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Exploring the structural and electronic properties of nanowires at their mechanical limits

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The drive towards smaller and more efficient electronic devices has resulted in an increased need to understand the physical properties of nanostructures, such as semiconductor nanowire (NW) crystals [1,2]. The shape and size of nanowire crystals offer new prospects, which do not only rely on electron confinement effects, but also offer the possibility to manipulate the intrinsic properties by elastically bending and stretching the NWs up to the limit of plastic deformation.

Here we report on the simultaneous biasing/deformation in the TEM to explore the structural and electronic properties of Group III-V NWs at their mechanical limits. Figure 1a and b show HRSTEM images of InAs and InAs/GaAs core-shell NWs grown on Si by MBE. In-situ TEM experiments were performed on a FEI Titan microscope equipped with PI-95 PicoIndenter (Hysitron, Inc.). NWs were mounted in a specialized sample holder that enables applying strain while measuring the electrical resistance of individual NWs. Figure 2a and b are snapshots in a DualBeam FIB, where a NW is transferred using a microprobe on to a MEMS-based electrical Push-To-Pull (EPTP) device (Hysitron, Inc.). I-V curves were recorded at gradually increased strain state. Figure 3a displays the I-V curves for InAs NW showing the decrease in resistivity with increasing tensile strain. Both InAs and InAs/GaAs NWs show linear dependence with respect to tensile strain as shown in Figure 3b. Larger decrease in resistivity was observed for InAs/GaAs core-shell NWs as compared to InAs NWs. Decrease in resistivity under axial tensile strain can be attributed to increase in mobility rather than a change in carrier density.

In this contribution we will cover the guidelines for simultaneous biasing-deformation of NWs including sample preparation and experimental setup for in-situ TEM as well as data analysis to correlate the structural and electronic properties at the nano-scale.

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[1] P. Krogstrup et al. Nature Photonics 7, 306 (2013)
[2] Mourik et al. Science, 336, 6084 (2013)

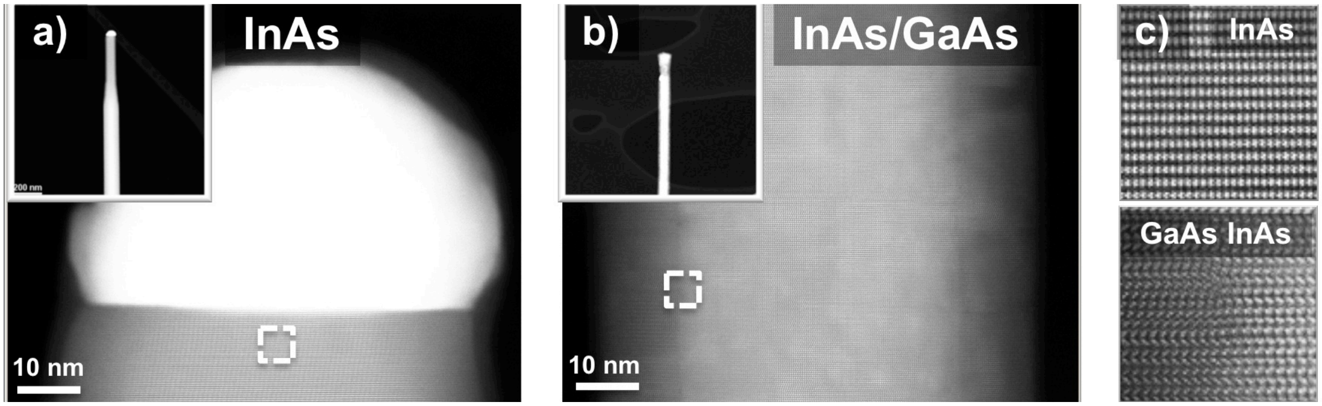

Figure 1 HRSTEM images of an InAs (a), and InAs/GaAs core-shell (b) NWs. Atomic-resolution images of InAs and InAs/GaAs core-shell interface are shown in (c).

