Spatial correlations of self-assembled nanostructures using a squared lattice InP/InGaP template

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Semiconductor nanostructures have shown properties that can be tailored during fabrication, making possible the engineering of quantum effects in finite low-dimensional systems. Such nanostructures can be synthesized by different techniques; one of the most common relies on strained heteroepitaxial growth. In this process, coherently strained islands are formed on the surface, presenting a continuous variation of the lattice parameter (from bottom to top) and making them energetically stable against the formation of a uniform (flat) strained film. Strain distribution is thus one of the significant factors that determine the shape, size and facet formation in these self-assembled semiconductor nanostructures.

We present here results on material systems where different structural characteristics were obtained by changing the InGaP buffer layer properties and creating a stress field to drive the nucleation of a first InP dot layer. Once buried, this two-dimensional array of InP dots was used as a template for the lateral ordering of both InAs and GaP dots in InAs/GaAs and GaP/GaAs bilayers, respectively. In both cases, a two-dimensional array very similar to the InP template buried underneath the bilayer was observed. Also, an increase in the dot dimensions – as compared to those grown on unstressed surfaces - occurred due to the buried strain field lateral period. For the InAs in particular, clustering of small dots is observable, probably due to a finite size effect of the InP dots.

The correlation between the ordering of the top dot layer and the buried InP template was investigated by cross-section High Resolution Transmission Electron Microscopy (HRTEM) measurements. Our results show that the InAs dots are vertically correlated to the InP template, while the GaP dots are vertically anti-correlated, nucleating in the position between two InP dots. In this latter case, grazing incidence X-ray diffraction measurements have shown that the strain relaxation rate is not significantly altered with regard to the GaP dots grown on unstressed GaAs, although the strain at the base of the dots is lowered when the template is used. These results validate this approach as a new path to produce high quality III-V self-assembled pseudocrystals.

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Figures:

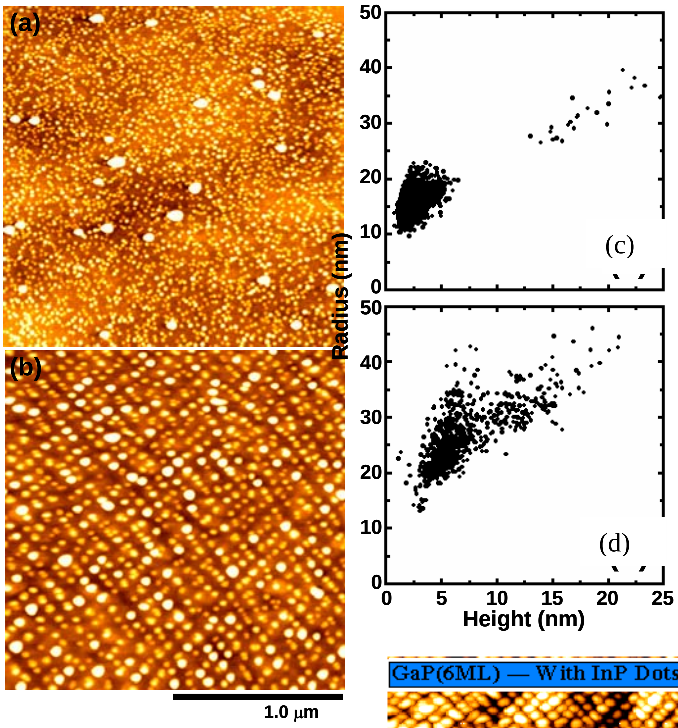
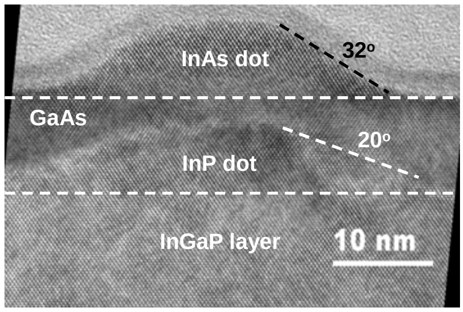
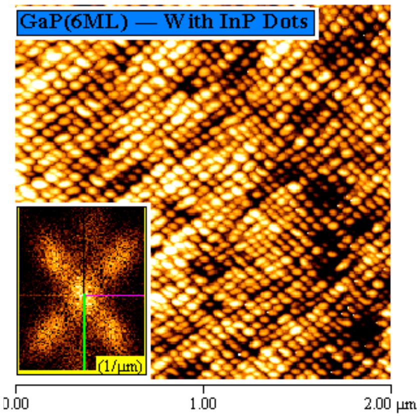


