doi:10.1017/S1431927610062033
Microsc. Microanal. 16 (Suppl 2), 2010

Aberration-corrected TEM Study of Defects in III-V Films Grown on Si

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Heteroepitaxial semiconductor layers grown on silicon have the potential to provide a wide range of optoelectronic properties making new applications beyond the Si-roadmap possible. In particular, III-V compound semiconductors and their alloys provide a range of tunable bandgaps allowing these materials to emit and absorb photons over a wide range of energies. This wide range makes them suitable for various applications from light-emitting diodes to solar cells. The lattice mismatch between Si and the heteroepitaxial layers, however, is a major limitation for the growth of high-quality films. Various interface properties and defects depend on the structure and the preparation of Si surface prior to growth, the thickness of the films, the growth conditions, lattice parameter of the heteroepitaxial layers and buffer layers used. Of particular interest is the misalignment of group III and group V sublattices at surface steps of the Si substrate which eventually result in antiphase domain (APD) formation [1-3]. Incomplete or dangling bonds in the core of dislocations and defects as well as strain fields of the dislocations can cause deep and shallow gap states, which eventually result in the deterioration of properties.

In this work we study the structure of interfaces in GaSb thin films deposited on miscut Si substrates by gas-source molecular beam epitaxy (MBE). Using aberration-corrected high-resolution transmission electron microscopy (HRTEM) and high-angle annular dark-field (HAADF) imaging on a FEI Titan 80-300 double corrected TEM/STEM, we have studied the GaSb/Si interface structure and strain distribution around defects. Multislice simulations [5] of HAADF images show that there is a detectable difference in the intensity of Ga and Sb atomic columns below 60 nm thickness of specimen (Figure 1). With HAADF-STEM imaging, we have observed interfacial misfit dislocations with ½a[110] Burgers vector (Figure 2a). The extra atomic half plane at interface due to a misfit dislocation is clearly visible in the Bragg filtered image (Figure 2b). Based on these images and the high stability of the microscope, we have measured the displacement of atoms in proximity of the dislocation and defects (Figure 3) with the geometric phase analysis (GPA) method. Furthermore, the ability of observing single atomic columns with HAADF-STEM makes it possible to observe the missing atomic columns in a triple joint defect (Figure 4).

References

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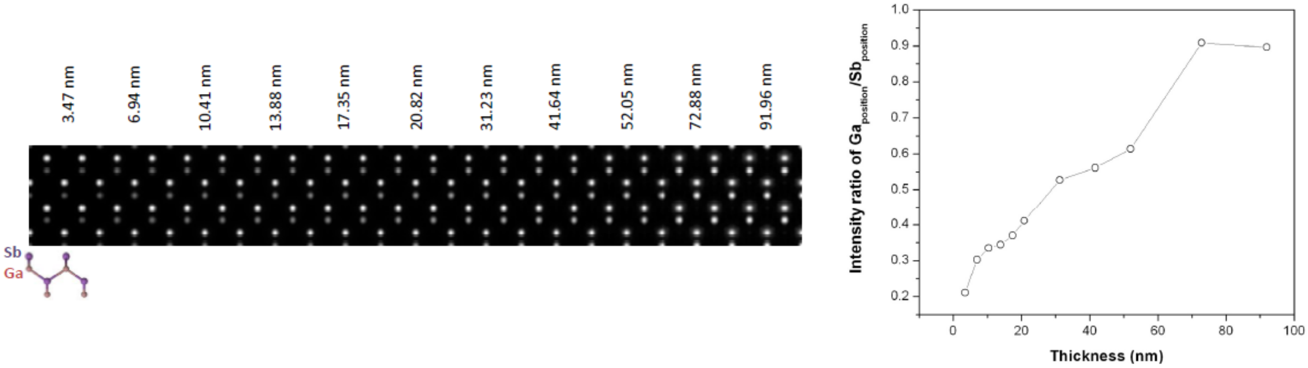


FIG. 1. Multislice simulation of HAADF image of GaSb with different specimen thicknesses

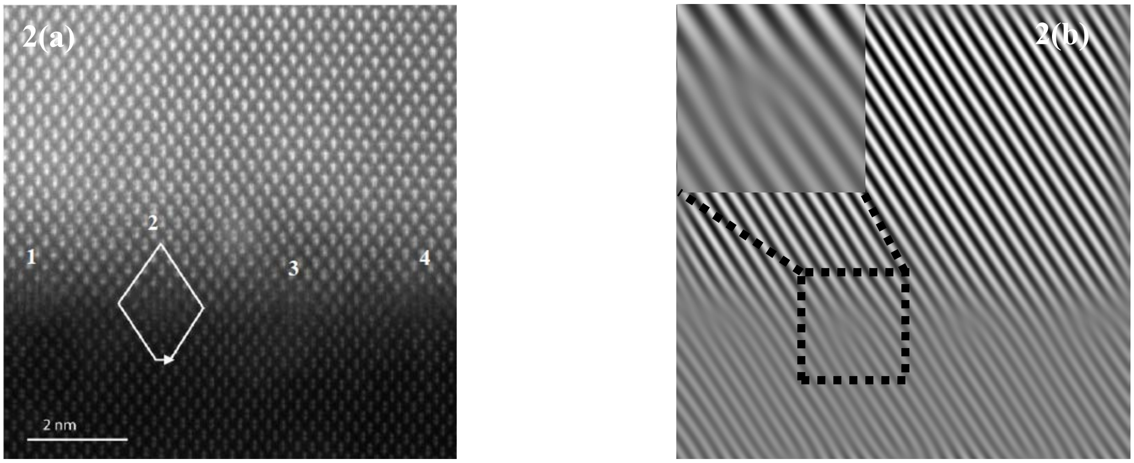
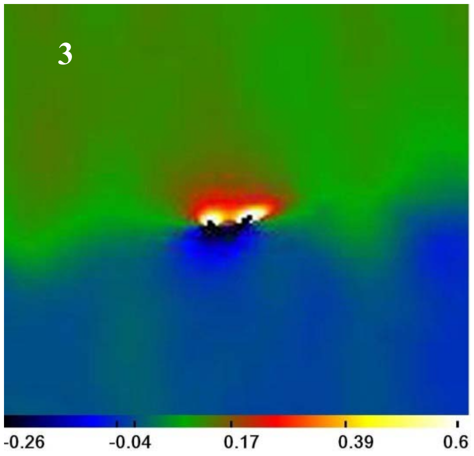


FIG. 2. (a) HAADF image of an interfacial misfit dislocation with a Burgers circuit around it and with b= 1/2a[110] Burgers vector (b) Bragg filtered image of [-111] reflection highlighting the misfit dislocation



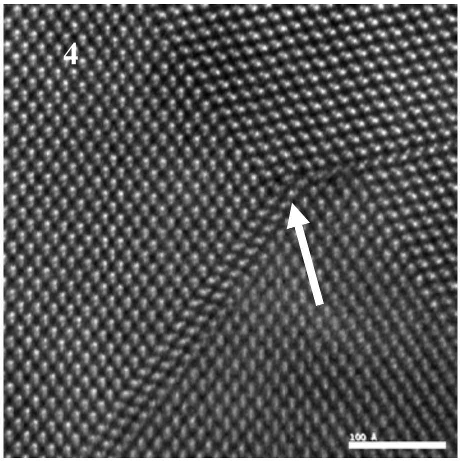


FIG. 3. Strain field (ε_{xx}) of a misfit dislocation obtained by geometric phase analysis (GPA) of FIG. (2a)

FIG. 4. Missing atomic columns in triple joint defect as pointed by arrow