomes less than 1, conventional diamagnetic shift of exciton and trion PL lines were observed for all samples regardless of the 2D electron concentration. A photoluminescence line connected with a triplet trion state has been found in magnetic fields higher than 25T.

The observed behavior is interpreted in a frame of a model, which takes into account combined exciton electron recombination processes. In the absence of magnetic field we have a trion in an initial state. The binding energy of this trion, of course, depends on the electron density because of screening, but in 2D case a weakly bound state still remains despite of screening. After the trion annihilation we have a photon plus one electron in the final state: $\mathrm{T}r \to \hbar\omega_{tr} + e^*$. This residual electron e^* can be placed in the empty states above the Fermi level only. Consequently, the energy of the emitted photon is: $\hbar\omega_{tr} = E_{Tr} - E^*$, here: $E^* \in (E_F, \infty)$ is the energy of the residual electron, E_{Tr} is the energy of the trion in the initial state. Although the residual electron after the trion annihilation can have any energy from the Fermi energy to infinity, the probability of such processes decreases rapidly with increasing of the electron energy. So, the maximum of the PL intensity is expected to be located at the energies close to $(E_{Tr} - E_F)$.

Therefore, the maximum of the trion PL line in heavily doped samples at zero magnetic fields is shifted to lower energies from the trion PL line position in comparison with undoped samples. The value of this shift is of the order of the Fermi energy. In the presence of magnetic fields the Fermi energy goes down and the PL peak shifts closer to the trion energy. It shifts jumping from the higher Landau levels to the lower Landau levels as higher Landau levels become empty until it reaches the trion energy. It happens just when the filling-factor is equal to 2. The jumps are more or less smoothed due to Landau level temperature and disorder induced broadening. At the lowest filling factors (ν<2) we observe a conventional excitonic/trionic behavior.