Stuttgarter Physikalisches Kolloquium

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Semiconductor nanowires for applications in photonics and solar cells

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Abstract

Nanowires are filamentary crystals with a tailored diameter between few and ~100 nm. Their special morphology and dimensions render them especially interesting for the study of low dimensional semiconductor physics and for opto-electronic and energy harvesting applications.
Our GaAs nanowires are grown by molecular beam epitaxy (MBE), following the Ga-assisted method [1]. This method was originally applied to GaAs substrates and recently adapted for Si. As shown in Fig. 1a, by carefully choosing the Ga, As_4 molecular fluxes and substrate temperature, we are able to grow GaAs nanowires on Si with a 100% yield perpendicular to the surface [2]. This constitutes the first step for the application of such nanostructures in photonic and solar cells applications.

I will show two of our latest results obtained with GaAs nanowires. I will start reporting on the formation of extremely high quality GaAs quantum dots in an AlGaAs shell to be used in quantum information technology. These quantum dots form by self-segregation in ternary alloy shells such as AlGaAs (Fig. 1b,c). It turns out that the alloy is not homogeneous and that nanoscale islands with a lower concentration of Ga are formed. These nanoscale islands behave electronically as quantum dots. They exhibit extremely high brightness and reduced linewidth [3].
Nanowires have also been looked as building blocks for next generation solar cells. We will show that nanowires standing on a substrate exhibit an absorption cross-section much larger than their physical bounds. Effectively, they act as nanoscale self-concentrating lenses. As a result, in real devices nanowires can be spaced much further, resulting in considerable savings in materials use. Also, because they absorb light under concentration, their efficiency can potentially be higher than the equivalent thin films. Overall, this demonstrates the advantages of nanowires in next generation photovoltaics to overcome the Shockley-Queisser limit in efficiency [4].

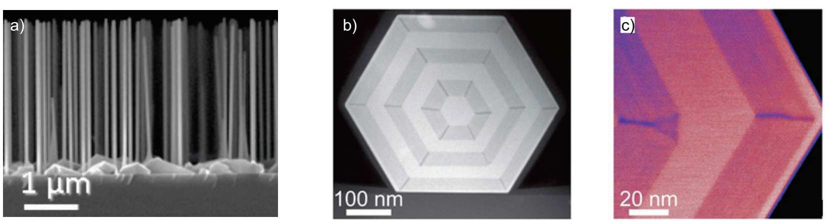

Figure 1
a) scanning electron micrograph of an array of GaAs nanowires grown on Si (111); b) cross-section transmission electron micrograph of a GaAs nanowire coated with various GaAs/AlGaAs shells and c) detail of b) showing segregation at the nanoscale in the AlGaAs layers.

References:
[1] C. Colombo et al, Phys. Rev. B. 77, 155326 (2008).
[2] E. Uccelli et al, Nano Lett. 11, 3827 (2011);
E. Russo-Averchi et al, Nanoscale 4, 1486 (2012).
[3] M. Heiss et al, Nature Mater. 12, 439 (2013).
[4] P. Krogstrup et al, Nature Photon, 7, 306 (2013).