High growth efficiencies in helium ion beam induced deposition at short beam dwell times

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Helium ion beam induced deposition (He-IBID) is one of the methods to grow nanostructures. It is a good alternative for the slow electron beam induced deposition (EBID) and the coarse gallium ion beam induced deposition (Ga-IBID).[1]

In this work we have used the sub-nanometer focused ion beam of an Orion helium ion microscope to optimize He-IBID conditions. PtC nanopillars were grown on a silicon substrate using the $(CH_3)_3Pt(C_PCH_3)$ precursor. Beam current, beam dwell time, and gas refreshment time have been varied independently, while the beam energy and ion dose were kept fixed at 25 keV and 6 pC, respectively. Uninterrupted exposure resulted in narrow but short pillars, while interrupted exposure in thicker and higher ones, see Figure 1. Furthermore, at short dwell times (<<100 us, corresponding to ~100 ions per exposure cycle), the deposition efficiency can be very high, see Figure 2. The interpretation of the experimental data is aided by Monte Carlo simulation of the deposition.[2]

The results indicate that two regimes are operational in IBID. In the first one, the adsorbed precursor molecules originally present in the bombarded area are either being converted into a deposit by beam induced decomposition or disappear by beam induced desorption. After the original precursor layer has vanished, growth continues thanks to a fresh supply of molecules via surface diffusion and continued adsorption. The balance between these processes determines the growth efficiency and the achievable spatial resolution.

Hence, optimization of writing strategies promises efficient fabrication of extended and complex nanostructures by He-IBID. Very high efficiencies and good precision are achievable, but the method of precursor supply is decisive.

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[1] P. Chen *et al.*, Nanotechnology **21**, 455302 (2010).
[2] D.A. Smith, D. Joy and P.D. Rack, Nanotechnology **21**, 175302 (2010).

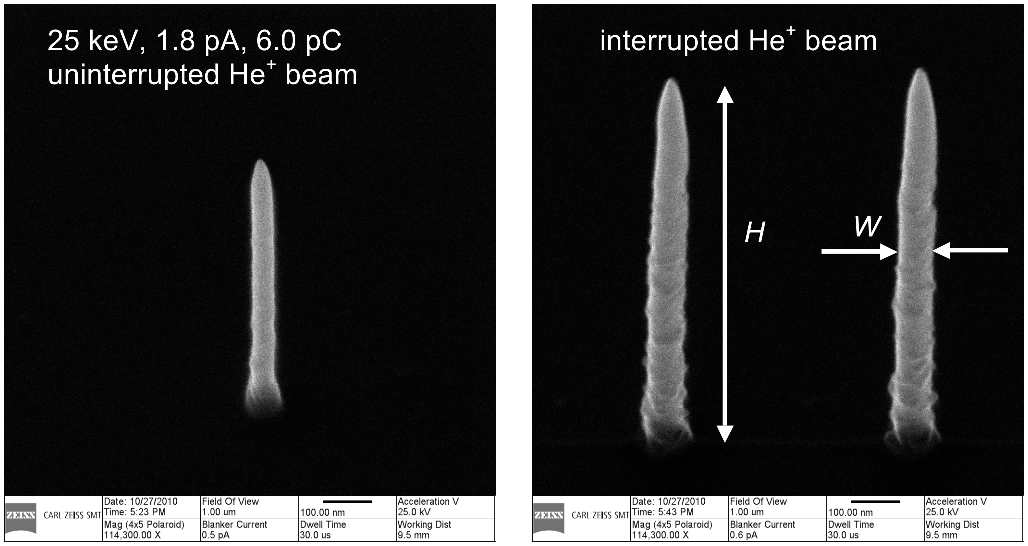

Figure 1: PtC pillars grown with an uninterrupted beam (left) and an interrupted beam (right), same conditions. The interruption of the beam allows for refreshment of the precursor layer, leading to enhanced vertical and lateral growth.

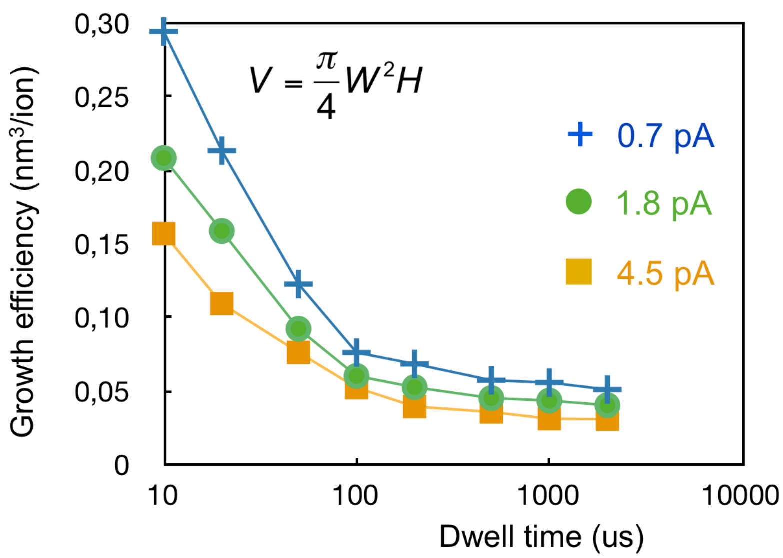

Figure 2: Growth efficiency for pillars as a function of helium ion beam dwell time for various beam currents but fixed dose. The growth efficiency, viz. the deposited volume V per incident ion, is a strong function of beam dwell time. Dwell times below 100 us correspond to typically 40 to 3000 ions per cycle. For longer dwell times (>100 us) deposition is due to precursor refreshment by diffusion or continued adsorption.