SEMICONDUCTOR NANOWIRES

NANOTECHNOLOGY GROUP

OPTOELECTRONICS LABORATORY

The shrinking of semiconductor device dimensions has started a new era due to quantum confinement effect. Semiconductor nanowires are one-dimensional structures with typical diameters of less than 100 nm and lengths of up to several micrometers. They offer the possibility of probing the basic physics of one-dimensional transport and are emerging as versatile building blocks for a variety of novel devices including single electron transistors, lasers, photodetectors, gas detectors and biological sensors. Single-crystal nanowires can be grown by the vapour-liquid-solid (VLS) method, using a metal droplet as catalyst. The large length-to-diameter aspect ratio enables the wires to be contacted by standard lithographic procedures, incorporating them into an electronic or optoelectronic device. The conductance of nanoscale quantum wires is very sensitive to binding of molecules at its surface, thus enabling high-sensitive biological detection. Nanowires with a built-in p-n junction or a zero-dimensional quantum dot can be synthesized. Such systems are very promising for nanoscale devices with novel functions, such as the emission of polarized photons and single-photon pulses. For such applications a profound knowledge of the formation, structure, and optical properties of the nanowires is required. Within this project we focus on the experimental research, fabrication and characterization of semiconductor nanowire structures and their exploitation to novel devices.

RECENT RESULTS:

We have fabricated InP nanowires on InP(111)B substrates by metal organic vapor phase epitaxy (MOVPE) using gold colloids as catalysts. The wire growth takes place below the gold colloids. The dimensions and orientation of the nanowires have been found to critically depend on the growth temperature, as shown in Fig. 1 and 2.

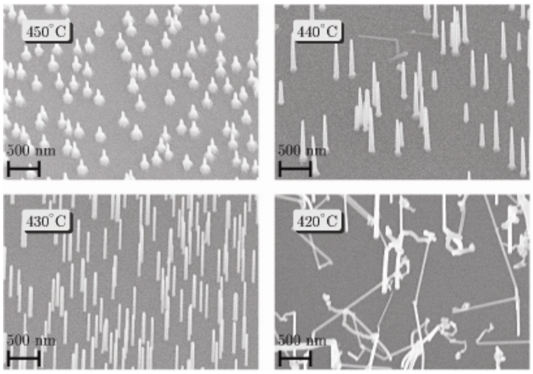

Figure 1. Scanning electron microscope images from InP nanowires grown at different temperatures. The nanowires grown at 450°C show a wide faceted base, a clear indication of a lateral 2D growth. At 430°C vertically <111> oriented uniform nanowires having an average diameter of about 50 nm are observed. Growth at lower temperatures results in oddly shaped wires with various orientations.

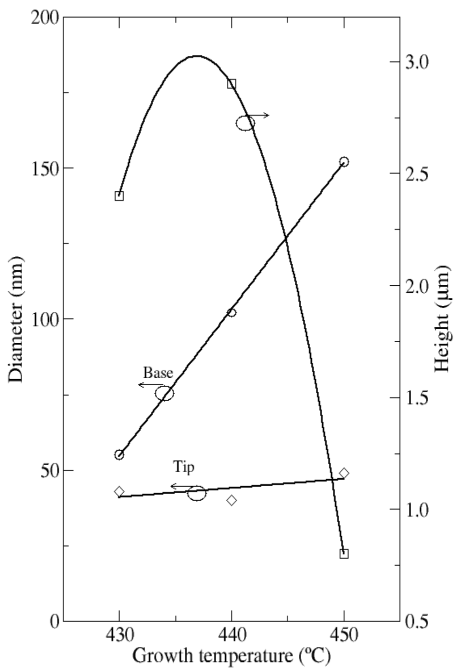

Figure 2. Average diameters (base and tip) and height of the InP nanowires as a function of the growth temperature.

Photoluminescence (PL) from the nanowires has been measured at room temperature. A general problem when measuring PL from nanowires that are standing on the substrate is that the substrate signal tends to mix with the luminescence coming from the nanowires. We have solved this problem by detaching the wires from the substrate with a standard adhesive tape. The PL measurements are carried out by focusing the laser beam onto the wires attached to the tape. As shown in Fig. 3 all the originally vertically oriented nanowires show a blue-shift of the PL emission that can be caused by various reasons. Further investigations are currently under way to reliably clarify the exact mechanism of the blue-shift. The structure of individual nanowires has been studied in more detail by transmission electron microscopy (see Fig. 4). The future challenges within this project include optical measurements of individual nanowires, electrical characterization of the structures, fabrication of heterostructured nanowires and finally the demonstration of nanowire devices.

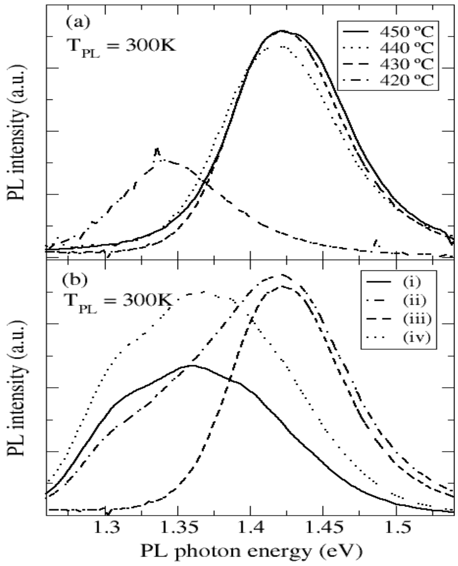

Figure 3. (a) Room temperature PL spectra from InP nanowires on adhesive tape. The label shows the growth temperatures. (b) PL spectra from (i) InP (111)B substrate, (ii) InP nanowire sample grown at 430 °C, (iii) nanowires on adhesive tape, and (iv) InP substrate after removal of the nanowires. The shape and position of the PL curves (i)-(iv) clearly demonstrates that a standard tape can be used to isolate the nanowire luminescence from the substrate signal.

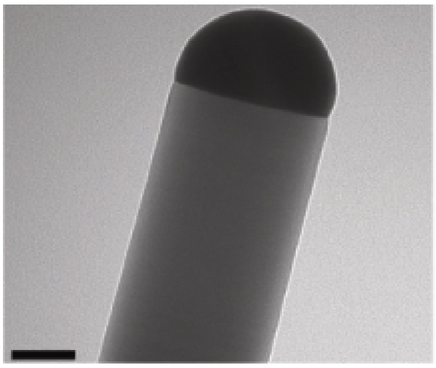

Figure 4. A transmission electron microscope image from the tip of an single-crystalline InP nanowire grown at 430 °C. The gold colloid on top is clearly visible. The scale bar depicts 40 nm.

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