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New Opportunities with Nanowires

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Light emission from Si, would allow integration of electronic and optical functionality in the main electronics platform technology, but this has been impossible due to the indirect band gap of Si. In this talk I will discuss 2 different approaches, using unique properties of nanowires, to realize light emission from Si-based compounds.

In the first route we focus on the fabrication of defect-free GeSn compounds. GeSn has been shown to exhibit a direct band gap at Sn concentrations above 12.5% in the infrared part of the spectrum (around 0.5 eV).[1] However, in bulk layers the strain between the Ge and the GeSn layer is released by the introduction of defects near the interface affecting the optical properties of the layer. In the nanowire geometry the lattice strain can be effectively relieved in the radial direction, which is exploited to grow Ge/GeSn core shell nanowires with high (13%) Sn content. The wires are grown by the Vapor-Liquid-Solid (VLS) growth mechanism in an Metal-Organic Vapor Phase Epitaxy (MOVPE) system at low temperatures. The core/shell nanowires are free of dislocations and therefore show a very high photoluminescene internal quantum yield of around 10% at room temperature. In this talk the growth mechanism is discussed, the structural properties are investigated by Electron Microscopy and Atom Probe Tomography and the temperature dependent optical properties are studied.

In the second route we concentrate on Si and Ge with a different crystal structure. It has been predicted that SiGe alloys with the hexagonal (2H) crystal structure have a direct band gap. It has been shown that by using the VLS nanowire growth mechanism it is possible to fabricate III-V semiconductors, which normally crystallize in the cubic phase, can now been grown with a 2H crystal structure.[2] This system has the unique ability to control and switch the crystal structure with a precision at the atomic monolayer level.[3] Here, we employ crystal structure transfer, in which we use wurtzite GaP as a template to epitaxially grow SiGe compounds with the hexagonal crystal structure (see figure 1).[4] We show that with this method we can grow defect free hexagonal SiGe shells and branches with tunable Ge concentration. The structural and optical properties of these new crystal phases will be discussed.

We believe that these new 3-dimensional epitaxial nanostructures have great potential to integrate optical functionality in Si technology.

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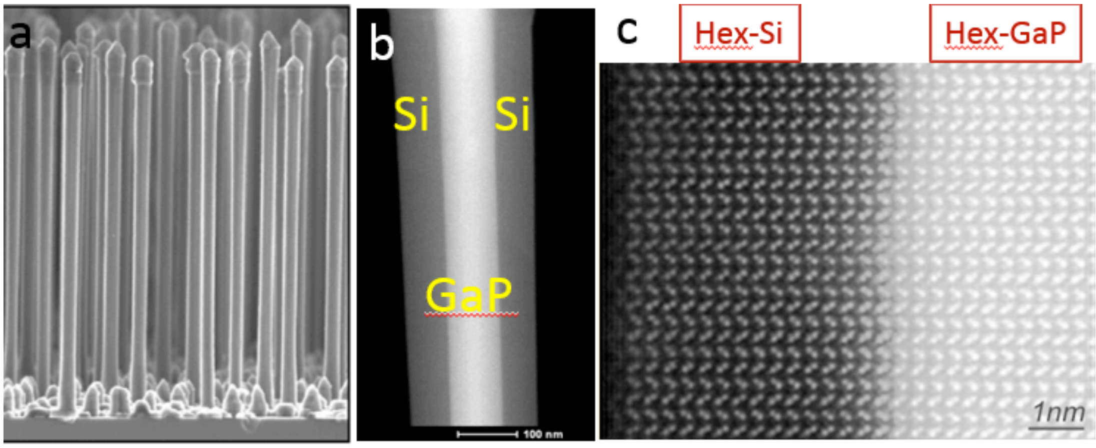

Fig. 1*: Transfer of the crystal structure from a wurtzite GaP core wire into a Hex-Si shell. (a) SEM image of GaP/Si core/shell NWs, (b) TEM image of a Hex-GaP/Si core/shell NW, (c) High-resolution TEM image of GaP/Si interface confirming the hexagonal Si crystal structure.*[4]

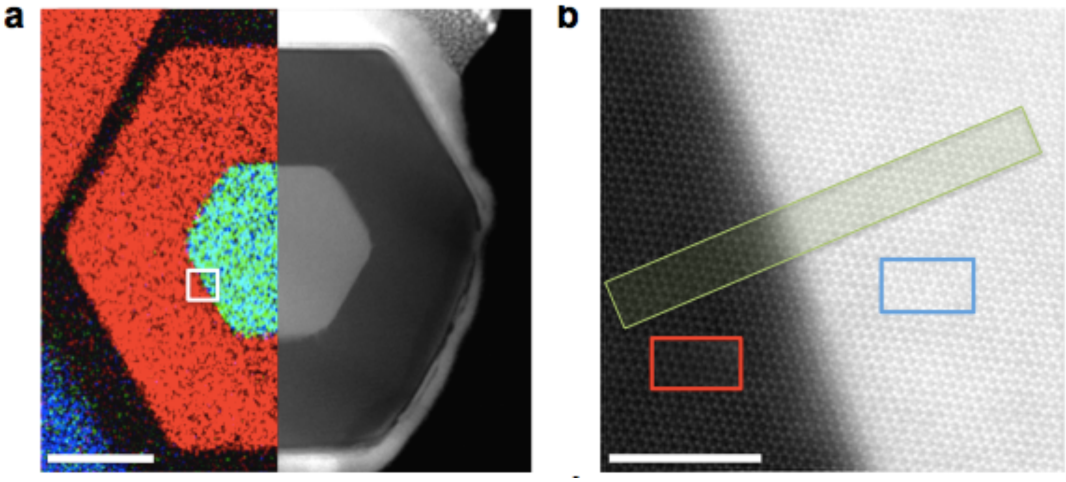

Fig. 2 *: (a) cross sectional TEM image of a hexagonal GaP/Si core/shell nanowire illustrating the conformal epitxial growth, (b) High-resolution TEM image of the GaP/Si interface substantiating the defect-free hexagonal Si crystal structure.*[4]