Correlated and anti-correlated vertical self-organization of InAs quantum wires in InAs/InP stacked structures versus the spacer layer nature

M. Gendry*, J. Brault*, C. Monat*, J. Kapsa*, G. Grenet*,
O. Marty**, M. Pitaval**, G. Hollinger*

**LEOM, Ecole Centrale de Lyon, 69131 Ecully Cedex, FRANCE*

***LENAC, Université Lyon 1, 69622 Villeurbanne Cedex, France*

Stacking process is today a widely used approach to improve strain-induced quantum island self-organization. We address here the vertical self-organization of stacked InAs quantum island layers grown on InP(001) substrate using either InP or InAlAs as spacer layers, two favorable systems for low threshold quantum dot lasers (QDL) [1] and intraband infrared photodetectors (QDIP) [2], respectively.

From AFM imaging and TEM microscopy, the vertical arrangement is shown to be strongly dependent on the nature of the spacer layer. On the one hand, for InP spacers, cross-sectional TEM images exhibit the well-known correlated vertical alignment of InAs islands (figure 1) similar to that observed for Ge/Si and InAs/GaAs systems and classically explained as due to the strain field induced by the buried islands. On the other hand, for InAlAs spacers, (spacer thickness less than 25nm), the stacking process gives rise to an anticorrelated vertical arrangement of the InAs islands (figure 2b). In the AlInAs case, whatever the first-layer island shape (i.e. dot-like or wire-like) is, the stacking process favors a pronounced wire-like shape (figure 2a). The InAs wire widths and heights are dependent on the spacer thickness. Actually, the wire size homogeneity is improved for a spacer thickness in the 10-15 nm range. This anticorrelated arrangement is the result of a phase separation taking place in the InAlAs spacer layer [3]. Hence, Indium-rich V-like arms originate from each InAs wire and evanescently propagate within the InAlAs spacer layer, and the meeting point of two adjacent arms appears to be an adequate nucleation site for a new InAs wire growth.

We will discuss how growth conditions should be chosen in order to improve the stacking process versus the vertical arrangement kind. For correlated arrangement, we have to restrain the increase of the wire size during the stacking process. In contrast, for the anticorrelated arrangement, a relationship between the wire width and the spacer thickness ought to be fulfilled in order to avoid the coming out of wire missing rows responsible for a worsening of wire organization.

[1] C. Seassal and al, *InAs quantum wires in InP-based microdisks: mode identification and CW room temperature laser operation,* to be published in J. Appl. Phys., December 2000.
[2] F. Fossard and al, *Infrared spectroscopy of self-organized InAs nanostructures grown on InAlAs/InP(001) for infrared photodetection applications,* proceedings of International Conference QWIP 2000, Dana Point, July 27/29, 2000. To be published in Infrared Physics and Technology.
[3] J. Brault et al, *Staggered vertical self-organization of stacked InAs/InAlAs quantum wires on InP(001),* Appl. Surf. Sci, 166, 326, 2000.

