Direct atomic scale interface characterisation of a single-barrier tunnel diode

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There is a continuing increase in the research on possible device applications of semiconductor heterostructures. However, only a small number of research projects have led to the commercial production of devices, although molecular beam epitaxy (MBE) and metal-organic chemical vapour deposition (MOCVD) have been refined over the past two decades for the deposition of semiconductor layers with a precision approaching the atomic scale [1].

An important barrier stands in the way. Once the key design features of a device approach atomic dimensions, the device performance becomes ever more sensitive to atomic-scale variations [2]. It is, therefore, very important to have satisfactory materials characterisation tools that are not only of sufficient precision, but also quick enough to provide rapid feedback to materials growers. High-resolution electron microscopy, using both elastic and inelastic electrons, has been regarded as the best solution for the analysis of crystal interfaces [3, 4].

We have recently demonstrated a direct atomic scale characterisation of the interfaces in a single-barrier tunnel diode based on an AlAs/GaAs heterostructure, using both high resolution Z-contrast scanning transmission electron microscopy (STEM) and high-resolution transmission electron microscopy (HRTEM) with the use of chemically sensitive reflections. The cross-sectional specimens for this study were prepared along the [100] orientation using conventional sample preparation techniques, involving mechanical thinning followed by ion-milling using Ar^+ at 3-5keV. High-resolution Z-contrast scanning transmission electron microscopy was performed in an aberration corrected dedicated STEM – VG HB501 FEG equipped with a Nion corrector and the chemically sensitive HRTEM was performed in a JEOL 4000EX TEM operated at 400kV. As shown in Figures 1 and 2, similar results have been obtained from these two microscopes. It was also found that the specimen thickness had an effect on the imaging results, i.e. thicker specimens appear to have a broader interface region. The lateral coherence length of the electrons in a tunnel diode is ~10nm. Atomic scale variations over this wavelength may have a significant effect on the diode's electrical properties. It is therefore important to measure structural variations on this length scale if the diode's properties are to be understood and improved. [5]

1. M. J. Kelly in "Low dimensional semiconductors", (Oxford University Press, Oxford, UK) (1995).
2. M. J. Kelly, Electronics & Communication Engineering Journal **4** (2002), p. 73.
3. H. Ichinose, Science and Technology of Advanced Materials, **1** (2000), p. 11.
4. N. D. Browning, I Arslan, P. Moeck, and T. Topuria, Phys. Stat. Sol. (b) **227** (2001), p. 229.
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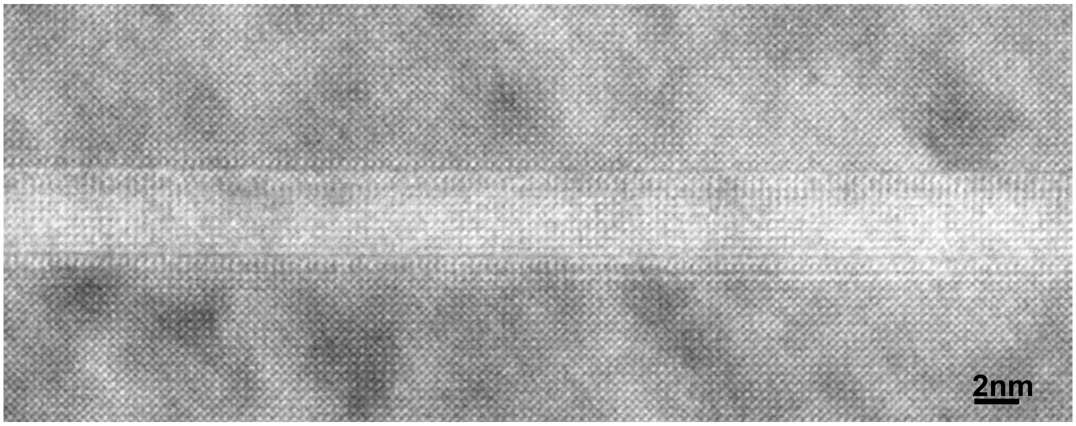
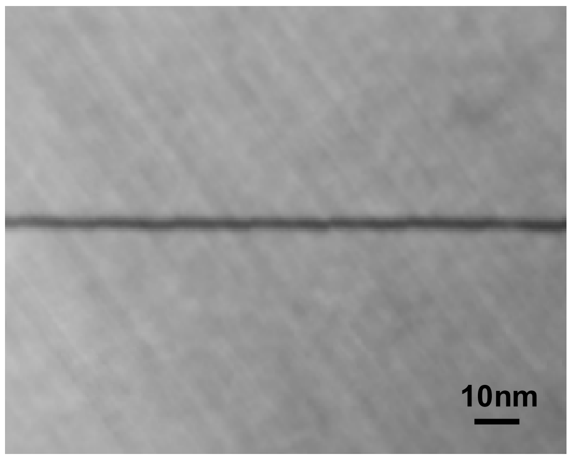


Figure 1. [100] HRTEM image of a 10ML AlAs layer in a GaAs matrix.

(a)



(b)

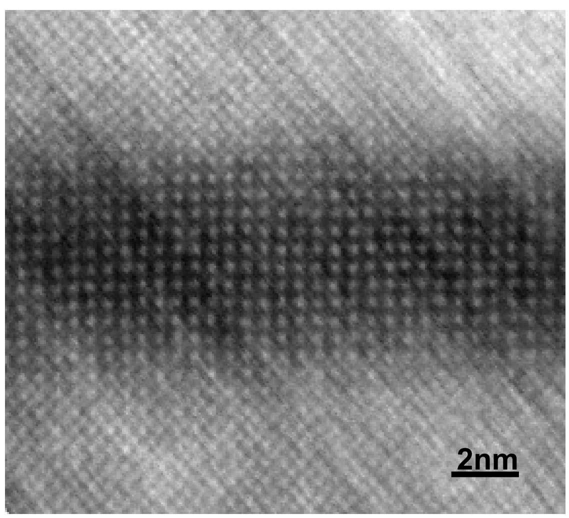


Figure 2. (a) Low magnification high angle annular dark field (HAADF) image of an AlAs layer in a GaAs matrix. (b) High-resolution Z-contrast STEM image of the AlAs layer.