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TEM Correlation between the Structural and Optical Properties Of Rotationally Twinned InP Nanowires

David C. Bell, Jiming Bao, and Federico Capasso

School of Engineering and Applied Sciences, and Center for Nanoscale Systems, Harvard University, Cambridge, Massachusetts 02138

Jakob B. Wagner,

nCHREM Polymer and Materials Chemistry, Lund University,

Thomas Mårtensson, Johanna Trägårdh, and Lars Samuelson

Solid State Physics, Lund University, PO Box 118, SE-22100 Lund, Sweden

Nanotechnology based on semiconductor nanowires has opened up new directions in band gap engineering of optoelectronic devices due to the large design space made possible by the relaxation of many constraints typical of thin film growth. However, the study of the structural and optical properties of the *same* nanowire, which is essential to correlate them in an unambiguous way, has not yet been performed.

In order to establish this correlation, we have developed a special grid so that both high-resolution micro-photoluminescence (PL) and transmission electron microscopy (HRTEM) measurements over a large range of optical power can be performed on the *same* nanowire. We will show how using this new technique, we have established a direct correlation between the structural and optical properties of rotationally twinned (RT) zinc blende (ZB) InP nanowires. RT heterostructures observed in these nanowires are based on a heterojunction consisting of adjacent rotated lattices in InP. Scanning electron microscopy (SEM) images revealed that the InP nanowires are long (□8 μm) and uniform in diameter (80 nm) along the growth direction. The structure of InP nanowires was studied with TEM, using selected area electron diffraction (SAD) and HRTEM imaging. The SAD aperture used was 2 μm in diameter to correspond to the nominal size of the laser spot. We focused on the nanowires that grow in the <111>and <001>directions. The nanowires with <001>as growth direction were single crystal ZB, whereas the nanowires with <111>growth direction showed ZB structure with RT along the <111>growth direction. The HRTEM from a typical nanowire with RT is shown in Figure 1.

Using this technique, we have observed a different PL behavior for RT InP nanowires compared with single crystal ZB InP nanowires. Our observations were qualitatively explained based on the staggered band alignment between ZB- and WZ-InP. Because the results of higher bandgap of the WZ structure, and the staggered band alignment between ZB/WZ, apply to nearly all direct bandgap semiconductors, similar blue shift of PL is expected in other RT semiconductor nanowires such as InAs, ZnS, or ZnSe. Our findings support early theoretical studies that rotation twinning introduces a heterojunction in a chemically homogeneous material, thus creating new opportunities for materials engineering employing controlled twin formation.

References

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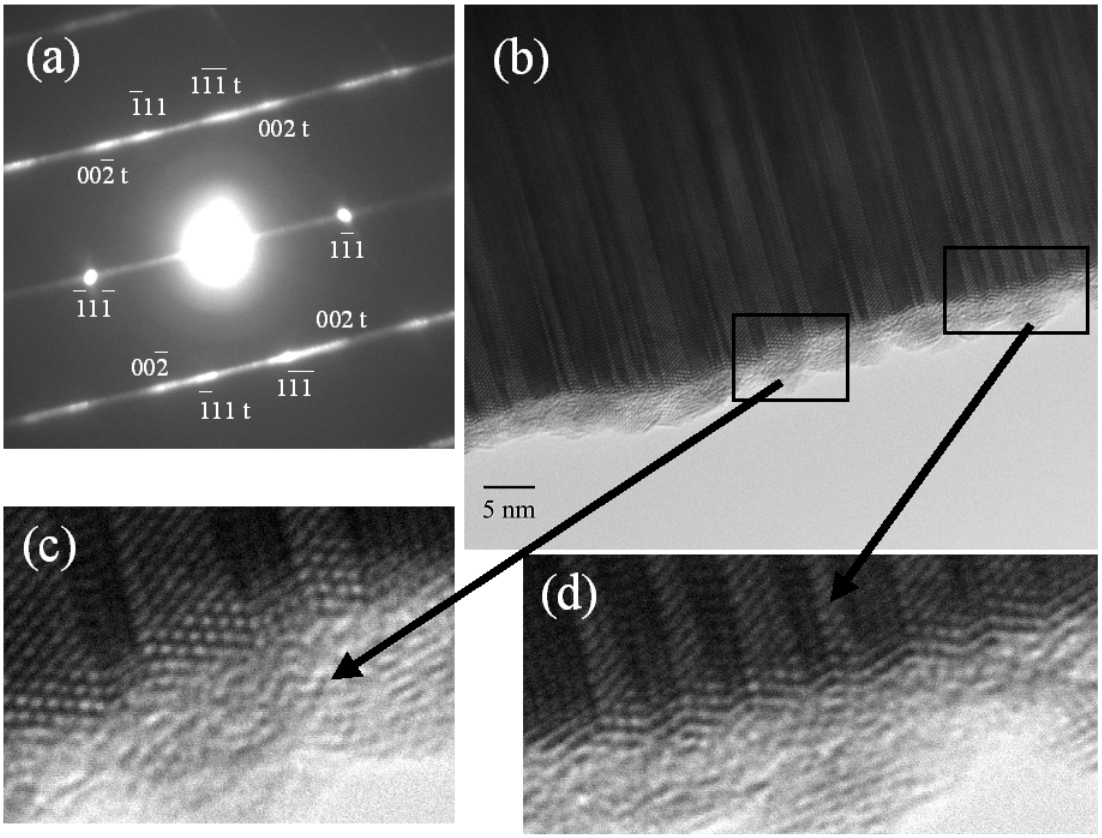

Fig. 1. TEM diffraction pattern (a) and HRTEM lattice image (b). (c) and (d) are the close-up views of the lattice images marked in (b). Gray stripes and black stripes in (B) indicate two different orientations of ZB segments.

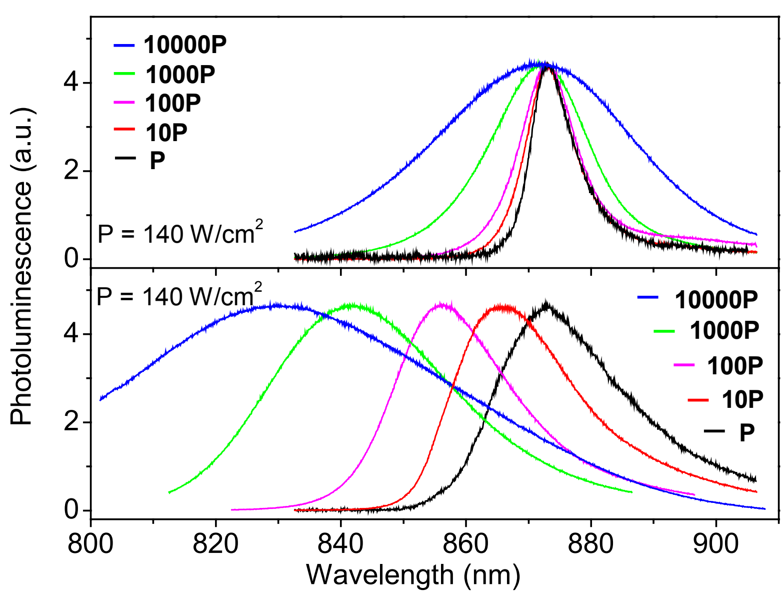

Fig.2. Photoluminescence spectra of a typical single crystal ZB InP nanowire (top) and a typical twinned ZB nanowire (bottom) under different excitation intensities at 7 K. The wires were laid on silicon substrate. A 488 nm laser is focused to a spot of about 1 um. The spectra are normalized to the same height for ease of comparison.