Agnieszka Pieniążek
Institute of Physics PAS

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Local optical properties of ZnO microrods grown by hydrothermal method

Zinc oxide (ZnO) has a great potential for use as a functional material in blue/ultraviolet spectral range optoelectronic devices working at room temperature, due to its wide direct bandgap of 3.37 eV at room temperature and significant exciton binding energy of 60 meV. Today, a variety of growth techniques e.g. metalorganic chemical vapor deposition, molecular beam epitaxy, atomic layer deposition, and hydrotherm al method provides research with rich family of ZnO nanostructures. Advantageous features of ZnO nanostructures, including nanorods are e.g. high surface-to-volume ratio, possible dimensional confinement of the charge carriers, subwavelength optical phenomena, support for whispering gallery modes and a large number of extrinsic and intrinsic deep-level impurities that can emit light of different color, including blue, green, yellow and red. All these features can be applied in sensors and detectors.

In order to realize the potential of ZnO for practical applications, stable and reproducible *p*-type ZnO must be fabricated. The synthesis of *p*-type ZnO has proven to be difficult due to native point defects present in the material acting as donors and determining *n*-type conductivity of ZnO. Bulk and surface defects control electrical and optical properties of ZnO and, respectively, the characteristics of devices with ZnO-based building blocks. It is therefore crucial to identify and remove/create defects in ZnO to be able to incorporate acceptors and reduce effective donor concentrations.

Another necessary step for efficient exploitation of ZnO in optoelectronics is to introduce quantum heterostructures into ZnO nano- and microrods. The wavelength of light emitted by the heterostructure can be tuned by changing the quantum well thickness and the composition of the barrier. The increase in ZnO bandgap energy can be achieved with Mg doping and the light emitting properties of the formed ZnO/$Zn_{1-x}Mg_xO$ quantum structure could be significantly enhanced compared to pristine material.

The general aim of this work is to deepen our knowledge about the ZnO electronic states and optical transitions related to impurities and defects, as well as to find the dependence of the structural and optical properties of ZnO microrods on growth and annealing conditions. Optical properties of the individual ZnO microrods grown by a microwave-assisted hydrothermal method have been investigated by spatially and spectrally resolved cathodoluminescence spectroscopy and imaging. The detailed investigation of impurities, defects and lattice dynamics of ZnO has been performed. As a consequence, ZnO growth and annealing conditions are optimized to obtain the microrods with low concentration of intrinsic point defects, especially ones with donor-like behavior and strong excitonic emission.

As a result, for ZnO microrods grown in the optimized conditions strong localization of cathodoluminescence at the six corners of the individual microrod has been revealed. Locally distributed luminescence and fine structure of near-band-edge emission was analyzed as a manifestation of whispering gallery modes of the hexagonal resonator. The optical resonance phenomena have been confirmed. Changes in the ZnO microrod emission were observed as a function of the excitation power, which can be associated with the transition from the exciton gas to electron-hole plasma conditions.

While synthesis methods for the pure ZnO nano- and microrods are well established, an efficient technique for growth of the ZnO-based microrods that incorporate a quantum structure is still to be developed. Here, the report on the successful fabrication and optical properties of an axial $Zn_{1-x}Mg_xO/ZnO/Zn_{1-x}Mg_xO$ quantum well deposited on the top of the hydrothermal ZnO microrods by molecular beam epitaxy is presented. Comprehensive cathodoluminescence studies of local optical properties of the individual $Zn_{1-x}Mg_xO/ZnO/Zn_{1-x}Mg_xO$ axial microrod structures containing single and multiple quantum wells have confirmed the growth of the axial heterostructure on the *c*-plane of the microrods.

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