How can band offsets in III-V nanowires be determined correctly by scanning tunneling spectroscopy?

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Scanning tunneling microscopy (STM) and spectroscopy (STS) allow a unique high resolution insight simultaneously into the structural and electronic properties of III-V semiconductor nanowires (NWs). Particularly interesting are heterostructured NWs with interfaces between different polytypes or different materials. Since the carrier transport through such NWs is expected to be affected by different band gaps and band offsets, the accurate determination of these values are critical. Although STM and STS is presented as the ideal technique for this, we demonstrate that STS measurements (and possibly other measurement techniques) are mostly wrongly interpreted and it is thus unclear if any of the published band offset values is reliable.

In this presentation we demonstrate that sidewall surfaces of III-V NWs regularly exhibit high step densities (or surface states as for III-nitrides), which induce a pinning the Fermi energy within the band gap. The pinning level is, however, different on every polytype or on every material. Hence, the relative band edge positions between different types of NW segments are extrinsically determined by the different pinning levels, but not by the intrinsic band offsets. Furthermore, extrinsic band offsets turn out to be much larger than intrinsic one. Hence, defect or surface states at the sidewall surface likely affect the carrier transport much stronger than intrinsic band offsets. Thus, it is of prime interest to determine pinning levels and extrinsic band offsets at the sidewall surfaces. We demonstrate these extrinsic band offsets using zincblende-wurtzite GaAs NW junctions.[1]

In order to nevertheless have experimental access to intrinsic band offsets, we developed a new methodology to determine accurate band offsets between different NW segments.[2] It uses a thin overgrown shell of a material with wider band gap. This allows electron tunneling through this thin shell directly into the core. The shell furthermore assures that the pinning of the overgrown and pure segments is identical. Then the differences between the band edge positions of both materials provide the correct band offset values. We applied this methodology to axial GaAs/$GaAs_{0.81}Sb_{0.19}$/GaAs heterostructure NWs.

[1] P. Capiod *et al.*, Appl. Phys. Lett. **103**, 122104 (2013).
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