InP Nanopatterning based on non contact mode Atomic Force Microscopy and modulated voltage

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The miniaturization of electronic or optoelectronic components induce a perpetual increasing of lithography cost. In the future, this increasing will be accelerating by the emergency of the deep-uv or the x-ray lithography technique. In this context, alternatives techniques, like lithography based on Atomic Force Microscopy [1] (AFM) or electronic microscopy [2] (e-beam) could be a good solution to develop demonstrated devices in advance on heavier technologies. Theses techniques come to be mature and "easily" allow to obtain nanoscale writing. The weakness of writing velocity of such local probe lithography could be compensated by integrating them in a traditional lithography process, allowing nanodevice integration. Regarding the importance of InP in telecommunication technology, the AFM nanolithography has been rarely investigate in order to fabricate nanophotonic devices.

The InP local oxidation studies by AFM are reported. The main purpose is to control a nanoscale writing process which allows to either isolate or/and organize nanostructures. The chosen approach is an original technique combining an AFM intermittent contact mode with a modulated voltage. This method is implemented on an AFM DI3100 working under controlled atmosphere in term of gas composition and hygrometry. Different pattern were realized in order to bothly understand the oxidation mechanisms and to characterize the oxides quality. The first realized patterns are solid lines (figure 1a) ranging from 40 nm to 100 nm in width and from 1.5 to 10 nm in high. These lines enabled us to analyze the growth of oxide formed according to the applied voltage as well as the lithography velocity. The second used patterns are dots (figure 1b) for which the diameter and the height are ranged respectively from 15 to 80 nm and from 1 to 5 nm. Therefore, it was possible to characterize the influence of applied voltage and time exposition onto oxidation process. The homogeneity has further been analyzed.

The results obtained with this intermittent contact mode oxidation are contrasted. Its present in comparison to a standard oxidation (positive voltage applied in contact mode) an improvement for both homogeneity and resolution (below 20nm). An oxidation growth linear law is obtained for both voltage amplitude and oscillating amplitude agreed with standard mode oxidation law. However we obtain more specific results to this method. Oxide growth kinetic (figure 2a) highlights saturation for low tip velocity (below 5um.s-1). The Studies on the influence of the oxidation time have emphasized two regimes (figure 2b). First, a high growth rate was found for oxidation times less than 100 ms. Second, for oxidation times more than 100 ms, we observe an oxide height saturation and a lower lateral growth rate. These results provide a way to control separately both heigth and diameter of oxide dots. Finally to characterize volume aspect of these oxides, the samples were selectively etching with hydrofluoric acid. The growth is symmetric from the surface ("surface" oxide accounts for 40 to 52% of total volume). All our resulted could be explained in terms of space charge behavior during lithography induced by the modulated voltage.

In conclusion a control of local oxidation parameters and surface morphology after etching leads to consider AFM lithography as a promising technique to fabricate nanoscale devices. Concerning the good control of the localization and its lateral resolution, AFM lithography technique could be envisaged to perform nucleation sites for nanoobjects (quantum dots, molecules…)

References:

[1] J.A. Dagata Applied Physics Letters Vol.73 Nbr.2

[2] J.A. Dagada, F. Perez-murano, G. Abadal and al, Appl. Phys. Lett. ,79(19), 2000, 2710

Figures:

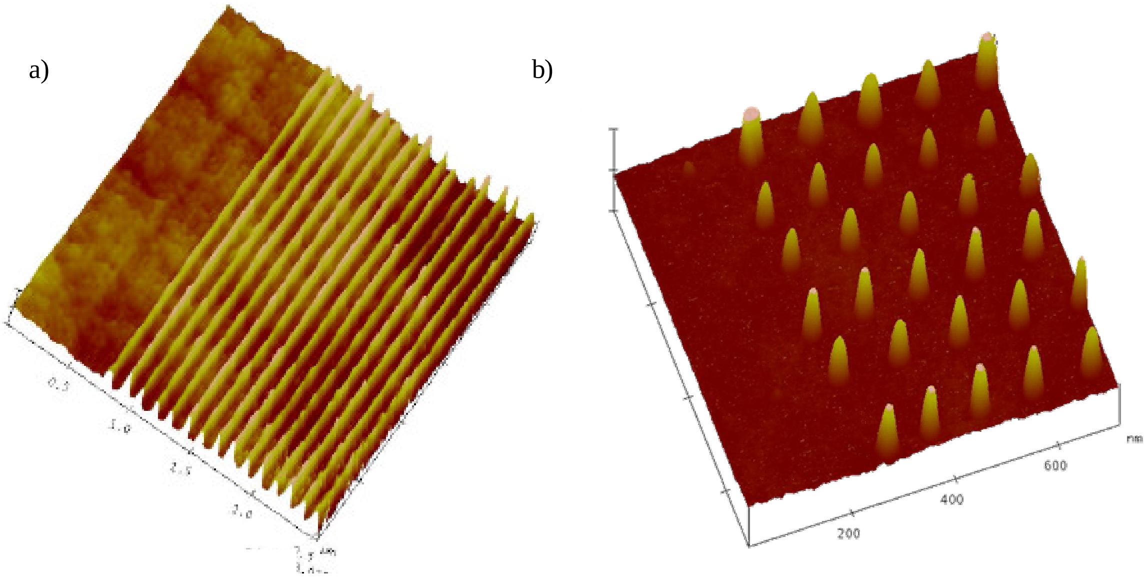

Figure 1: a) Solid oxide line and b) oxide dots realize by non contact oxidation

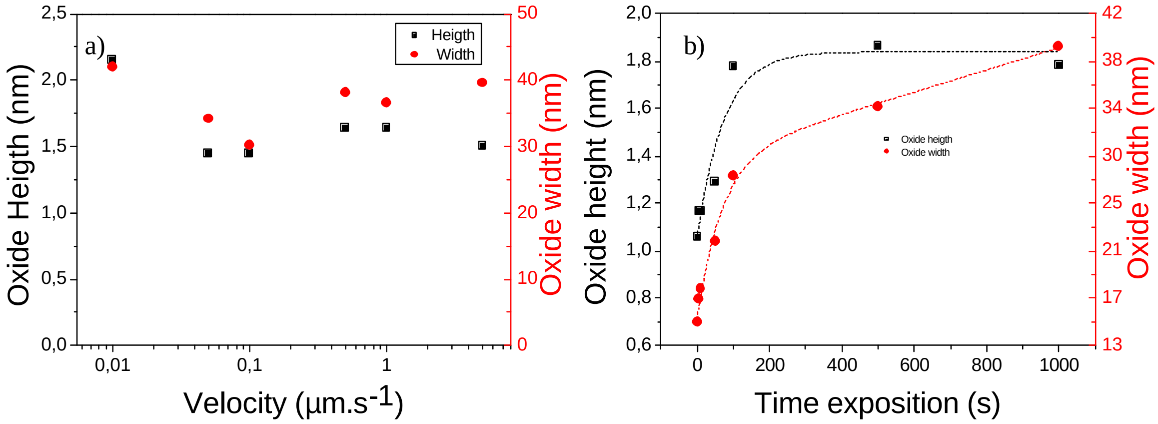

Figure 2: oxide evolution with a) tip velocity and b) oxidation time exposition