GaAs-AlGaAs nanowire quantum well tubes: self-assembly and nano-scale spectroscopic imaging

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III-V compounds nanowires (NWs) have attracted considerable research interests in recent years, due to their potential applications to novel nano-scale photonic devices, such as nano-lasers, photo-detectors and solar cells. Radial modulation of NW composition to form core-(multi)shell hetero-structures impacts the design of such nano-devices by adding new degrees of freedom associated to quantum confinement [1,2]. Understanding of their nano-scale optical (radiative) properties and correlation with their self-assembly mechanisms are however, necessary to gain full control over their epitaxial growth.

In this work we report on the metalorganic vapor phase epitaxy (MOVPE) of free-standing GaAs-AlGaAs core-multishell NW quantum hetero-structures, their spectroscopic characterization by low temperature photoluminescence (PL) and cathodoluminescence (CL) measurements, and their correlation to the nanostructure dimensions. Dense arrays of vertically-aligned GaAs NWs were fabricated by Au-catalyzed self-assembly, and radially overgrown by two AlGaAs shells between which a few-nm thin GaAs shell was introduced to form a quantum well tube (QWT). Besides the free-exciton emission of the GaAs core, the PL spectra of present NWs show an additional broad peak at higher energy ascribed to recombination of electron and hole confined states within the GaAs QWT, whose emission blue-shifts with shrinking of the QWT thickness. CL imaging performed in a field-emission scanning electron microscope (FE-SEM) enabled to spatially resolve these emissions and to observe spatial inhomogeneity of the GaAs QWT emission along the NW trunk, further ascribed to thickness fluctuations of the QWT. Moreover, AlGaAs emission channels related to unintentional formation of Al-rich alloys within the nanostructure (as result of the Au-catalyst assisted growth mechanism [3]) is evidenced close by the Au-catalyst droplet. Present findings are discussed based on self-assembly mechanisms of NWs.

References

[1] Saxena et al., Nano Lett. 16 (2016) 5080.
[2] Fickenscher al., Nano Lett. 13 (2013) 1016.
[3] Scuderi et al., Mater. Sci. Semicond. Proc. 65 (2017) 108.

Figures

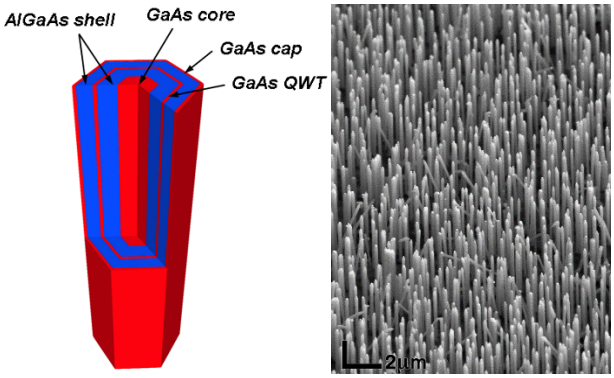

Figure 1. (a) 3-dimensional schematic of a GaAs-AlGaAs core-multishell NW quantum structure; (b) FE-SEM micrographs (45°-tilted view, 10,000× magnification) showing the morphology of as-grown GaAs-AlGaAs core-multishell NWs vertically standing on their original (111)B-GaAs substrate.

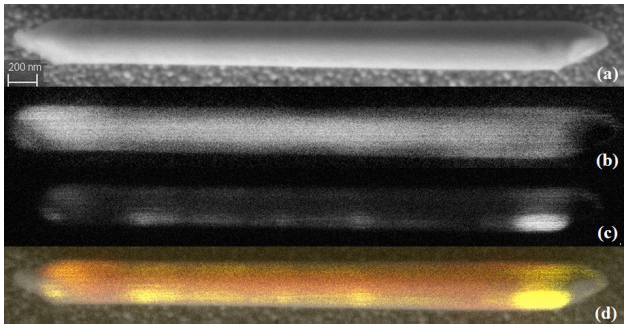

Figure 2. (a) FE-SEM micrograph of a single core-multishell NW. Monochromatic CL images of the NW emission recorded at (b) 1.507 eV (core emission) and (c) 1.540 eV (QWT emission). (d) color-coded (red: core; yellow: QWT) superposition of the two images in (b) and (c).