Catalyst-Free Selective-Area Metalorganic Chemical Vapour Deposition of InGaAs/InGaP Core-Shell Nanowire Arrays

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Abstract

III-V semiconductor nanowires (NWs) offer promising solutions for on-chip light sources in integrated photonics with small device footprint and ultra-low power consumption. Growing NWs by catalyst-free selective-area epitaxy (SAE) offers many advantages, such as the compatibility with silicon manufacturing and the capability to control NW diameter and position precisely. An array of NWs can be exploited as either a 1D or 2D photonic crystal, while every single NW operates as a vertical optical cavity, offering the flexibility for photodetector and laser designs. In this work, we demonstrate catalyst-free selective area metalorganic chemical vapour deposition (MOCVD) of InGaAs/InGaP core-shell NW arrays on patterned n-GaAs (111)B substrates, with an aim to realize high-performance avalanche photodiodes toward single photon sensing at near-infrared (NIR) wavelengths and bottom-up photonic crystal cavities. By carefully optimizing the growth parameters, the core-shell nanowires show a high uniformity in diameter (~180 nm) as well as in height (~1.6 μm), where a vertical growth yield of ~100% was obtained on large area array (50 × 50 μm^2) containing approximately 5,000 NWs. Figure 1 gives a representative 30°-tilted SEM image. Micro-photoluminescence (μ-PL) spectrum at room temperature exhibits a strong emission peak at a wavelength of 1060 nm, corresponding to a 20% In composition of the InGaAs core. Furthermore, the μ-PL results reveal that the use of an $In_{0.5}Ga_{0.5}P$ passivation layer is crucial to minimize the surface recombination and enhance the emission efficiency of the $In_{0.2}Ga_{0.8}As$ core NWs.

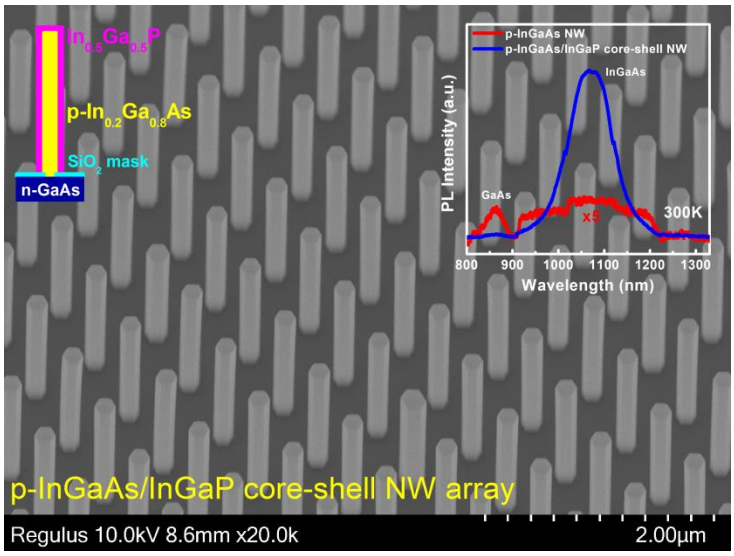

Figure 1. 30° tilted SEM image of $In_{0.2}Ga_{0.8}As/In_{0.5}Ga_{0.5}P$ core-shell nanowire array. Inset is room temperature μ-PL spectra of $In_{0.2}Ga_{0.8}As$ NW arrays with and without $In_{0.5}Ga_{0.5}P$ passivation layer.