Understanding electronic and structural properties of III-V nanowires via aberration-corrected/monochromated STEM techniques

Zamani, R.R.[1,2], Namazi, L.[1], Hage, F.S.[3], Gren, L.[1,4], Garbrecht, M.[5], Lehmann, S.[1], Ramasse, Q.M.[3,6,7] and Dick, K.A.[1,8]

[1] Solid State Physics, Lund University, Sweden, [2] Chalmers Materials Analysis Laboratory (CMAL), Chalmers University of Technology, Sweden, [3] SuperSTEM Laboratory, SciTech Daresbury Campus, United Kingdom, [4] Ergonomics and Aerosol Technology, Lund University, Sweden, [5] Thin Film Physics Division, IFM, Linköping University, Sweden, [6] School of Chemical and Process Engineering, University of Leeds, United Kingdom, [7] School of Physics, University of Leeds, United Kingdom, [8] Centre for Analysis and Synthesis, Lund University, Sweden

III-V heterostructured nanowires have been proven to be excellent platforms for studying the fundamental physics of semiconductors as well as the functionality of the devices made out of them. As an example, axial and radial InAs-GaSb nanowires have been used as field effect transistors (FETs) and tunneling FETs (TFETs).[1,2] The heterointerfaces, in such devices, have a considerable impact on the functionality as they can influence the band alignment. Therefore, it is of high importance to study them at the atomic scale. In this context, scanning transmission electron microscopy (STEM) offers an ample range of complementary techniques which are able to provide information about the physical and structural properties of the materials at the atomic scale. Recent advancements in TEM instrumentation, in particular aberration correction and monochromation, are enabling pioneering experiments in such complex nanostructured systems.

In this work, we employ aberration-corrected STEM imaging and monochromated low- and core-loss electron energy-loss spectroscopy (EELS) on heterostructure InAs-GaSb nanowire systems. We use STEM imaging and core-loss EELS chemical mapping to study the sharpness of the heterointerfaces in zinc blende GaSb-InAs axial/radial and wurtzite InAs-GaSb radial (followed by a zinc blende GaSb axial segment) nanowire systems. Our studies, an example of which is shown in Figure 1, reveal the structural/chemical differences between the radial and axial heterointerfaces. In both systems, intermixing of the two compounds occurs at the axial heterointerfaces, whereas the radial heterointerfaces are sharp.[3,4]

By taking advantage of the unprecedented energy resolution of monochromated low-loss EELS, we measure the bandgap value of such narrow-bandgap (<1 eV) materials. In the case of wurtzite GaSb, a novel material for which the bandgap has never been reported experimentally, we show that the bandgap value of wurtzite GaSb is approximately 50-80 meV higher than that the one of its zinc blende counterpart (Figure 2). Moreover, we show that at the axial heterointerface between wurtzite InAs and zinc blende GaSb, the measured bandgap value increases, which is likely due to the formation of a few nanometers of a ternary GaAsSb material caused by intermixing of the two compounds during nanowire growth.[5]

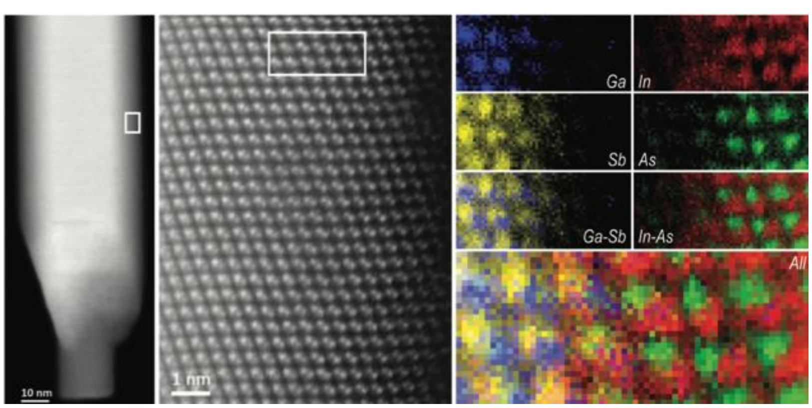

Figure 1. *STEM images and EELS compositional maps of a zinc blende GaSb-InAs core-shell nanowire*

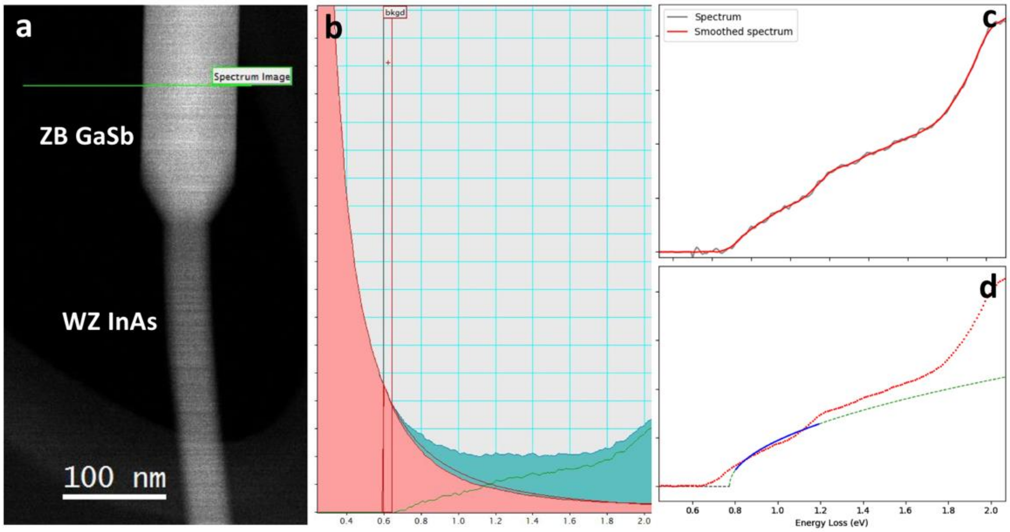

Figure 2. *(a) STEM image, (b) low-loss EEL spectrum from the zinc blende GaSb axial segment (subtracted zero-loss peak on vacuum in pink, signal in green), (c) smoothed spectrum, and (d) fitted curve.*

References

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