MBE Growth of GaAs Whiskers on LPCVD Si Nanowire Trunks

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We present the growth of III-V GaAs whiskers on group IV Si nanowire trunks. This merging of III-V and IV technology is accomplished by a combination of low pressure chemical vapor deposition and molecular-beam epitaxy. The resulting single GaAs whiskers have a 6-fold symmetry perpendicular to the {112} facets of the Si nanowire trunks and grow in a wurtzite crystal structure. The hetero-epitaxial growth shows strong luminescence, blue-shifted from zinc-blende GaAs.

Introduction

Nanowires are quickly bridging the gap from fundamental growth research to realized electronic and photonic devices. They present an excellent opportunity to combine materials when the differences in lattice mismatch, thermal expansion coefficients, or polarity prevent layer-by-layer 2D growth. We present the hetero-epitaxial growth of single crystalline GaAs whiskers on Si-nanowire (Si-NW) trunks forming hierarchical structures with a 6-fold symmetry [1]. The hetero-epitaxial growth and the good crystal quality of the Si-NWs and GaAs whiskers were confirmed by high-resolution transmission electron microscopy (HRTEM), powder x-ray diffraction (XRD), photoluminescence (PL), and energy dependent micro-PL measurements.

Experimental

The [111] oriented Si-NWs are grown on a (111) Si substrate utilizing vapor-liquid-solid (VLS) growth with Au colloids, 80 nm in diameter, by low pressure chemical vapor deposition (LPCVD), Fig. 1. HRTEM studies reveal the [111] growth direction of the core Si nanowires (Si-NWs) and cross-sectional HRTEM of the Si-NWs shows that the circumference of the Si-NW is composed of six {112} facet planes. The NW templates are removed from LPCVD and loaded into the molecular-beam epitaxy (MBE) for the GaAs deposition. The sequentially grown branches are single crystalline GaAs nanowhiskers which grow without a catalyst and are perpendicular to the {112} facets of the Si-NW backbone. Powder XRD has revealed that the GaAs whiskers are wurtzite and HRTEM of the NWs shows a [0001] orientation of the wires. The single crystal whiskers grow without observable defects on the SiO_x on the facets of the Si-NW trunk. Various GaAs deposition amounts and temperatures were investigated. Deposition amount (20 – 200 nm) and temperature (450 – 550 °C) were studied. Whisker growth first initiates at the Si-NW tip and whisker length and diameter were found to scale with the GaAs deposition while the temperature influenced the tapering of the whisker. PL measurements on template areas without NWs show no luminescence after GaAs deposition while areas with GaAs whiskers show a peak with a blue-shift of about 30 meV compared to bulk zinc-blende GaAs, Fig. 2. Micro-PL was done on GaAs/AlAs “superlattice” whiskers and shows very bright luminescence from the whiskers and no luminescence from the other areas of the sample.

