Microsc. Microanal. 8 (Suppl. 2), 2002
10.1017.S1431927602107872

Evolution of GaSb/GaAs Quantum Dot Strain Relaxation.

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The composition and strain relaxation of GaSb quantum dots grown by organometalic vapor phase deposition (OMVPE) on GaAs (001), is investigated by transmission electron microscopy (TEM) and atomic force microscopy (AFM) techniques. Similar to reports in previous publications [1-2], OMVPE growth of GaSb on GaAs occurs initially via the formation of a uniform 2D wetting layer. At some thickness, islands nucleate randomly and grow via mass transport from the wetting layer. The initial islands are coherently strained with round or elliptical shapes but eventually relax via the formation of edge dislocations (in-plane, 90° burgers vectors). Questions remain as to the degree of incorporation of As into the dots as a function of the growth conditions, and to the exact mechanism of the strain relaxation process.

We find that the deposition of GaSb at 520C, V:III ratio of 2.5, to a thickness exceeding 2 monolayers (ML) results in the spontaneous assembly of GaSb islands. TEM plan-view images, FIG. 1, show islands with a density of 70 μm^{-2} and a rectangular morphology, always with the [1$\underline{1}$0] direction elongated. These islands have relaxed as seen from the square network of misfit dislocations. FIG 1 (a) shows a dark field image with g = [220] that identify the burger's vector of the misfit dislocations to be the expected 90° edge type. FIG. 1 (b) shows a magnified image of a cluster of these islands taken under g = [004] 2-beam conditions. The misfit dislocations aligned with <110> directions are clearly distinguishable from translational Moiré fringes along [001]. The island shapes and densities observed by TEM are comparable to those observed by AFM (FIG.2), which also shows that the island heights grow from 5 to 10 nm with increasing GaSb growth time.

The edge dislocations in FIG. 1 (b) occur with a 6.25 nm interspacing whereas the (004) Moiré fringes have a spacing of 2.12 nm. This Moiré fringe spacing indicates that the dot composition is GaSb (with little or no As). However, complete relaxation of a GaSb/GaAs interface (7.8% mismatch) by the formation of a/2[110] edge dislocations would mean a dislocation spacing of 5.2 nm smaller than the observed 6.25 nm. The results suggest that the dot composition is graded from 12% As at the interface decreasing to 100% Sb at the surface.

This rectangular morphology indicates that the growth is not occurring at the same rate in each <110> direction. The ratio of the length to width of the islands ranges from 2 – 5. This is either due to a difference in the surface diffusion of atoms to the island or due to differences in the rate of formation of the edge dislocations as the island exceeds a certain size in each direction. Studies of the effects of GaSb p-type doping on the island morphology will be described. [3]

References

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[3] Research supported by the Canadian National Science and Engineering Research Council.

GaSb Islands on GaAs

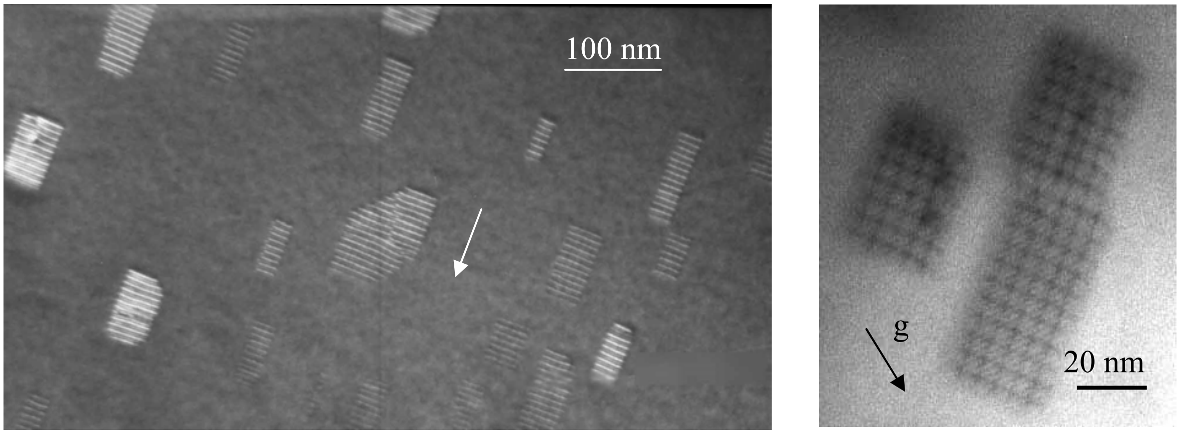

FIG. 1. Transmission Electron Microscopy (TEM) micrographs of GaSb islands grown on GaAs (001): (a) lower magnification dark field g = [220] showing island morphologies, and (b) bright field [004] showing edge dislocations (dark square network) and fainter Moirè fringes with 2.12 nm spacing.