Fig.1 – AFM images and dot size distribution for InAs dots grown on (a,c) GaAs and (b,d) the InP template (GaAs/InP/InGaP/GaAs); (bottom) HRTEM image showing the vertical correlation between InAs and InP dots.





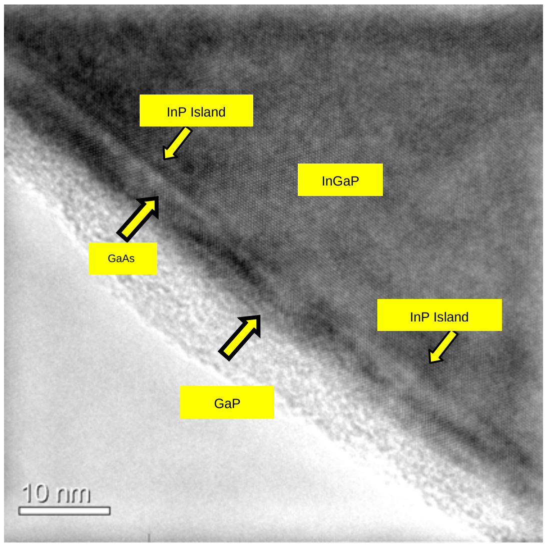


Fig.2 – (left) AFM image of the laterally ordered GaP dots, the inset shows the Fast Fouried Transform of the image; (right) HRTEM image showing the vertical anti-correlation of GaP and InP dots.

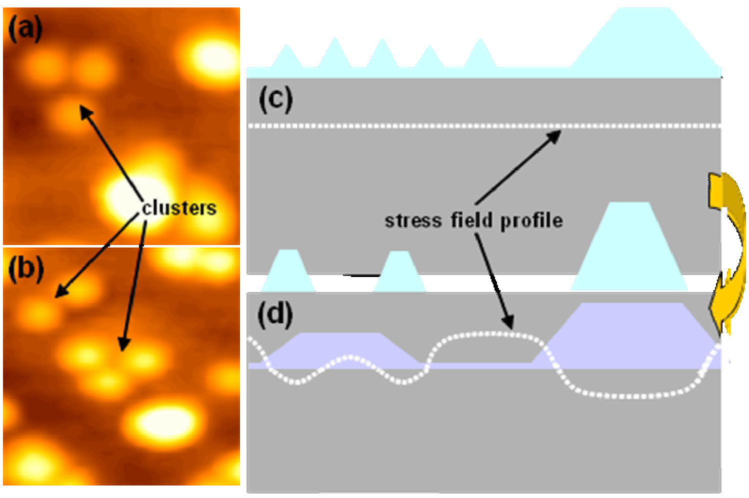


Figure 3- (a) and (b) typical clusters of 2 or 3 small InAs islands formed on top of one buried InP/InGaP dot; (c) schematic distribution of InAs when deposited on GaAs buffer without InP/InGaP template. Two ensembles of islands randomly distributed on top of the wetting layer are formed; (d) schematic distribution of InAs when deposited on GaAs with InP/InGaP template. The stress field on top GaAs due to InP/InGaP template induces the InAs island nucleation on top of buried InP dot in two different ways due to the height distribution of the buried InP dots. The wetting layer may be absent due to non-uniform strain field created by InP/InGaP template.