High-accuracy (0.1±0.2 nm) analysis of GaAs/$Al_xGa_{1-x}As$ layers using beam-exit cross-sectional polishing and selective etching

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Microscopy of semiconductor heterostructures on the sub-nm scale is presently only possible with techniques such as transmission electron microscopy (TEM), cross-sectional scanning tunneling microscopy and atom probe tomography which are expensive, of limited availability and require considerable expertise. We report a novel sample preparation technique, which, when combined with scanning probe microscopy (SPM), has the potential to provide easy access to high-resolution microscopy of semiconductor nanostructures [1].

A test structure with a variety of GaAs/$Al_xGa_{1-x}As$ layers (Fig. 1) was first prepared with beam-exit cross-sectional polishing (BEXP) [2], a modified form of cross-sectional Ar^+-ion polishing in which the Ar^+ beam impinges on the side of a sample and exits at the surface at a small angle. BEXP (i) enables cross-sections to be produced with roughness on the atomic scale close to the sample surface where nanostructures are located, and (ii) 'stretches' the vertical scale. The polished sample was then treated with a citric-acid/hydrogen peroxide selective chemical etch to introduce material-dependent topology on the polished surface so that the layer structure could be measured using tapping mode atomic force microscopy.

Fig. 1 compares composite images of the sample produced by this method with TEM. All layers are visible with both techniques (even at 1 nm thickness), with better contrast for $Al_xGa_{1-x}As$ layers that are thicker or have higher Al content, as might be expected. For a quantitative analysis SPM measurements were made using 750 nm scans at 512 samples per line. The thicknesses of 167 different layers were measured, and the results were compared with TEM. For layers <20 nm the difference between SPM and TEM was just 0.1±0.2 nm.

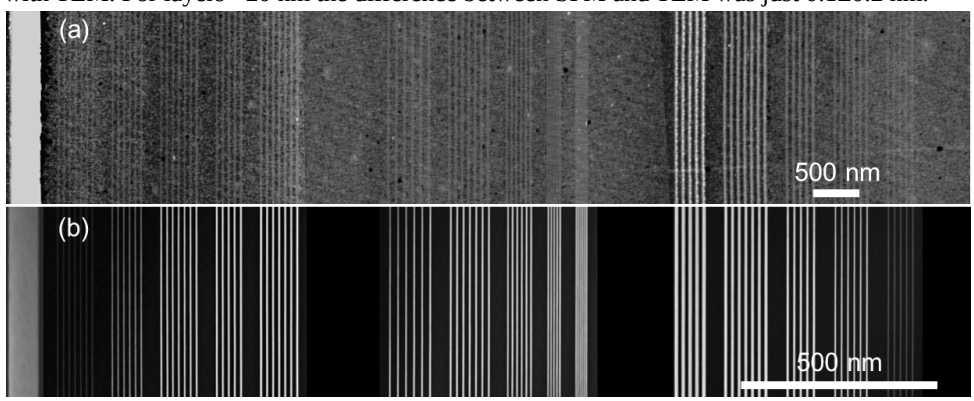

Fig. 1: Composite (a) BEXP-SPM and (b) TEM image of the GaAs/$Al_xGa_{1-x}As$ structure. From left to right: 75 nm AlAs barrier layer, 3 nm $Al_xGa_{1-x}As$ composition *x* varying layers (0.2 to 1), 3 nm AlAs layers with different GaAs spacing, and differing thickness AlAs and GaAs layers (from 8.5 to 1 nm). The scale bars are different due to the shallow angle of the BEXP cross-section.

[1] A. Robson *et al*., submitted to Appl. Mater. Interfaces.
[2] O.V. Kolosov, I. Grishin and R. Jones, Nanotechnology **22**, 185702 (2011).