Investigation of Surface-near Charge Carrier Transport in Depleted GaAs Nanowires

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Nanowires have been proposed for various electronic and optoelectronic applications including FETs, LEDs, laser diodes and devices for solar energy conversion i.e. solar cells and water splitting devices. In particular, III-V nanowires grown by the vapor-liquid-solid (VLS) approach have been investigated intensely due to the high performance and flexibility of this class of materials. However, difficulties remain, in particular with respect to the controlled incorporation of dopants in the nanowire structures. Fabrication of high-quality pn-junctions has proved difficult and thus far is marred by excessive reverse currents, leading to degraded device performance. In this context, surface properties are much more critical in nanowires than in planar devices due to the enhanced surface to volume ratio. Surface states can lead to performance-limiting minority charge carrier recombination, and they can also cause band-bending resulting in charge carrier depletion near the surface, or potentially across the whole nanowire.

Dopant incorporation in nanowires has been investigated by several methods, one of them employing a 4-tip STM. This allows to directly probe the electronic properties of the nanowires without removing them from the growth substrate by carrying out 4-point probe measurements where current is passed through the nanowires by one of the STM tips and the potential is probed by two other tips contacting the nanowires at the side. This method has proved particularly valuable in detecting reduced dopant incorporation near the base of the nanowires [1].

In this paper we investigate the influence of surface conditioning on charge carrier transport in GaAs nanowires grown by metalorganic chemical vapor deposition (MOCVD) in the VLS mode. We employ a contamination-free MOCVD-to-UHV transfer system, allowing to perform in-system 4-tip measurements of nanowires, either as-grown or subsequent to controlled oxidation. We compare two differently prepared nanowires before and after surface oxidation. While the homogeneously doped nanowire of sample A exhibits only a small change in conductance upon oxidation, the base of the nanowire of sample B exhibits a drastic decrease in conductance after oxidation. We argue that a parasitic, doped shell cannot explain the observed conductance values and conclude that this conductance is, at least partially, mediated by a surface-related charge carrier transport mechanism.

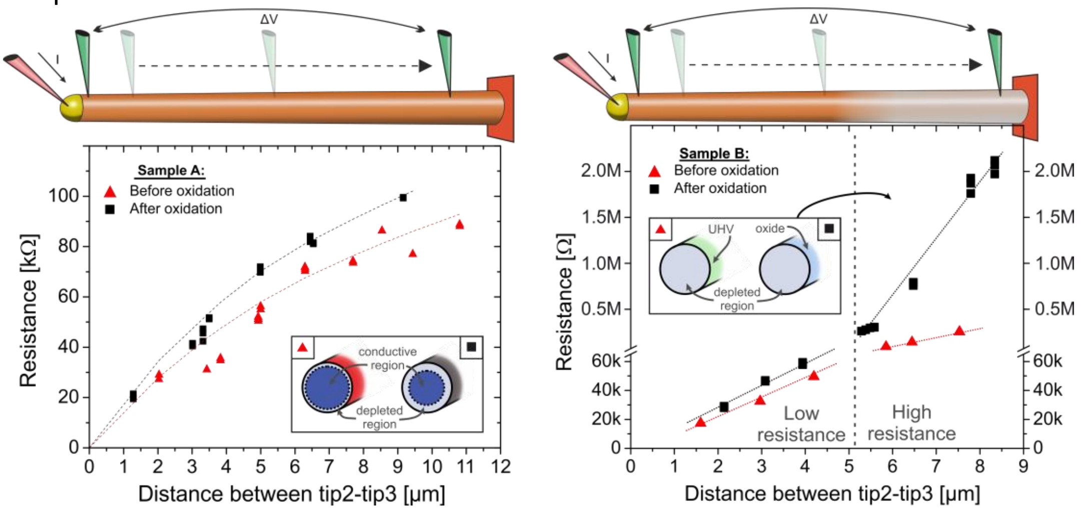

Figure 1: Resistance profiles of nanowires with different doping incorporation before and after surface oxidation. Sample A is homogeneously doped whereas sample B has an intrinsic base.

[1] Korte, S. et al., Appl. Phys. Lett 103, 143104 (2013).