Unlocking the potential of GaAs nanowires for telecom photonics

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Strain engineering is a powerful tool in designing nanowires with tailored properties for a variety of applications. By carefully controlling the built-in strain in nanowires, it is possible to tune their bandgap to the near-infrared region, making them ideal for applications in telecommunication and imaging. In our previous work, we demonstrated that in GaAs/$In_xAl_{1-x}As$ core/shell nanowires, the bandgap of the core can be narrowed by up to 40%, for x up to 0.54, via strain due to the lattice mismatch between the core and the shell [1]. Here, we explored the upper end of the lattice mismatch regime, extending the same concept to In contents of the shell towards x=1, achieving unusually high strain values. The strain in the core and its effect on band structure are studied by a combination of spectroscopic methods and high resolution transmission and scanning-transmission electron microscopy (HR(S)TEM). Raman spectroscopy showed that the tensile strain in the GaAs core increased linearly with increasing the In content in the shell (Fig. 1a), following the trend we reported in the past for lower values of x [1]. This behavior suggests the absence of plastic relaxation despite the very large lattice mismatch between the core and the shell. Using cross-sectional and longitudinal HR(S)TEM observations, we assessed the strain distribution normal and along the nanowire axis (Figs. 1b to 1d), which was found to be in good agreement with finite element and molecular dynamics simulations. Above a critical x value, plastic relaxation set in via dislocations (Fig. 1b). We also correlated the photoluminescence emission properties with the strain distribution in the core and the shell, and the corresponding band alignment via band structure simulations. All in all, our results identified the limits of coherent core/shell heterostructures and the potential application of tensile strained GaAs nanowires for C- and O-band telecom photonics.

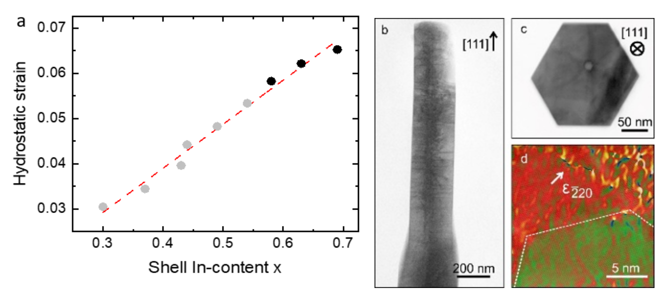

Figure 1. (a) Hydrostatic strain vs. In-content x in the shell measured by Raman spectroscopy on single nanowires. Black and grey symbols correspond to samples from this work and previous work [1], respectively. (b and c) Longitudinal TEM and cross-sectional STEM images from a relaxed GaAs/InAs nanowire. (d) Strain map obtained from a core-shell interface of (c) using processing of a probe-corrected HRSTEM image by geometrical phase analysis.

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[1] L. Balaghi et al., Nature Commun **10**, 2793 (2019); Nature Commun **12**, 6642 (2021).