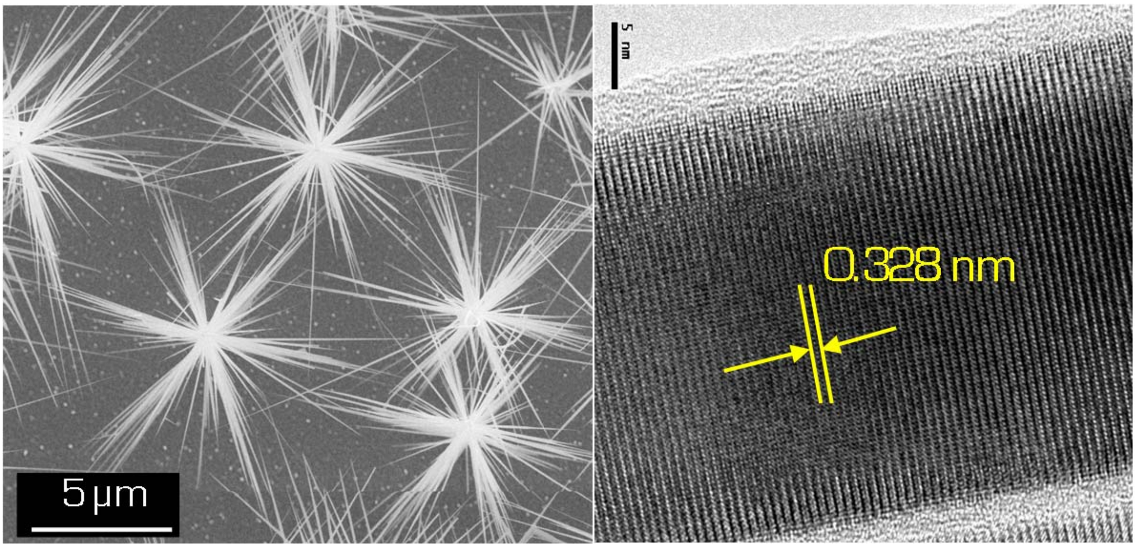

Fig. 1: Scanning electron micrograph of GaAs whiskers grown on Si nanowire trunks. The GaAs forms [0001] wurtzite whiskers on the 80 nm diameter Si-nanowires.

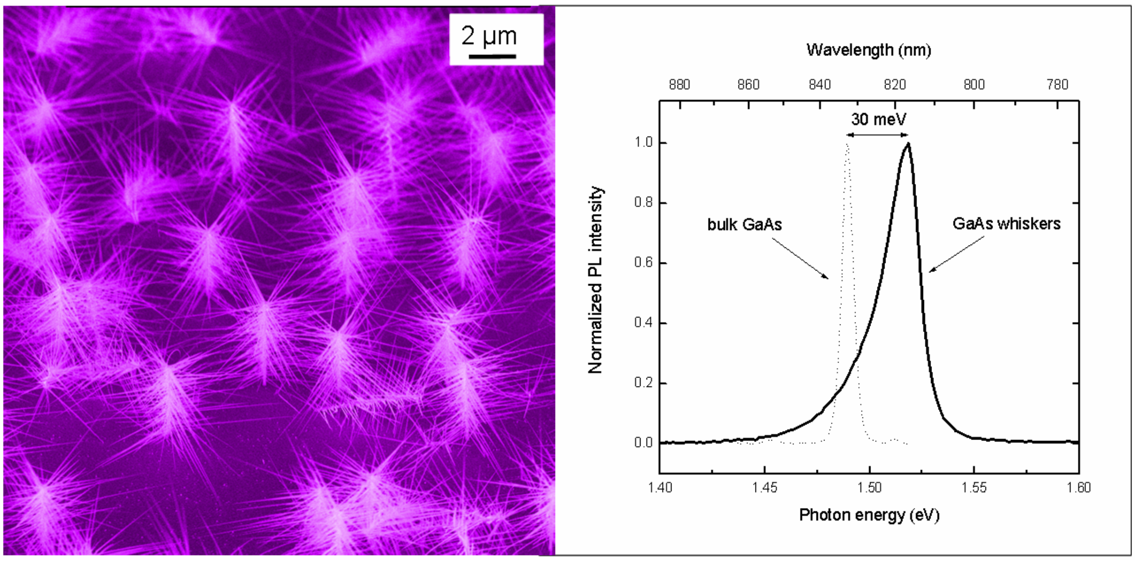

Fig. 2: Scanning electron micrograph of GaAs whiskers grown on Si nanowire trunks with the corresponding photoluminescence spectra. The wurtzite GaAs whiskers show a blue shift of 30 meV compared to bulk zinc-blende GaAs.

Conclusion

The ability to prepare rotationally branched NW structures should open new opportunities for both fundamental research and applications including monolithic 3-dim nanoelectronics and -photonics.

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References

[1] A. Lugstein, A.M. Andrews, M. Steinmair, Y.-J. Hyun, E. Bertagnolli, M. Weil, P. Pongratz, M. Schramböck, T. Roch, and G. Strasser: “Growth of branched single-crystalline GaAs whiskers on Si nanowire trunks”, Nanotechnology, Vol. 18, 2007, pp. 355306-10.