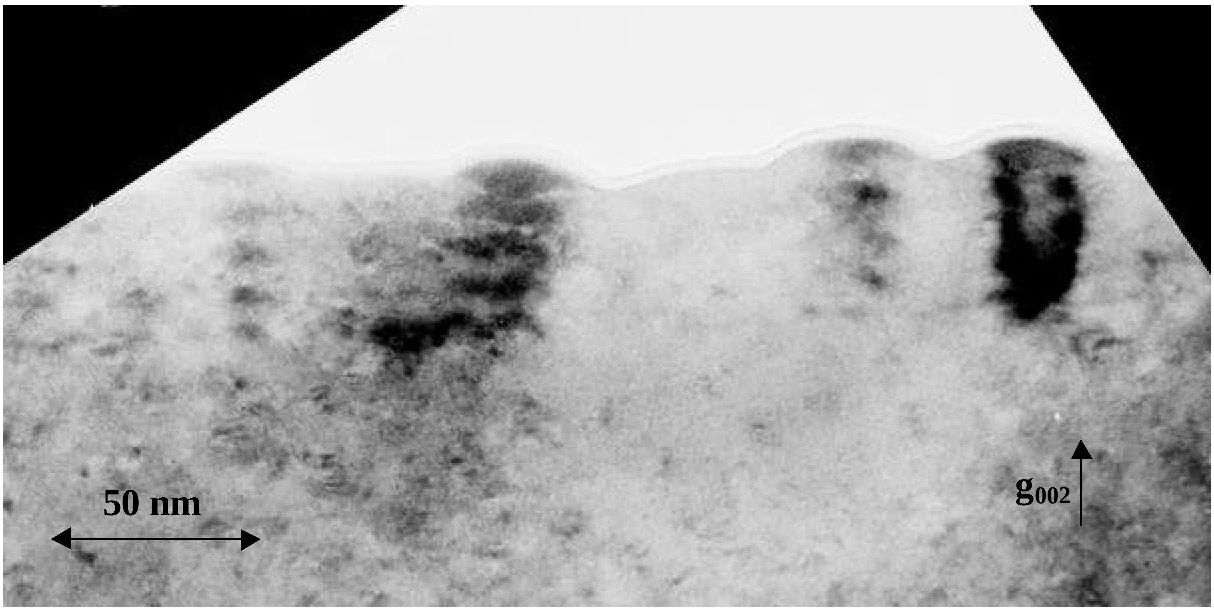

Figure 1: Cross-sectional TEM image showing the correlated vertical alignement for InAs/InP stacked strucures on InP(001) with a 10 nm spacer thickness.

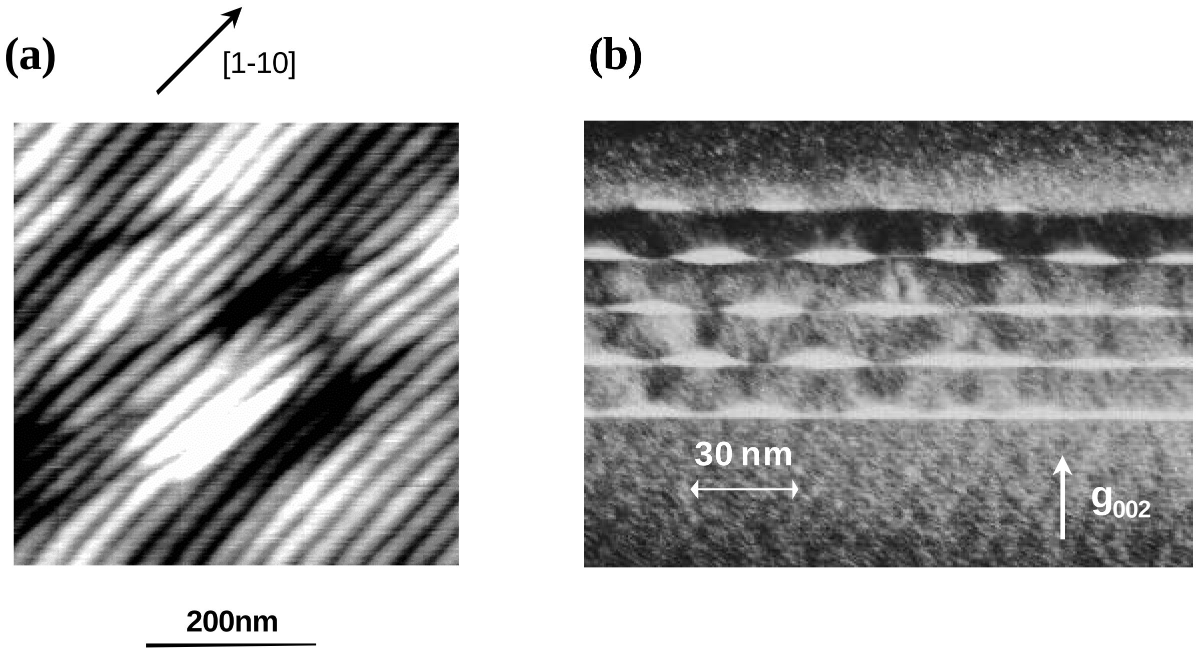

Figure 2 – InAs/InAlAs stacked structures on InP(001) with a 15 nm spacer thickness: (a) AFM image of the 5th plane showing the wire-like shape of the InAs islands and b) cross-sectional TEM image showing the anticorrelated vertical arrangement.