A Mechanism for Dendritic Nano-Pillar Growth using EBID

J. Bishop, R. Crendal, J. Cullen, C. Lobo, M. Ford, M.R. Phillips and M. Toth
School of Physics and Advanced Materials, University of Technology, Sydney NSW 2007, Australia
matthew.phillips@uts.edu.au

Electron beam induced deposition (EBID)[1] is a direct-write nanofabrication technique in which a focused electron beam is used to irradiate gaseous precursor molecules that are adsorbed onto a solid substrate. The adsorbates are dissociated by primary and emitted electrons, generating reactive fragments that give rise to deposition. In this work the growth mechanisms that govern the size, shape and growth rate of EBID nanostructures are studied with an emphasis on a precursor decomposition mechanisms caused by beam heating during growth.

The time evolution of deposit geometry and growth rate can be obtained from images of pillars fabricated as a function of growth time and beam current (I_B) using a stationary electron beam. I_B affects deposit aspect ratio[2] because the electron flux and adsorbate concentration at the deposit apex and sidewalls control the vertical and lateral growth rates respectively. The energy (E_O) of the primary electron beam determines the energy and flux distributions of electrons crossing the substrate-vacuum interface, while the substrate temperature (T_S) affects the precursor residence time and diffusivity at the surface. Complex deposit morphology (Figure 1) dependencies on E_O and T_S have been used to confirm a continuum model[3] of growth kinetics.

At elevated substrate temperatures, a new precursor decomposition pathway was identified, observed as rapid dendritic growth of nanostructures such as the one shown in Figure 2. The onset of dendritic growth can be detected *in-situ* by monitoring the emitted or absorbed specimen current (I_S) during EBID. I_S vs time profiles at T_S of 127 and 368°C (Figure 2) illustrate processes that do not and do transition to dendritic growth respectively. Dependencies on T_S and I_B show that dendritic growth results from thermal decomposition of the precursor due to beam heating of pillars during growth.

Due to the high carbon content of material grown using $Si(OC_2H_5)_4$, a purification method was explored to determine the effects of deposit composition on dendritic growth.[4] The use of an $O_2/Si(OC_2H_5)_4$ mixture as an EBID precursor was observed to lower the T_S needed to achieve dendritic growth, and to alter deposit morphology. These results are ascribed to the effects of O_2 on charge stabilization during EBID, and on the composition and thermal conductivity of deposits grown in the presence of O_2.

[1] W. F. van Dorp and C. W. Hagen, Journal of Applied Physics **104,** 8 (2008)
[2] Y. R. Choi et al., Scanning, **28,** 6 (2006)
[3] C. J. Lobo et al., Nanotechnology, **19,** 2 (2008)
[4] A. Perentes and P. Hoffmann, Chemical. Vapor. Deposition. **13** 4 (2007)

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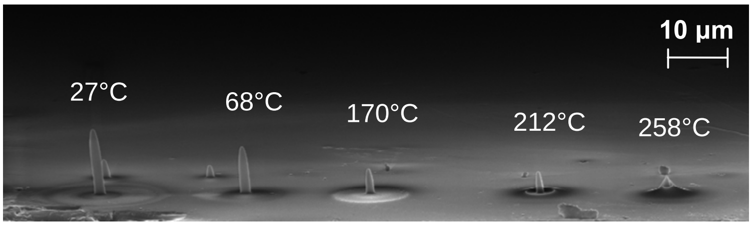

Figure 1: SEM image of deposits grown at number of substrate temperatures.

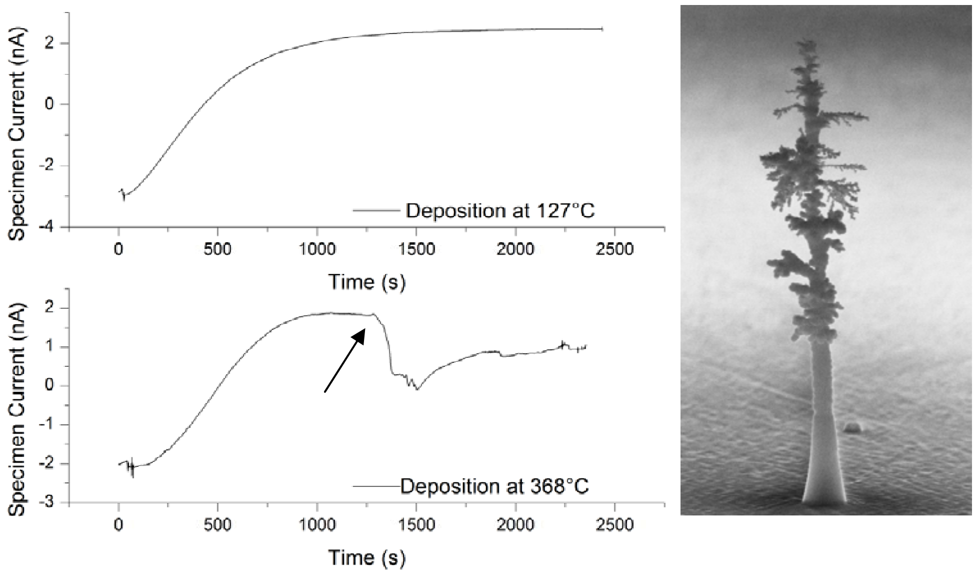

Figure 2: (Left) Specimen current curves for two deposits, with the arrow indicating the onset of dendritic growth at elevated temperatures. (Right) SEM image of deposit grown on a silicon substrate heated to 368°C.