Spectroscopy of Excitons in a Single ZnO/(Zn,Mg)O Quantum Well

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Zinc Oxide is a wide-bandgap material with a high exciton binding energy of 60 meV. As a result, binding energies of charged excitons in ZnO based low dimensional structures should be substantially larger than in their counterparts based on other semiconductors.

The sample used in our studies contains a single 2 nm wide ZnO quantum well embedded between Zn0.79Mg0.21O barriers. It is grown by molecular beam epitaxy on a-plane sapphire substrate. Measurements of transmission and photoluminescence (PL) in magnetic field up to 10 T applied in Faraday geometry, as well as of time-resolved PL have been performed at cryogenic temperatures.

The PL spectra indicate that the QW emission consists of a strong peak at 3.41 eV and a much weaker peak at 3.43 eV (see Figure 1). Absorption spectra confirm presence of two transitions related to the QW. Both transitions exhibit lifetime of about 4 ns, but different dependencies of emission intensity on excitation power suggest their different formation mechanism.

The PL transition at 3.41 eV exhibits a clear circular polarization in the magnetic field with much stronger σ+ component. The 3.43 eV transition practically does not polarize in the magnetic field. These findings can be explained in a consistent manner if 3.41 eV transition originates from recombination of negatively charged exciton X-, while 3.43 eV of neutral exciton X, both related to the highest valence subband of Γ7 symmetry. In such a case, the X- spin splitting is defined by a negative Landé factor of the minority carrier, that is Γ7 hole. In consequence, the X- thermalization to the state of lower energy, involving the hole with mJ = +1/2, enhances the X- signal in σ+ polarization. Accordingly, Landé factor of the X is negligible due to cancellation of positive Landé factor of electron with the negative one of the Γ7 hole (both assumed as for bulk ZnO). This results in negligible splitting and lack of apparent emission polarization of the X in magnetic field.

The X- binding energy extracted from the optical spectra attains a record value of 20 meV. It is much more than a few meV typical for other QW systems and than 13 meV found previously for 4.5 nm wide ZnO/(Zn,Mg)O multiple Quantum Wells [1]. The reported on X- binding energy agrees very well with the prediction from the semi-empirical formula published by Sergeev [2], what supports the presented interpretation.

Observed large X- binding energy and resulting increased stability of charged exciton complex is beneficial for coherent control of a QW confined carrier spin and for implementation in low-threshold lasing devices.