III-V nanowires and nanoneedles on silicon

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The heterogeneous integration of III-V optoelectronic devices with Si electronic circuits is highly desirable because it will enable many otherwise unattainable capabilities. However, direct growth of III-V thin films on silicon substrates is very challenging because of high lattice mismatches and thermal coefficients. The use of laterally confined nanostructures shows great promise to overcome these issues. In this talk, I will consider two types of highly anisotropic III-V nanostructures grown on Si: Ga-catalyzed GaAs nanowires [1,2] and core-shell heterostructures in III-V nanoneedles and nanopillars [3,4].

As regards Ga-catalyzed GaAs nanowires, I will review their growth properties and modeling, including a new, “wetting” mode of the vapor-liquid-solid growth, where the Ga droplet entirely surrounds the nanowire tip [2]. It will be shown that such a growth configuration suppresses the crystallographic polytypism on surface energetic grounds, which is why Ga-catalyzed GaAs nanowires (as well as other III-V nanowires catalyzed by group III metals) are usually almost pure zincblende. Some relevant experimental data will be presented to support this theoretical conclusion.

For III-V nanoneedles and nanopillars, I will first discuss the driving force for their self-induced formation and the root structure which helps to either suppress or localize the interface dislocations near the substrate [3]. Then, I will consider a surprising defect-free structure of lattice mismatched InGaAs/GaAs nanopillars. The core diameter typically amounts to 600 nm, the shell thickness is around 160 nm, and the lattice mismatch amounts to 2% for the 20% In content in wurtzite crystal structure. Surprisingly, the transmission electron microscopy studies reveal an excellent crystal quality in the entire pillar with no noticeable defects even though the critical thickness for dislocation formation in GaAs shell is only 10 nm in the thin film case.

To explain the observed effect, a model will be presented that is capable of describing a huge increase of the critical thickness for plastic deformation owing to the core-shell geometry. Finally, continuous wave operation of an InGaAs nanolaser based on these nanopillar structures [3] will be considered.

[1] G.E. Cirlin *et al*., *Phys. Rev. B*, **82**, 035302 (2010).

[2] V.G. Dubrovskii *et al*., *Nano Lett*., **11**, 1247 (2011).

[3] K.W. Ng *et al*., *ACS Nano*, **7**, 100 (2013).

[4] M.V. Nazarenko *et al*., *J. Appl. Phys*. **113**, 104311 (2103)