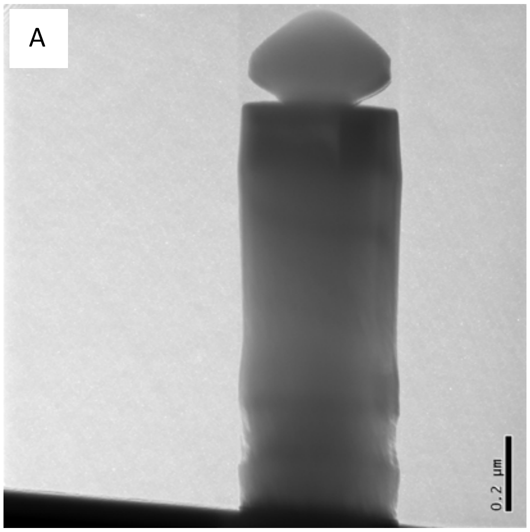
Transmission Electron Microscopy of Fabricated Nanostructures

Axel Scherer, Uday Kharanjole, Jinqing Huang, Guy DeRose and Bophan Chhim

Kavli Nanoscience Institute, California Institute of Technology, Pasadena CA 91125

We use a 200kV transmission electron microscope to analyze electron-transparent nanostructures that have been defined through anisotropic etching or growth without their removal from their original substrate. This technique enables the rapid determination of the internal structure, surface morphology and even surface damage of such nanostructures and can be used to optimize nanofabrication procedures such as etching or growth recipes. Although thin sectioning of electron-transparent through ion etching and extraction is a very common method for sample analysis, these thin sections are typically removed from their original substrates. Instead, we use TEM as an analysis step to characterize functional nanostructures nondestructively. Of course, the overall sample sizes are limited by the pole piece spacing of the electron microscope. Two general applications have emerged for this technique: In the first application, the rapid characterization of either crystal quality and layer thicknesses of grown and fabricated structures by rapid thin sectioning is desired. In the second, the quality and accuracy of nanofabricated device geometries is confirmed by high-resolution examination. In both of these applications, the surface and internal structure of nanofabricated features can be observed with higher resolution than possible by SEM microscopy.

In the first application of the rapid definition of electron-transparent thin sections, we find that very simple sample preparation can provide thin sections. For example, we typically use aluminum oxide polishing powder particles with lateral sizes below 300nm or silicon dioxide micro-beads as etch masks that can then be transferred by anisotropic reactive ion etching to define electron transparent thin sections. These samples are then loaded into our FEI TF-20 STEM and analyzed on a reflection microscopy holder. The attached figures show typical TEM images of quantum well samples defined with 200nm microsphere masks and with lithographic lift-off masks. Conversely, already fabricated nanostructures that have been defined through nanowire growth or by more conventional top-down lithography techniques can be analyzed through transmission electron images. We show images of GaAs nanowires that were grown from lithographically perforated silicon dioxide templates through chemical vapor deposition. The internal structure of the electron-transparent features, such as stacking faults or quantum wells, can therefore be imaged and characterized with the high resolution characteristic to TEM in both bright and dark-field mode. Modern field-emission TEMs even enable lattice imaging on etched structures without removal from the substrate, and this TEM imaging feedback enables the rapid optimization of nanofabrication procedures.



A. Transmission image from an etched pillar in InGaP/AlGaAs heterostructure using a silicon micro-bead mask
B. Dark-field and light-field image of a thin section through quantum well laser material formed by anisotropic etching with an alumina particle mask
C. Bright-field image of same etched pillar
D. Bright and dark-field images of GaAs nanowires grown on a 111 GaAs substrate through a lithographic oxide mask
E. 6nm wide nanostructures etched into InGaAs/GaAs quantum wells