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Site control of InAs quantum dots on GaAs(001) substrates patterned by local oxidation Atomic Force Microscopy nanolithography

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Resumen

Local oxidation nanolithography with an atomic force microscope (AFM) has shown its capabilities as a powerful technique for the fabrication of patterned semiconductor substrates with an accurate control in shape, size and position of printed motives [1,2]. In this work, we present a fabrication process that combines local oxidation nanolithography by AFM with molecular beam epitaxy (MBE) growth techniques in order to control the nucleation sites of InAs quantum dots (QD) on GaAs (001) substrates [3]. The precise location of these nanostructures is critical for the fabrication of single photon emitter devices, where an isolated QD has to be situated at a specific site inside an optical microcavity [4].

Our approach basically involves three steps: i) Fabrication of patterned GaAs(001) substrates by AFM local oxidation lithography: The pattern consist of a 2D array of nanometric size oxide dots (see Fig. 1a). The GaAs oxide dots are removed by FH selective etching obtaining 2D arrays of nanometric holes (see Fig. 1b); ii) Preparation of GaAs(001) patterned substrates for further epitaxial growth by a process that preserves the pattern. This process includes GaAs native oxide desorption and GaAs buffer layer growth; iii) InAs deposition on patterned substrates.

Our experimental results show that a high selectivity of InAs nucleation in the nanoholes can be achieved when appropriate growth conditions are used. Therefore, the QD density can be freely chosen just by varying the pattern design (Fig. 2). The number of QD obtained inside each nanohole can also be chosen by controlling the geometrical shape of each oxide dot. (Fig. 3).

Finally, in order to validate our whole fabrication process, micro-photoluminescence characterization of a single InAs QD obtained by this process will be presented.

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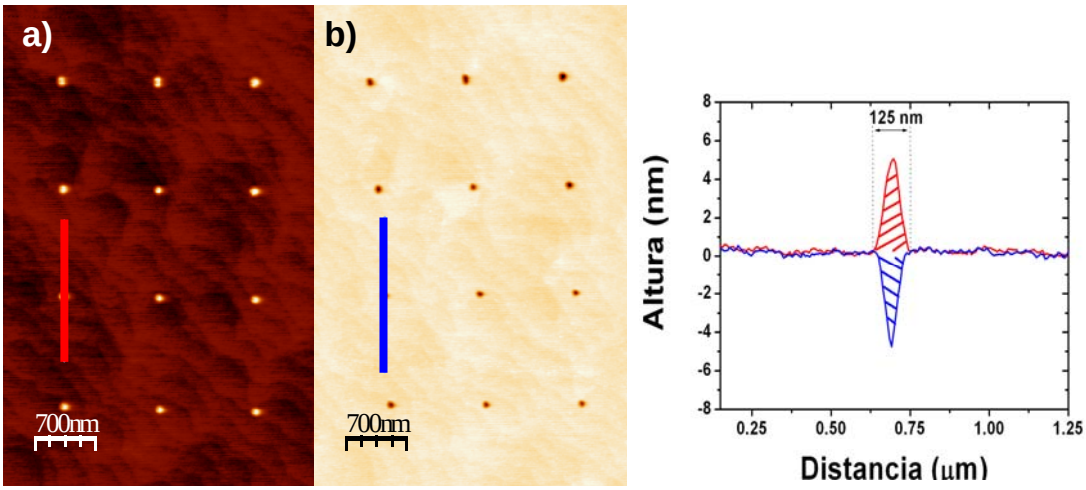

Fig 1: a) Atomic Force Microscopy (AFM) images of oxide dots fabricated by AFM local oxidation nanolithography. b) 2D array of nanoholes obtained after selective FH chemical etching of oxide dots . Notice on profiles shown on the right that the volume of emerging oxide dots are similar to that of the resulted holes.

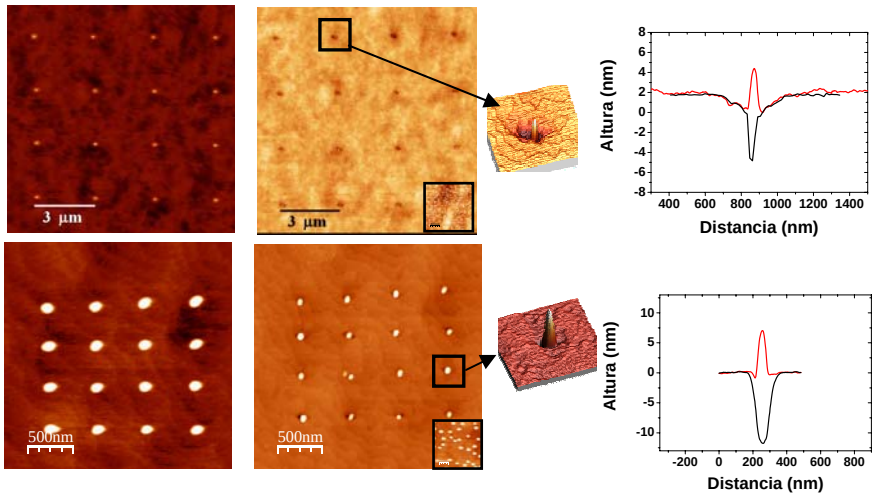

Fig. 2: AFM images of 2D arrays of oxide dots fabricated by AFM local oxidation technique (left) and resulting InAs QDs after growth process (right). Density of QDs can be controlled as desired varying the pattern design.

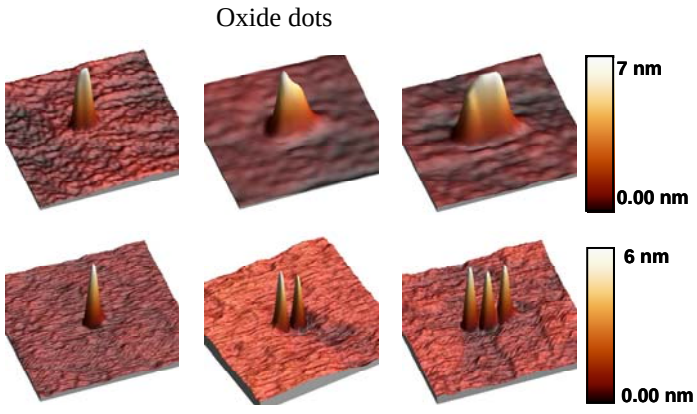

Fig 3: AFM images of oxide dots fabricated by AFM local oxidation (top row) and resulting InAs QD after growth process (bottom row). Different number of QD can be obtained by varying oxide dot shape.