Growth of SiOx Nano-Pillars using Electron Beam Induced Deposition in an Environmental SEM

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Silica nano-structures can be fabricated and accurately positioned on a substrate using electron beam induced deposition (EBID) in a scanning electron microscope (SEM). In this work, SiOx nanopillars have been grown on silicon substrates using tetraethyl orthosilicate (TEOS) precursor gas in a FEI XL30 environmental SEM with a stationary electron beam. The nano-pillar growth rate and morphology has been investigated as a function of electron beam current (I_B), deposition time (t_D), accelerating voltage (kV), precursor pressure (P), working distance (WD) and substrate temperature (T_S). The pillars were measured using a Zeiss Supra 55VP FEGSEM and a Digital Instruments Dimension 3100 atomic force microscope.

Figure 1 shows a typical set of SiOx nano-pillar deposits, in this case as a function of t_D. A linear vertical growth rate of 15.8 ± 0.2 nm/s was obtained for the first 200 s of deposition at 20 kV, 1 nA, WD = 4 mm and P = 0.2 torr. Time-dependent broadening then saturation of the pillar width and the tapering growth tips are consistent with electron forward scattering models producing secondary emission on the pillar side walls[1,2] and were supported by Monte Carlo simulations. The results also suggest that forward scattered electrons also contribute to the growth of the SiO_x deposition skirt surrounding the base of the nano-pillar.

A decrease in the vertical deposition rate of the nano-pillar with increasing t_D and the development of significant surface roughening are ascribed to electron beam heating effects[3]. To investigate this phenomenon, nano-pillars spaced at 12 μm apart were grown between 265 K and 313 K at 8°K increments for 2160 sec under the same deposition conditions as indicated above. At 265 K a smooth 20 μm high conical tipped SiOx pillar was produced. The nano-pillars were found to lengthen by 5 μm with each 8 K increment to 289 K at which point pronounced surface roughening occurred at the growth end with its onset taking place closer to the substrate with increasing T_S. At 313 K, thinning along nano-pillar below the change in growth morphology was observed. The results indicate that additional temperature dependent growth mechanisms are possible in EBID deposition of SiOx nano-pillars with TEOS precursors, which are attributed to electron beam assisted thermal dissociation of TEOS and thermally enhanced precursor surface diffusion.

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[1] W.F. van Dorpa_ and C.W. Hagen, J. Appl. Phys. **104,** 081301 (2008)
[2] Y.R. Choi, P.D. Rack, S.J. Randolph, D.A. Smith, D.C. Joy, Scanning **28,** 311 (2006)
[3] S.J. Randolph, J.D. Fowlkes, and P.D. Rack, J. Appl. Phys. **97,** 124312 (2005)

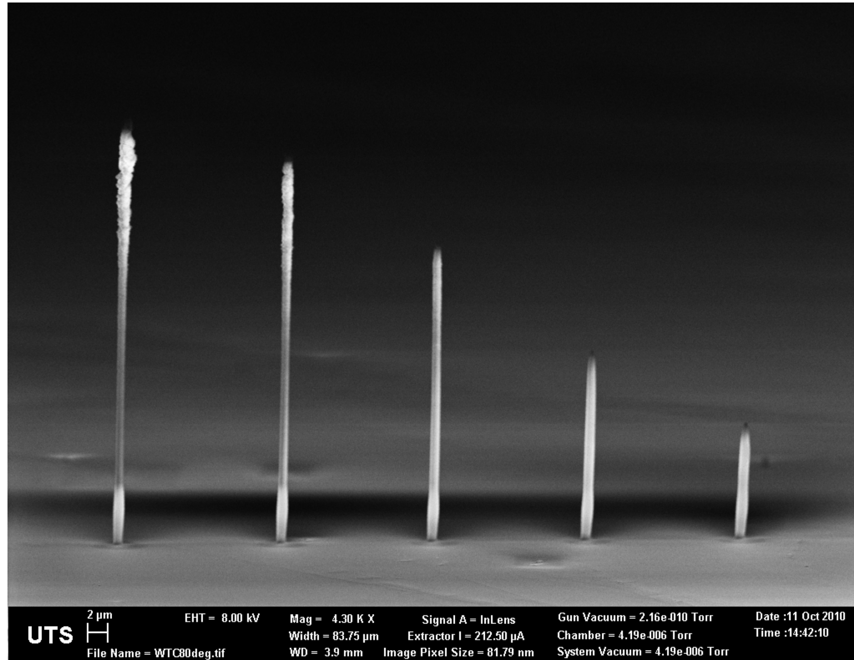

Figure 1: SiOx nano-pillars growth versus deposition time: Electron beam induced deposition of SiOx nano-pillars on a silicon substrate using tetraethyl orthosilicate (TEOS) precursor gas. Deposition conditions were 20 kV, 1 nA, WD = 4 mm and P = 0.2 torr with deposition times increasing from 10, 15, 20, 25 and 30 minutes from right to left.