

INFLUENCE OF QUANTUM DOTS DENSITY ON AVERAGE IN-PLANE STRAIN OF OPTO-ELECTRONIC DEVICES INVESTIGATED BY HIGH-RESOLUTION X-RAY DIFFRACTION

R.O. Freitas^(a), B. Díaz^{1(b)}, E. Abramof^(b), A.A. Quivy^(a), S.L. Morelhão^(a)

^(a) Universidade de São Paulo, São Paulo, SP, Brazil

^(b) Instituto Nacional de Pesquisas Espaciais, São José dos Campos, SP, Brazil

Self-organized quantum dots (QDs) grown on semiconductor surfaces are typically used as light-emission sources in many types of opto-electronic devices where, due to processing requirements, the QDs are to be encapsulated. Although surface probing techniques can supply information on morphology and strain profile of exposed QDs, in most optical devices QDs are covered by few layers of another material, *i.e.* a cap-layer. Recently [1,2], ultra-precise lattice parameter measurements in shallow layers at the GaAs (001) substrate interface have shown that covering InAs QDs significantly increases the average residual in-plane strain, which seems to depend strongly on the density of QDs prior to covering. As a secondary effect related to the residual strain, anisotropy in the broadening of symmetric Bragg reflection as a function of the azimuthal angle has also been noted [2]. However, due to the limited number of samples in previous works, it has not been possible to establish the critical density of QDs above which high levels of stress and anisotropic growth of the cap-layer take place. Since the integrity of the QDs is an important issue for light emission, a more detailed investigation about the strain diffusion mechanism from the either strained or defective cap-layer to the system must be undertaken.

In this work, reciprocal space mapping (RSM) of the 002 reflection has been used to monitor lattice strain and tilt of the cap-layer in the InAs/GaAs (001) QDs system as a function of the QDs growth rates. Bragg-surface diffraction [3] conditions have also been exploited to enhance the cap-layer (30 nm) contribution on the reciprocal space maps carried out in a Philips X'Pert MRD high resolution diffractometer, Cu-K α radiation. QDs are formed from 2.4 monolayers (ML) of InAs, MBE grown, with rates ranging from 0.0055 ML/s (low density of large QDs) up to 0.1 ML/s (high density of small QDs). Since size and density of the QDs change systematically with the growth rates [2], critical values of lattice stresses during covering induce a major tilt in the cap-layer lattice, as clearly observed in the RSMs shown in Fig. 1. These results are in agreement with the previous ones showing that for certain rates, which change the morphology and density of QDs, important alterations on the growth mechanism of the cap-layer occur. Structure models accounting for these alterations are discussed, as well as their effects on the integrity of QDs.

[1] S. L. Morelhão *et al.*, Microelectr. J. 36, 219 (2005). [2] R. O. Freitas *et al.*, Phys. Stat. Sol. (a) 204, 2548 (2007). [3] M.A. Hayashi *et al.*, Appl. Phys. Lett. 71, 2614 (1997).

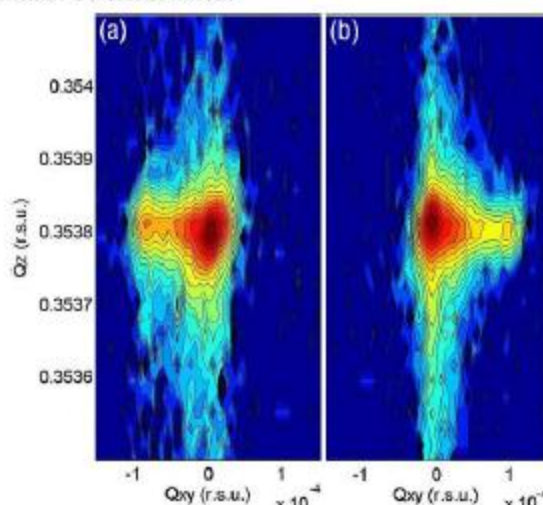


Figure 1: Reciprocal space mapping, 002 reflection, on GaAs/InAs-QDs/GaAs (001) system carried out at two different azimuthal angles: (a) $\varphi = \varphi_0$ and (b) $\varphi = \varphi_0 + 180^\circ$ where φ_0 stands for a Bragg-surface diffraction excitation condition. Reciprocal space units (r.s.u.) = \AA^{-1} .

¹ beatriz@las.inpe.br