Structural and Optical Characterization of Vertical GaAs / GaP Core-Shell Nanowires Grown on Si Substrates

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Abstract: GaAs nanowires were grown on Si (111) substrates. By coating a thin GaAs buffer layer on Si surface and using a two-temperature growth, the morphology and crystal structure of GaAs nanowires were dramatically improved. The strained GaAs/GaP core-shell nanowires, based on the improved GaAs nanowires with a shell thickness of 25 nm, showed a significant shift in emission energy of 260 meV from the unstrained GaAs nanowires.

1 Introduction: GaAs nanowires (NWs) are particularly promising for future optoelectronic devices such as nanowire lasers, owing to the direct band gap and high carrier mobility of the GaAs-based material systems [1]. Obtaining good morphology and high quality GaAs NWs on Si is difficult because the misfit problems between group III-V and IV materials. However, device applications require NWs with uniform diameters and good crystallographic, electronic and optical properties. In this study, we investigate vertical growth of GaAs or GaAs/GaP NWs using a thin buffer layer on Si substrates. A two-temperature growth procedure was used to produce defect-free GaAs NWs suitable for optoelectronic device applications [2], and a strained GaAs/GaP core-shell (CS-) structure was used to tune the bandgap of GaAs NWs.

2 Experiments: GaAs and GaAs/GaP CS-NWs were grown by horizontal flow

metal-organic chemical vapor deposition (MOCVD) reactor at 100 mbar. First, a thin GaAs buffer layer was deposited on HF-etched Si (111) substrates (growth details can be seen in Ref [3]). After the deposition of the buffer layer, the samples were annealed in-situ at 750 °C for 15 minutes under AsH₃ atmosphere. The Si substrates coated with the buffer layer were treated by Poly-L-lysine (PLL) solution to attach Au particles onto the surface. Au particles having a diameter of 50 nm were used as catalysts. After Au attachment was finished, the sample was annealed again under AsH₃ ambient at 600 °C to remove contamination and form the eutectic alloys. GaAs NWs were grown with two-temperature procedure: growth initiated with 1 minute growth at a nucleation temperature of 450 °C. The temperature was then rapidly ramped down to 375 °C whilst growth was maintained for the next 30 minutes. For CS structures, after growth of the GaAs core, GaP shell was grown at 650 °C for 10 minutes.

All NWs were characterized by field emission scanning electron microscopy (FE-SEM), transmission electron microscopy (TEM), and micro-photoluminescence (μ -PL) measurements.

3 Result and Discussion: The NWs grew vertically along the [111] direction on Si (111) substrates coated with a thin GaAs layer [Fig. 1a]. The use of a GaAs buffer layer demonstrates that the interfa-

cial problems related to growth of III-V NWs on Si are eliminated or reduced. Furthermore, the use of two-temperature method results in NWs without tapering [Fig. 1b] and pure zinc-blende structure without any crystallographic defects, such as twins and stacking faults [Fig. 1b-c].

Fig. 1 (a) FE-SEM, (b) TEM, and (c) high resolution (HR)-TEM images showing morphology and crystal structure of vertical, defect-free GaAs NWs grown on Si (111) substrates coated with GaAs buffer layers, respectively

Fig. 2a shows straight, vertical single GaAs/GaP CS-NW which has crayon shaped structure at the tip. The GaAs core NW can be clearly observed to be buried inside the GaP shell [Fig. 2b]. The shell has a hexagonal cross-section [Fig. 2c] and strain contrast due to lattice mismatch between GaP and GaAs ($\sim 3.8\%$) can also be clearly observed [Fig. 2d].

Fig. 2 (a) FE-SEM image with single GaAs / GaP CS-NW and (b-d) TEM images showing high-strained crystal structure inside GaP shell

The low-temperature PL spectrum from GaAs/GaP CS-NWs is shown in Fig. 3. For comparison the PL emission from GaAs NWs without the GaP shell is also shown

for comparison. The PL peak of the GaAs/GaP is at 1.76 - 1.77 eV, shifted by about 260 meV from the GaAs free-exciton peak at 1.515 eV. The shift is due to hydrostatic strain between the GaP shell and GaAs core that increases the effective bandgap of the GaAs [4].

Fig. 3 Micro-PL spectra of GaAs NW and GaAs/GaP CS-NWs on Si substrates

Conclusions

Vertical GaAs NWs and GaAs/GaP CS-NWs were successfully grown on Si (111) substrates using a thin buffer layer. The GaAs NWs have pure ZB structure. PL spectrum of GaAs/GaP CS-NWs shows a dramatic blueshift of 260 meV from bare GaAs NW emission.

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