Nitrogen-induced strain in highly mismatched III-V heterostructured nanowires: a Raman spectroscopy investigation

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III-V semiconductor nanowires (NWs) are good candidates as building blocks in micro-electronic and photonic devices due to their sub-microscale diameters, low defect density, high electron mobility, and direct bandgap. This work investigates the vibrational properties of heterostructured dilute nitride NWs, namely core-shell-shell (CSS) $GaAs/GaAs_{1-x}N_x/GaAs$ NWs [1] with different nitrogen content x up to 4% (Figure 1, left). These NWs are promising for optoelectronic applications such as nanolasers, light-absorbing materials (for photovoltaics and photodetector devices), and telecom light-emitting diodes [2], due to the bandgap-engineering opportunities during NW growth and post-growth.

The purpose of this work is to characterize the effect of strain in these CSS NWs with different N content, namely a blueshift in the phonon modes and a redshift in the energy bandgap with increasing N [3], looking forward to the possibility of achieving controlled strain engineering through alloying and post-growth treatments. Raman measurements were performed to probe the shifts induced in the vibrational modes by compression and expansion of the crystals (Figure 1, right), which can be due to both alloying and strain [4]. The CSS NWs show indeed phonon frequencies largely dependent on the strain condition, arising from the lattice cell mismatch between the $GaAs_{1-x}N_x$ first shell and the GaAs core and second GaAs shell enclosing it. This investigation is being conducted through spatially-resolved photoluminescence and µ-Raman measurements both on the CSS $GaAs_{1-x}N_x$ NW sample and on reference strain-free, phase-pure (zincblende) GaAs NWs with different diameters. The experimental results are supported by numerical calculations of lattice mismatched heterostructures, which predict the optical and phononic properties of a crystal affected by the same axial and radial strain as in our samples, as well as by transmission electron microscopy measurements. The proposed method can potentially be used for investigating strain in different core-shell-shell heterostructures.

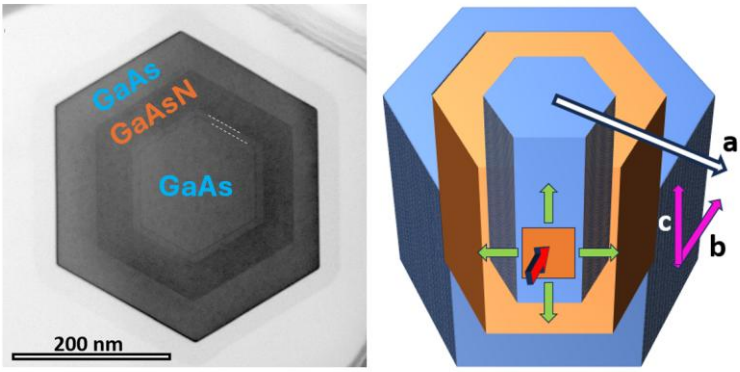

Figure 1. Cross-sectional TEM image of the CSS NWs [1] and related strain diagram [3].

[1] M. Yukimune *et al.*, Appl. Phys. Lett. 113, 011901 (2018)
[2] I. A. Buyanova, W. M. Chen, Nanotechnology 30, 292002 (2019)
[3] Pallucchi *et al.*, in preparation (2025)
[4] L. Balaghi *et al.*, Nat. Comm. 10, 2793 (2019)