

### III-V nanowire heterostructures for quantum technologies: from 1D to 0D quantum confinement

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Future quantum communication based on solid state platforms requires developing novel single photon sources (SPSs) integrated into photonic chips. Semiconductor quantum dots (QDs) based on epitaxial nano-structures have demonstrated considerable potentials for fabrication of SPSs [1]. Free-standing III-V compound semiconductor nanowires (NWs) represent a promising material platform for SPS. Indeed, QD in NW (QD-in-NW) structures have been proposed as convenient platforms for fabrication of future SPSs. Among major advantages are (i) the release of structural constraints in the choice of different materials, and (ii) improved light extraction due to the NW wave-guiding effects.

Both radial (core-multishell) and axial composition-modulated heterostructures are being studied to exploit quantum-confinement in III-V NWs. In core-multishell NWs, size quantization from 2D to truly 1D is demonstrated; 0D quantization could be further obtained in these structures due to potential/size fluctuations within the shell materials. Deterministic QD-in-NW structures can be alternatively synthesized by suitable combination of axial and radial compositional modulation of the NWs; single or multiple QDs can then be fabricated within the same NW host, by appropriate mastering of nano-epitaxial (self-assembly) technology.

The optical/structural properties of MOVPE-grown GaAs-AlGaAs core-shell NWs will be presented as example for the first class. The near band-edge absorption of such NWs was studied by spectroscopic analysis. We demonstrate a strong enhancement of the NW GaAs near band-edge absorption with respect to equivalent planar GaAs/AlGaAs structures; a first ever estimate of the GaAs near band-edge absorption enhancement factor (in the 22–190 range) with respect to bulk GaAs is further demonstrated, the actual figure depending on the AlGaAs shell thickness. The result is ascribed to improved wave-guiding of incident light into the GaAs core by the surrounding AlGaAs shell [2].

Insertion of a thin (few nm) GaAs shell in between two AlGaAs barrier shells was grown by MOVPE to form a quantum well tube (QWT) structure. QWT emissions in individual GaAs-AlGaAs core-multishell NWs were studied by low-temperature cathodoluminescence (CL) measurements performed in a high-resolution SEM [3]. Values of the GaAs QWT thickness (within the 3-7 nm range) were extracted for single NWs from SEM-measured NW diameters through a fine-tuned multi-shell growth model, the latter being validated against experimental data (core diameter and GaAs and AlGaAs shell thickness) obtained from HR-TEM investigation of GaAs-AlGaAs QWT NWs. The dependence of QWT emissions on GaAs shell thickness is demonstrated for single NWs and compared with theoretical values, the energy difference being ascribed to exciton localization at QWT thickness fluctuations. Hints of 0D confinement in these structures are presented and discussed.

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