Quantum dot formation from sub-critical InAs layers grown on metamorphic buffer

P. Frigeri [1,*], **G. Trevisi** [1] **and L. Seravalli** [1]

[1] *IMEM-CNR Institute, Parco Area delle Scienze 37/A, I-43124 Parma , Italy*

Low-density Quantum Dot (QD) structures are currently the object of intensive research devoted to develop novel nanophotonic devices for quantum communication and computing. In order to tune single-QD emission at telecom wavelengths (1.3 - 1.55 µm), the growth of InAs/InGaAs metamorphic QD structures on GaAs substrates, has been successfully proposed [1, 2]. InAs QDs grown on InGaAs show significant morphological differences with respect to more intensively studied InAs/GaAs system. Since quantum confinement effects in QD nanostructures are strongly dependent on island shape and island-size distribution and uniformity, a deeper understanding of QD formation process in metamorphic structures is essential to improve the prediction and control of their light-emission properties.

Here, we focus on the study of self-aggregation of low density InAs QDs on metamorphic InGaAs buffer by using Atomic Force Microscopy (AFM) and Photoluminescence (PL) techniques.

InAs QD layers were grown by molecular beam epitaxy on underlying structures consisting of: *i)* a 100 nm-thick GaAs layer, *ii)* a 500 nm-thick InxGa1-xAs (x = 0, 0.15, 0.30) and *iii)* a 5 nm-thick GaAs layer. Ensemble and single QD optical properties were studied on identical structures capped with 20 nm-thick $In_xGa_{1-x}As$.

The structure design and growth parameters were chosen to enable the study of the self-assembly mechanism considering the following two concomitant conditions. First, InAs QDs are formed during the post-growth annealing of an InAs layer thinner than the critical thickness for 2D-3D transition [3]. Avoiding the effects due to incoming In atoms, it is possible to highlight the nucleation mechanisms dependent on composition-related properties of InGaAs metamorphic layers, such as strain status and surface corrugation. Second, the insertion of a thin GaAs layer before InAs deposition, by reducing the role of the different growth front-Indium populations associated with the different buffer compositions, allows to investigate the effects on QD formation mainly due to the surface lattice parameter imposed by the metamorphic InGaAs layer.

We demonstrate that, by optimizing the values of sub-critical InAs coverage and post-growth annealing time, an accurate control on island morphology and very low QD density, down to 10^8 cm^{-2} (Fig 1), can be achieved. Moreover, micro-PL experiments performed on InAs/$In_{015}Ga_{0.85}As$ structures reveal an efficient single-QD emission [4].

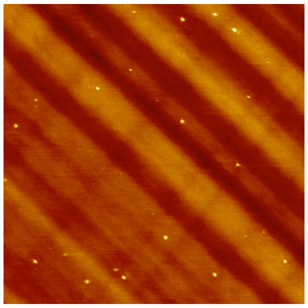

Fig 1: 5x5 µm^2 AFM image of QDs formed by postgrowth annealing (100 s) of a 1.5 ML of InAs grown on metamorphic $In_{015}Ga_{0.85}As$.

Finally, we discuss the challenges arising from the combined use of metamorphic and sub-critical InAs deposition approaches to drive the positioning of QDs on the surface, an essential requisite for quantum information applications.

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[*] Contact: p.frigeri@imem.cnr.it