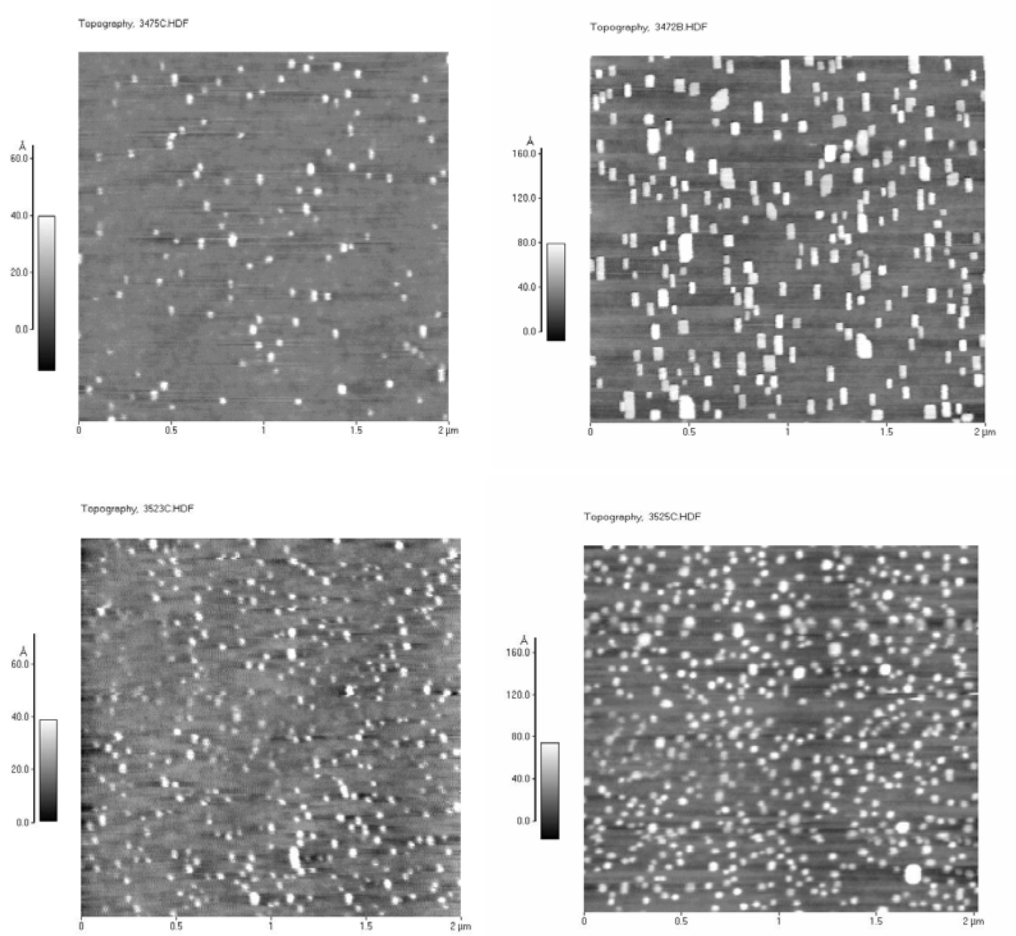

FIG. 2. Atomic force microscopy images (2 μm x 2 μm area) of GaSb islands grown on GaAs (001) at 520C with growth rates (Ga flow) of $5.2x10^{-6}$ mol/min.: (a) 1 s (b) 2 s; and $2.8x10^{-6}$ mol./min.: (c) 4 s and (d) 8 s. The islands increase in density and size with increasing growth time.

https://doi.org/10.1017/S1431927602107872 Published online by Cambridge University Press