Selectivity Control of InAs Shells on Crystal Phase Engineered GaAs Nanowires

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Crystal phase control in III-V NWs is a promising approach to fabricate quantum dots in NW [1] to inspect fundamental quantum effects [1,2]. By firstly knowing that different facets and crystal structures adopt different surface energies and by secondly having experimental control over their formation, it is possible to enable and control the selective core-shell growth [3]. However, the contours of the growth parameter window resulting in facet-dependent and crystal phase selective InAs growth over GaAs NW cores remain undefined. All NWs were grown by means of Au-assisted Metal-Organic Vapor Phase Epitaxy following the Vapor-Liquid-Solid (VLS) growth mechanism. In this work we demonstrate control over the crystal phase and facet dependent selectivity in the GaAs/InAs core-shell growth and we identify the two key parameters, growth rate and growth time, governing the selective core-shell growth. The observed selectivity occurs either due to the difference in crystal phase, lateral facet termination present in the NW core, or due to both factors. Firstly, to study the crystal phase selectivity mechanism, GaAs NW cores with controlled crystal structure along the axial direction were employed. A crystal phase selective growth of InAs on GaAs was found for high growth rates and short growth times. However, for extended growth times selectivity is lost, i.e. the InAs shell homogeneously covers the entire GaAs core. Secondly, the facet-dependant selectivity mechanism was studied on morphology-tuned GaAs cores, consisting of crystal phase-controlled GaAs NWs, which were homoepitaxially overgrown. After this overgrowth step the GaAs NWs cores evolved from hexagonal cross-sectional NWs with {110} sidewalls to triangular truncated NWs with large $\{112\}_B$ lateral facets together with three small ridges, thus, resulting in morphology and lateral facet termination controlled GaAs NW cores. By precisely controlling the conditions of InAs heteroepitaxial overgrowth, the growth of InAs can be promoted over the ridges and reduced over the $\{112\}_B$ facets and even, additionally maintain the crystal phase selectivity. However, the two types of selectivity studied (crystal phase- and facet termination selective growth) are lost when the growth time is above a critical limit, thus, restricting the total thickness of the shell grown under conditions promoting the selectivity. To overcome this issue, we develop a 2-step growth regime, combining a high growth rate step followed by a low growth rate step. Employing the 2-step growth approach, we demonstrate control over the thickness of the InAs shells while maintaining the selectivity of the growth. By means of a detailed Transmission Electron Microscopy and Energy Dispersive Spectroscopy analysis we demonstrate the preferential shell growth over the ZB segments. Therefore, it is possible to control the thickness of the InAs shells while maintaining the selectivity of the growth, allowing the design of highly complex 3D InAs structures.

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