InP surface patterning to localize InAs quantum dots

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Self-organized quantum islands (QIs) in InAs/InP system are promising candidates for realization of the building blocks that could be used in classical or quantum photonic circuits, such as low threshold microlasers or single photon sources, operating at 1.55 µm.

A simple way to obtain QIs, is to exploit the Stranski-Krastanov growth mode of strained layers. Beyond a critical thickness of deposited InAs layer, three-dimensional (3D) islands grow spontaneously in order to reduce misfit strain. In low mismatched (~3%) InAs/InP(001) system [1,2], the self-organized InAs QIs exhibit a wire or a dot-like shape depending on the growth conditions (Fig. 1), rather large size dispersion, typically in the 10-20% range, and high island density in range $2.5\ 10^{10}$ -$1\ 10^{11}$ cm^{-2}.

InAs QIs with dot-like shape, narrower size dispersion and controlled density and spatial localization are required either for low threshold laser or single photon source applications [3]. These goals can be achieved with surface nanopatterning that allows controlling of the QI nucleation sites. Two ways are mainly explored as surface patterning for nucleation control: i) arrays of nanoholes [4] and ii) arrays of nanomesas [5].

In this work, we focus on the fabrication of arrays of InP nanomesas with the following specific features: to obtain a single quantum dot (QD) on the top of nanomesa, it is necessary to fabricate nanomesas of diameter smaller than 80 nm. While for laser applications, nanomesas density must be higher than 10^2 μm^{-2}, for single photon sources the desired density can be close to 1 μm^{-2}.

Nanomesa arrays are obtained using electron beam (e-beam) lithography and CH_4-H_2 based reactive ion etching (RIE). E-beam lithography is performed with a JEOL 5500 SEM Microscope and a Elphy Quantum writing system (Raith), on InP epilayers covered with a SiO_2 hard mask. After patterning with nanomesas and preparing the InP surface for regrowth, a 5 nm-thick InP buffer layer is grown by Solid Source Molecular Beam Epitaxy (SSMBE), followed by the growth of the InAs QDs.

Isolated nanomesas and arrays of nanomesas are fabricated in order to study the influence of lithography, etching conditions and structure density (effect of proximity) on the nanomesa size and side abruptness (Fig. 2). The others issues investigated in this work are the resist adhesion on SiO_2 mask surface for small dimension features and the protection of the InP nanopatterned surface during SiO_2 mask deposition. Solutions such as a SiO_2 bi-layer hard-mask or a protective semiconductor cap layer are discussed. Finally, the dimensional stability of the nanomesas under thermal regrowth conditions and the first results of InAs QDs grown on patterned InP surfaces will be presented (Fig. 3). In order to help the localization of the QDs on top of nanomesas, what is done by induction of strain, a stressor layer is introduced in the nanomesas [5]. The effects of this stressor layer will be examined.

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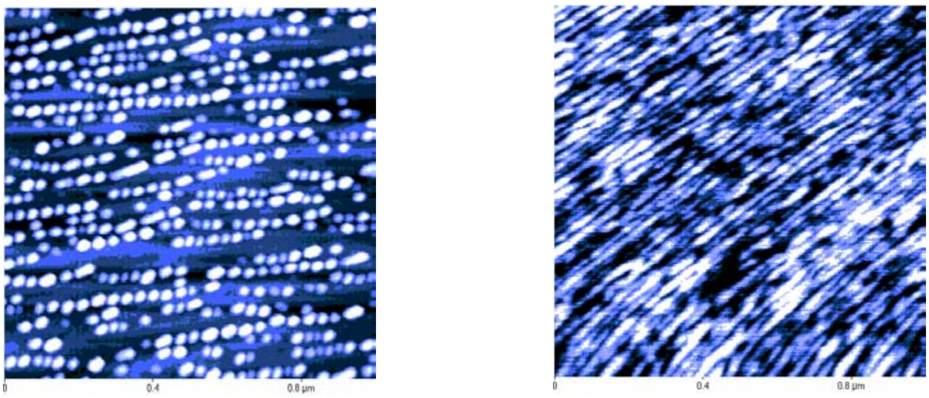

Fig 1 : AFM images of dot or wire-like InAs QIs grown on InP(001) depending on the growth conditions.

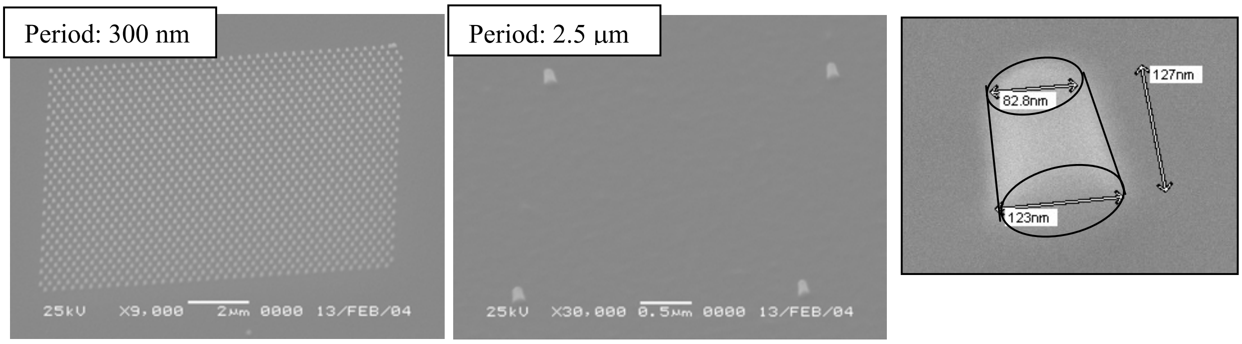

Fig. 2 : SEM images of arrays of nanomesas, about 100 nm large, with different periods.

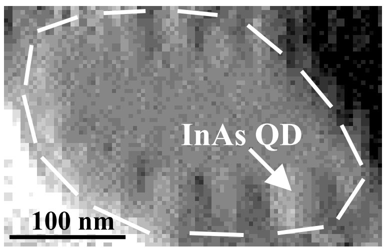

Fig. 3 : AFM image of InAs QDs grown on top of an InP nanomesa, 200x300 nm large.