Innovative self-assembling of QDs in InAs/GaAs multistacked structures: in-line correlation and ordering

Latini Valerio*,1, Placidi Ernesto1,2, Arciprete Fabrizio1, Magri Rita3, Patella Fulvia1

1Dipartimento di Fisica, Università di Roma Tor Vergata, Via della Ricerca Scientifica 1, 00133, Roma (Italy)
2CNR - Istituto di Struttura della Materia, Via del Fosso del Cavaliere 100, 00133 Roma (Italy)
3Dipartimento di Fisica, Università degli Studi di Modena e Reggio Emilia and Centro S3 CNR - Istituto di Nanoscienze, Via Campi 213/A, 41100 Modena (Italy)
*email: valerio.latini@roma2.infn.it

The use of Quantum Dots (QDs) in the fabrication of sophisticated devices requires a control on their spatial order and size uniformity. Over the last decades, great advances have been achieved by combining bottom-up and top-down growth methods, such as electron-beam or optical lithography pre-patterning of the surface, or by multilayer stacking in heteroepitaxy of highly mismatched semiconductors [1].

In the case of InAs/GaAs(001) multilayers, by applying an innovative Molecular Beam Epitaxy (MBE) growth of self-assembled QDs, we succeeded in growing distanced sets of ordered $n$-fold parallel chains of QDs along the $[1\bar{1}0]$ direction after the deposition of exactly $n$ layers (GaAs spacer plus InAs QDs), with $n$ as small as 2 [2]. In the AFM topographies of the samples $L_n$, the alignment of the chains is related to the mound structure elongated in the $[1\bar{1}0]$ direction (see Fig.1). The impressive self-organization of the QDs is explained in terms of a driven Indium surface diffusion by some different mechanisms acting in the growth process, at critical conditions [3].

From the AFM image of the $L_4$ sample and the cross sectional Transmission Electron Microscopy (TEM) image of the (-110) plane – Fig. 2 – we observe that the mound side hosting the QDs widens towards the Arsenic flux, so as to accommodate an additional unstacked QD chain every new layer.

We measured the in-line distances along the QD chains to study the correlation among them. The analysis of the in-line distance distributions shows a progressive ordering of the QD positions with average distance of about 75 nm, as the number of layers was increased.

Finite Element Method simulations – Fig.3 – of an experimental InAs/GaAs(001) multilayer confirmed this trend which is driven mainly by the propagation of the elastic strain field through the layers [4].

We concluded that the strain field of the buried QDs plays a crucial role in rendering the in-line distances between the QDs uniform, whereas the alignment of the single QD chain is mainly related to the morphological features of the mounded surface.