Available online at www.sciencedirect.com
SCIENCE DIRECT®
Physica E 17 (2003) 174–176
PHYSICA E
www.elsevier.com/locate/physe

Size self-filtering effect in vertical stacks of InAs/InP self-assembled quantum wires

B. Alén[a,*], J. Martínez-Pastor[a], D. Fuster[a], J.M. García[b], L. González[b], S.I. Molina[c], A. Ponce[c], R. García[c]

[a] *Instituto de Ciencia de los Materiales de la Universidad de Valencia, P. O. Box 2085, 46071 Valencia, Spain*
[b] *Instituto de Microelectrónica de Madrid (CNM-CSIC), Isaac Newton 8, P.T.M., 28760 Tres Cantos Madrid, Spain*
[c] *Departamento de Ciencia de los Materiales e Ingeniería Metalúrgica y Química Inorgánica, Universidad de Cádiz, 11510 Cádiz, Spain*

Abstract

Multilayer structure containing vertically stacked InAs/InP self-assembled quantum wires (QWR) have been successfully grown by molecular beam epitaxy. We have found that spacer layer thickness fully determines the structural and optical properties of the multilayer structure, being observed a strong improvement of the homogeneity and uniformity of the QWR stacks in the case of an appropriate layer spacing.

PACS: 73.21.Hb; 78.55.Cr; 78.67.Lt

Keywords: Quantum wires; Photoluminescence; Vertical stacks

The stacking of self-assembled quantum wires (QWR) in multilayer structures has been proposed as an efficient mechanism to improve uniformity and hence optical quality. Using InP as the spacer material, in this work we present evidences of a strain driven vertical filtering of the wire sizes in stacked InAs self-assembled QWR multilayers [1]. The samples studied here consist of a stack of ten layers containing self-assembled InAs QWRs separated by InP spacer layers with different thickness (5 nm for sample A and 12.5 nm for sample B), grown by MBE on InP[0 0 1] substrates. A similar sample containing a single QWR layer is used here for comparison.

Bright field XTEM images of samples A and B recorded under two beams condition exciting the 002 reflection are shown in Fig. 1. From the XTEM analysis of the wire stacks, the average height (H) and width (W) of the different QWRs, as well as the average distance between stacks (λ) can be extracted. In Fig. 1a we can observe that most of the wires in the first layer in sample A propagates vertically giving rise to aligned and uniform stacks of wires. The uniformity of the wires is measured by $\Delta H/H$ and $\Delta W/W$, which are around 18% and 10%, respectively. The uniformity of the spatial distribution of the stacks is measured by $\Delta\lambda/\lambda$, also around 10%. In contrast, only one from each three wires ($\lambda_A/\lambda_B \sim 1/3$) in the first layer in sample B becomes a nucleating wire and propagates vertically giving rise to QWR stacks. At the same time, the positions of the remaining wires

* Corresponding author. Fax: +34-963543633.
E-mail address: jbalen@uv.es (B. Alén).

1386-9477/03/$ - see front matter
doi:10.1016/S1386-9477(02)00740-3

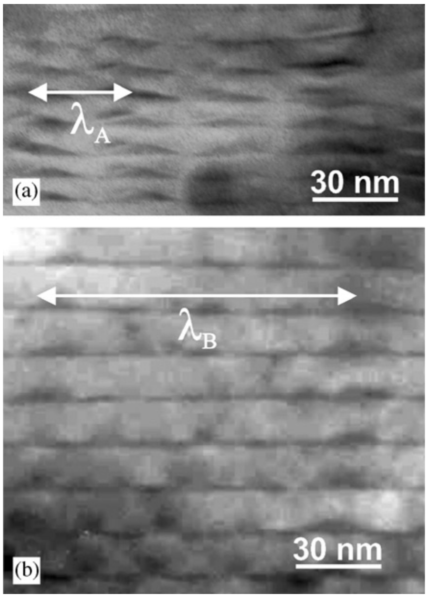

Fig. 1. XTEM images of samples *A* (a) and *B* (b). The typical distance between two consecutive stacks is shown in each case.

are not vertically correlated in the consecutive layers as shown in Fig. 1b. It is also noticeable that the nucleating wire in sample *B* is particularly big, namely, a 'defect' wire, and that the uniformity of the wires in the stacks is two times worse than in sample *A* (measured by $\Delta H/H$ and $\Delta W/W$), as also occurs for their spatial distribution ($\Delta\lambda_B/\lambda_B \sim 22\%$).

