Catalyst-free growth and transport properties of III-V nanowires

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By virtue of their unique properties, self-assembled nanowires (NWs) are the focus of research in various fields, such as nanoscaled transistors, single photon sources and chemical sensors. The possibility of wrapping a gate electrode around the NW makes it possible to drastically improve the electrostatics of a transistor. Adjusting growth parameters, vertical as well as lateral heterojunctions can be incorporated. The small footprint of the nanowires on the substrate surface also allows deposition of highly mismatched systems. In particular, nanostructured Si substrates may provide a compliant substrate for III-V NWs.

Here we demonstrate the catalyst-free deposition of NWs for 3 different systems: the growth of GaN and InN on Si and SiO_2 by MBE, the selective growth of AlGaAs NWs on GaAs by MOVPE and the deposition of InAs and GaAs NWs on GaAs by MBE. Catalyst-free formation avoids the contamination of the semiconductor NWs. Remarkably, using appropriate growth conditions, perpendicular nitride NWs can be grown by MBE both on crystalline Si and amorphous SiO_2 surfaces. Furthermore, AlGaN/GaN quantum structures as well as GaN/InN core-shell structures can be incorporated into the wires. Using MOVPE for the deposition of NWs, selective growth using a SiO_2 mask on a GaAs (111) substrate has been explored, as shown in Fig. 1. Moreover, by switching from $TMGa/AsH_3$ to a $DMEAAl/TEGa/AsH_3$ chemistry, the growth conditions can be switched from a perpendicular growth mode to conformal 3D growth, allowing the deposition of GaAs/AlGaAs core-shell structures. Using this technology, modulation-doped GaAs/AlGaAs NWs have been fabricated. Finally, solid source MBE was used to deposit InAs and GaAs NWs using Ga and In enriched growth conditions to initiate catalyst-free NW formation.

Our NWs have been characterized by magnetotransport measurements at low temperatures. The nanowires were removed from the substrate, spread on the surface of insulated SiO_2 substrates, and contacted using e-beam lithography. Figure 2 shows oscillations of the conductivity as a function of the magnetic field. The oscillations are periodic with the magnetic flux, indicating phase coherent electron transport in the tube like surface enhancement layer of the InN nanowire.

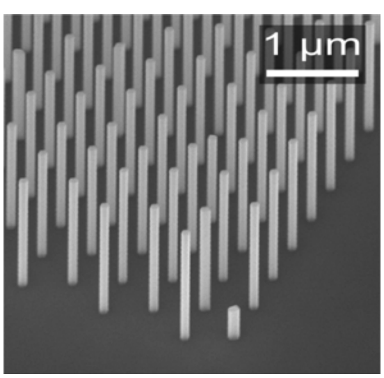

FIG 1. Ordered array of GaAs NWs by selective MOVPE.

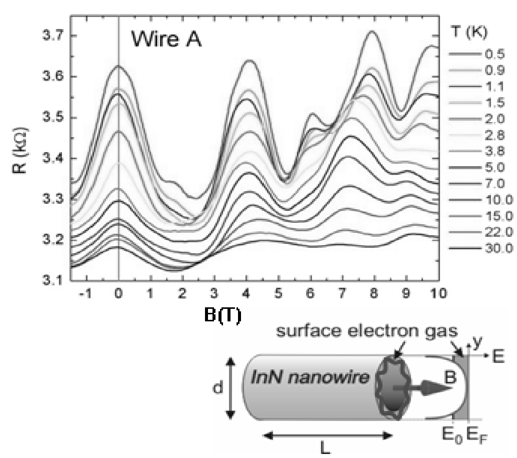

FIG. 2. Flux-periodic oscillations in an InN NW grown by MBE on Si.