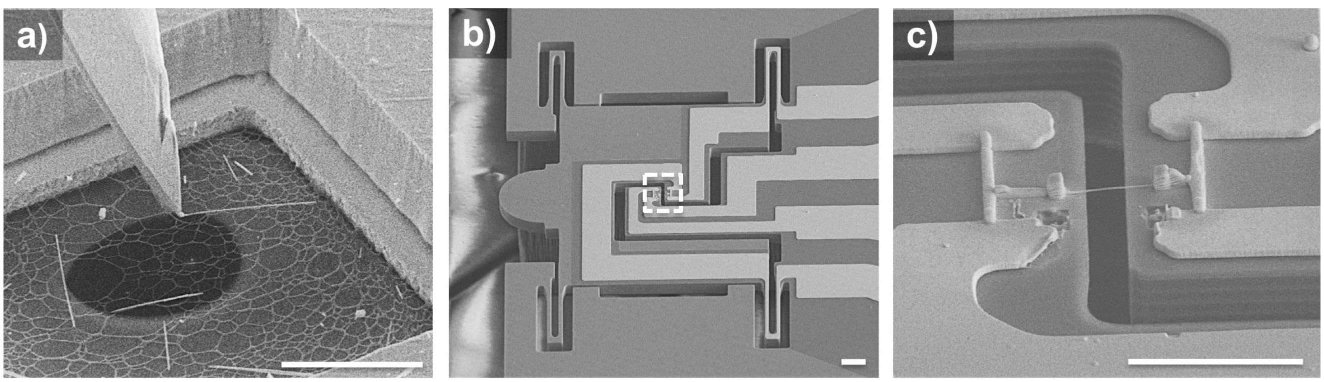

Figure 2 a) SEM image of a NW being transferred using a microprobe. b) MEMS-based electrical push-to-pull (EPTP) device for simultaneous biasing and straining. c) NW is attached to EPTP by means of e-beam Pt deposition. Scale bar = 10 µm.

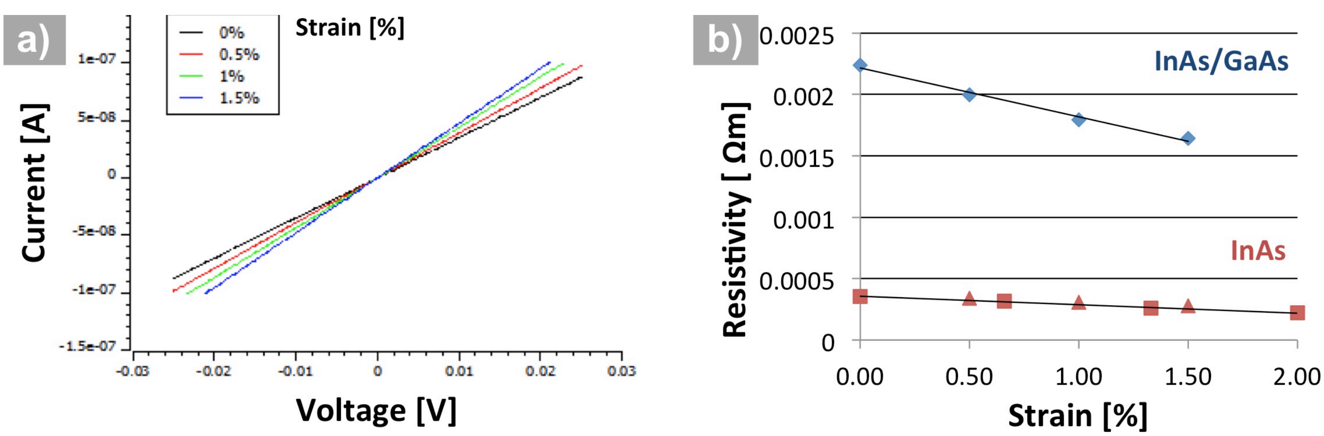

Figure 3 a) I-V curves for InAs NW at different tensile strain states. b) Resistivity vs. strain curves for InAs/GaAs core-shell and InAs NWs showing linear dependence.

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