Therefore, the above given results demonstrates how the 5 nm thick spacer is thin enough for enabling an efficient strain propagation along the growth direction through the whole structure. The wires are clearly piled up in a correlated way, and, at the same time, the strain redistribution between wires and spacer layer has a filtering effect on the size of the wires being stacked, giving rise to the observed vertical and lateral uniformity. The larger thickness (12.5 nm) of the InP spacer layers in sample *B* inhibits partially the strain propagation between consecutive layers and the wires in vertical stacks are only 1/3 of the total, promoted by 'defect' wires in the first layer.

Fig. 2 shows the PL spectra at 50 K for one sample containing single layer QWRs (Fig. 2a), samples *A* (Fig. 2b) and *B* (Fig. 2c). In the single layer case the PL band can be deconvoluted in several Gaussian

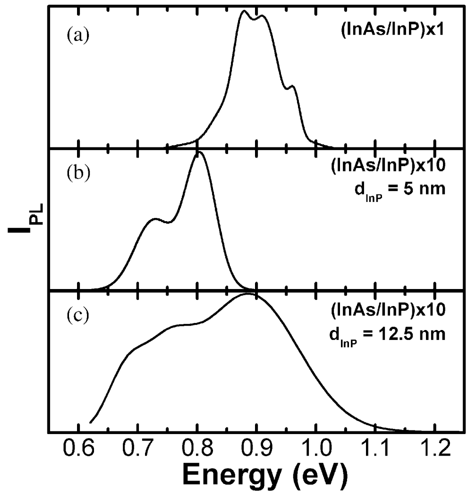

Fig. 2. PL spectra at 50 K of (a) sample containing a single QWR layer, (b) sample *A* and (c) sample *B*.

components. As was pointed out in a previous work [2], two consecutive components arise from 1 ML fluctuation in the wire height. In sample *A* we can deconvolute two Gaussian components, centered at 0.728 and 0.805 eV at 50 K, being the latter the dominant one. The line widths of such components are around 50 meV, approximately the double of the line widths deduced for single-height family emission lines in the single layer sample. In this way, each emission component in sample *A* would arise from a stack family in which the wire height fluctuations are around 2 ML (0.6 nm) in agreement with the standard deviation found by XTEM in this sample. On the contrary, we find a broad emission band at 0.89 eV in sample *B* and two not well resolved and narrower components at 0.678 and 0.745 eV. Correlating the PL results with the XTEM data, we can assign the broad band to the dominant vertically uncorrelated wires, 2/3 of the total. The low energy bands would be thus associated to vertical stacks of wires, in a 1/3 proportion. The overall line width of these poorly resolved bands, are compatible with the 4 ML (1.2 nm) standard deviation of the wire height found in the wires of the examined stacks in sample *B*. At the same time, the redshift of these bands is consequent with the larger average wire height found in the stacks of this sample (4.3 nm) with respect to the average value found in sample A (3.4 nm), for which we associate the main emission band at 0.805 eV shown in Fig. 2b.

This work has been supported by the Spanish CICYT under the project no. TIC99-1035-C02 and European Commission GROWTH program NANOMAT project, Contract no. G5RD-CT-2001-00545.

References

[1] B. Alén, J. Martínez-Pastor, L. González, J.M. García, S.I. Molina, A. Ponce, R. García, Phys. Rev. B Rapid Commun. 65 (2002) R241301 (and references therein).

[2] B. Alén, J. Martínez-Pastor, A. García-Cristobal, L. González, J.M. García, Appl. Phys. Lett. 78 (2001) 4025.