STRAIN AND BAND EDGES IN InAs/GaAs (11N) NANOSTRUCTURES

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The strain relaxation in typical lattice-mismatched heterostructures such as InAs/GaAs is the classical mechanism advanced to describe the self-organization of quantum dots (QDs) in the Stranski-Krastanov (SK) growth mode. On the other hand, the strain induced in these lattice-mismatched heterostructures modifies their band structures, that determined the PL peaks and other optical transitions.

Nevertheless, this SK mechanism seems to be restricted to the (001) orientation for the InAs/GaAs heterostructures. When the high-index orientations are involved, many workers reported contradictory results, revealing in some cases the inhibition of the SK mode. In fact, based on RHEED and STM measurements of InAs grown on (110) and (111)A substrate orientations, Joyce et al. [1] claimed that the 2D layer-by-layer growth of the InAs epilayers takes place, with the strain relaxation relieved by misfit dislocations. However, other groups [2] confirmed the formation of 3D islands without 2D wetting layer (WL) nucleation for (111)A/B orientations. When higher-index substrate orientations, such as (113)B or (115)B are used, many researchers confirm the 2D-3D transition SK mode, with PL spectra indicating a delay in the three-dimensional growth mode onset [3].

Following our previous works [4, 5], we characterize the SK growth mode, through the determination of the 2D-3D transition thickness and accumulated stress for InAs grown on (11n) substrate orientations, with n = 3, 5. The obtained results are discussed with respect to the InAs/GaAs (001) SK growth mechanism. Both strain relaxation and islanding mechanism are described using the elasticity continuum theory, where the relaxation is defined through the sigmoidal evolution of the lattice parameter with the island height. Beside, the non-rigid substrate approximation is used [4, 5], assuming a coherent behavior at the substrate/film interface. The obtained strain tensor components are used to discuss the effect of the substrate orientations on conduction, heavy- and light-hole band-edge energies, using respective deformation potentials [6]. Our results confirm the 2D-3D transition, following the SK growth mode for the (113) and (115) orientations. The obtained WL revealed higher delay in (113) in comparison to the (001) and (115) cases, with 2.07, 1.78 and 1.92 ML, respectively. However, for the (111) orientation, an unexpected WL of 1.87 ML is obtained. This last result contrasts with 2D layer-by-layer mechanism reported by Joyce et al. [1], while it confirms the Tsai et al. findings [7].

For the band-edges, the (115) reveals higher energy shifts with respect to the (001) in the island as the height changes. The effect of the WL is clearly observed [see figures 1, 2 and 3] in the conduction, h-h and l-h profiles through a kink across the film/substrate interface. Both results reproduce the tendency of potential profiles in good agreement with previous k.p works [6, 8].

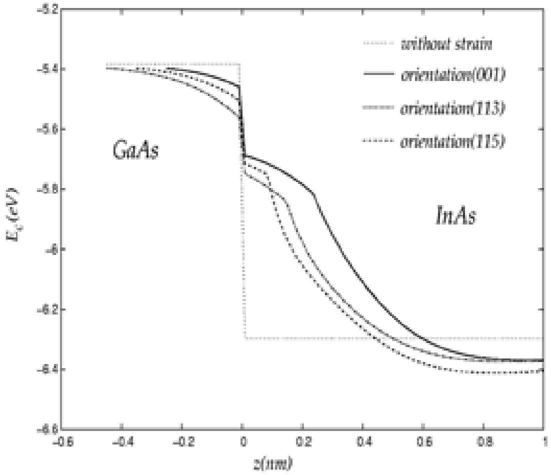

Figure 1. Conduction band edge along the growth direction for different substrate orientations.

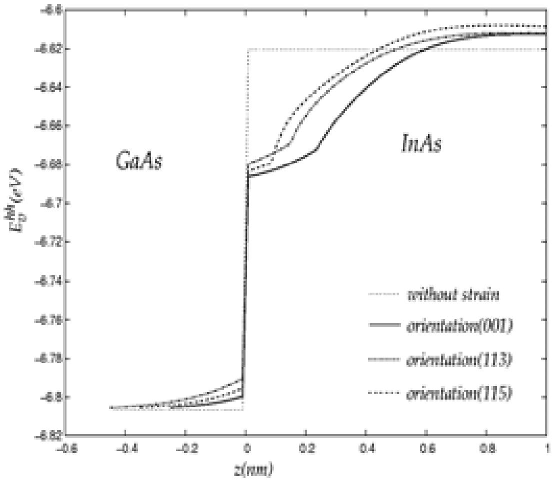

Figure 2. Heavy-hole band edge along the growth direction for different substrate orientations.

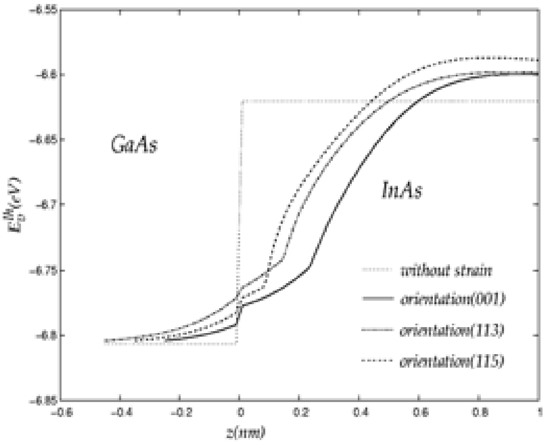

Figure 3. Light-hole band edge along the growth direction for different substrate orientations.

References

[1] B.A. Joyce, T.S. Jones and J.G. Belk, J. Vac. Sci. Technol. B **16**, 2373 (1998).

[2] P.P. González-Borrero, E. Marega, D.I. Lubyshev, E. Petitprez and P. Basmaji, J. Crys. Growth **175/176**, 765 (1997).

[3] S. Sanguinetti, G. Chiantoni, E. Grilli, M. Guzzi, M. Henini, A. Polimeni, A. Patané, L. Eaves and P.C. Main, Mat. Sci. Engineering B **74**, 239 (2000).

[4] S.N. Santalla, C. Kanyinda-Malu and R.M. de la Cruz, J. Crys. Growth **23**, 190 (2003).

[5] S.N. Santalla, C. Kanyinda-Malu and R.M. de la Cruz, Nanotechnology **15**, S215 (2004).

[6] V.G. Stoleru, D. Pal and E. Towe, Physica E **15**, 131 (2002).

[7] F.Y. Tsai and C.P. Lee, J. Appl. Phys. **84**, 2624 (1998).

[8] M. Tadic, F.M. Peeters, K.L. Janssens, M. Korkusinski and P. Hawrylak, J. Appl. Physics **92**, 5819 (2002).

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