Photoluminescence Dynamics in Core/Shell ZnTe/ZnMgTe Nanowires: Impact of Temperature and Shell Thickness

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Semiconductor nanowires (NWs) are attractive for a variety of applications e.g., in quantum information technologies and novel optoelectronic devices, such as light emitting diodes, lasers and high electron mobility transistors. In order to achieve high efficiency devices, the understanding of the recombination dynamics of excitons in such one dimensional systems is essential.

In this report, we study time-resolved photoluminescence (TRPL) of an ensemble of core/shell ZnTe/ZnMgTe NWs, and on single ones. The nanowires were grown in a molecular beam epitaxy chamber applying vapor−liquid−solid (VLS) mechanism. The growth occurred on Si substrate, using gold droplets as catalyst. In order to investigate single NWs, we ultrasonically remove the wires from the substrate and disperse them onto a silicon wafer. Time-resolved PL was excited at 505 nm by a frequency doubled output of an optical parametric oscillator pumped with a pulsed Ti:sapphire femtosecond laser. The laser beam was focused onto a ~2 µm spot with a microscope objective and the PL signal was detected using a streak camera. The time resolution of the system was about 10 ps. Measurements were carried out in temperature range between 5 K and 100 K.

The impacts of temperature and shell thickness on exciton lifetime are investigated. We find that the PL lifetime increases with increasing ZnMgTe shell thickness, as a result of reducing tunneling probability of carriers out of the core to nonradiative trap states. Individual nanowires exhibit a single exponential decay. In contrast, PL decays from the ensemble of NWs exhibit a nonexponential decay, independent of the excitation intensity. We interpret the short decay as resulting from the radiative recombination and the trapping of the excitons at the non-radiative states. The long decay is attributed to reexcitation of the trapped excitons back to radiative states. When the temperature is increased a significant shortening of the PL decay is observed. This shortening results from a thermal activation of non-radiative carrier recombination. The PL decays are modeled by rate equations, which allow to extract the temperature dependence of the characteristic times of the involved processes.

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