InP PATTERNING: COMPARASON BETWEEN CONTACT AND NON CONTACT MODE IN AFM LOCAL ANODISATION

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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 could be compensated by a complementary use of traditional lithography techniques which allows nanocomponents integrating. Although 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 in nanoscale writing process which allows to either isolate or/and organize nanostructures. Two approaches are explored. The first method consists to apply a constant potential between the probe and the substrate in contact mode. The second method proposes an original technique combining an AFM intermittent contact mode with an alternating voltage. These two methods are 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 characterize the created oxides. The first realized patterns are solid lines (figure 1a) ranging from 60 nm to 300 nm in width and from 4 to 30 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 250 nm and from 1 to 15 nm. Therefore, it is possible to characterize the influence of applied voltage and time exposition onto oxidation process. The homogeneity of these two oxidation techniques could further be analyzed. The results performed in contact mode exhibits an oxide growth linear law as function of applied voltage (figure 2a) but also a logarithmic evolution with velocity and oxidation time (figure 2b) in agreement with predicted nanoanodisation mechanisms [3]. This mode is also characterizing by a poor homogeneity with 50nm maximum lateral resolution. In intermittent contact mode, these results are more contrasted and highlight saturation for low velocity (below 0.1um.s-1) and a good resolution (15nm). 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). We will discuss and explain all our results in terms of space charge behavior during lithography and present possibilities for InAs Quantum Dots controlled growth on InP.

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. 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] T. Ishikawaet al., JVST B, 18(6), 2000, 2635

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

Figures:

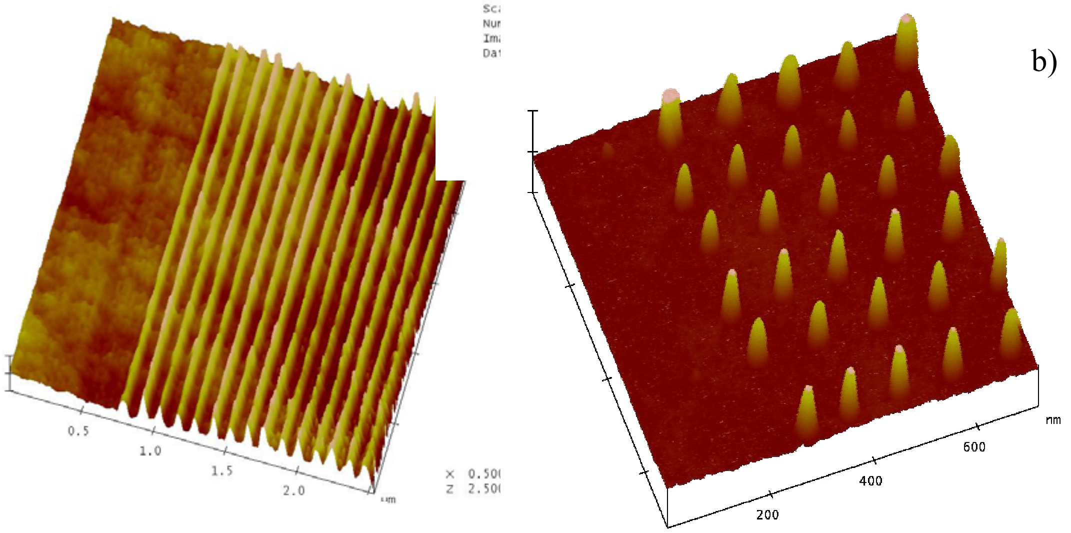

Figure 1: Solid line a) and dots b) realize by non contact oxidation (30 nm width for 1.5 nm of height)

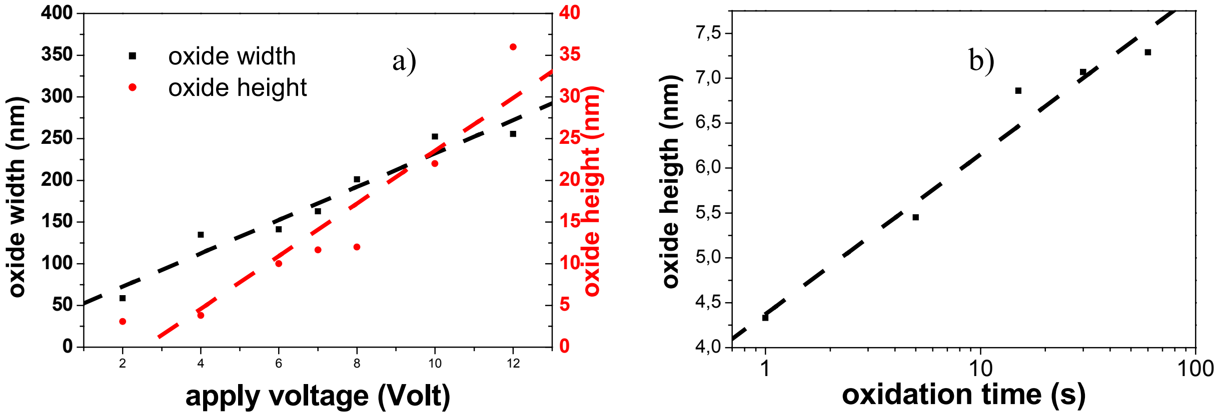

Figure 2: oxide evolution with apply voltage a) and oxidation time b)