Sub-10 nm area-selective ALD using block copolymer lithography

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Area selective atomic layer deposition (AS-ALD), is a promising technique to deliver dimensionally controlled material in both the vertical and horizontal dimensions. With ALD in general, the self-limiting nature of the process allows film thickness control at molecular levels. By introducing chemically patterned surfaces, where parts of the pattern resist the ALD growth, spatial selectivity can be achieved. There has been significant success using self-assembled monolayers as AS-ALD resists[1-3] with recent results showing this can be extended to the sub-10 nm regime.[4] Here we investigate AS-ALD of Al_2O_3 and HfO_2 on surface brushes compatible with PS-b-PDMS (polystyrene-b-polydimethylsiloxane) block copolymer lithography. Using the appropriate brushes and patterning techniques, we are able to achieve sub-10 nm selective ALD on PS and PDMS surface brushes patterned with PS-PDMS block copolymer.

Growth of alumina and hafnia in an Oxford Instruments FlexAl as a function of ALD cycles for 3 surfaces: bare silicon, treated silicon, polystyrene brush, and poly-dimethylsiloxane brush is shown in figure 1. There is no hafnia grown on PDMS and a growth delay on PS. Roughness from AFM measurements indicates hafnia island growth on PS. Figure 2 shows an AFM image of a section of patterned PS and PDMS brush. HfO_2 has been deposited selectively on the PS. Figure 3a shows PS and PDMS brushes patterned using PS-PDMS cylindrical block copolymer whereas figure 3b shows a similar area after HfO_2 ALD. Islands of HfO_2 grow selectively on the PS brush. Insets show fast Fourier transforms of the images and indicate the same periodicity before and after ALD deposition.

1. M. Yan, Y. Koide, J. R. Babcock, P. R. Markworth, J. A. Belot, T. J. Marks and R. P. H. Chang, Appl. Phys. Lett. **79** (11), 1709-1711 (2001).
2. R. Chen, H. Kim, P. C. McIntyre and S. F. Bent, Appl. Phys. Lett. **84** (20), 4017-4019 (2004).
3. M. H. Park, Y. J. Jang, H. M. Sung-Suh and M. M. Sung, Langmuir **20** (6), 2257-2260 (2004).
4. J. Liu, Y. Mao, E. Lan, D. R. Banatao, G. J. Forse, J. Lu, H.-O. Blom, T. O. Yeates, B. Dunn and J. P. Chang, J. Am. Chem. Soc. **130** (50), 16908-16913 (2008).

Acknowledgements: This work was performed at the Molecular Foundry, Lawrence Berkeley National Laboratory, and was supported in part by the Office of Science, Office of Basic Energy Sciences, Scientific User Facilities Division, of the U.S. Department of Energy under Contract No. DE-AC02—05CH11231.

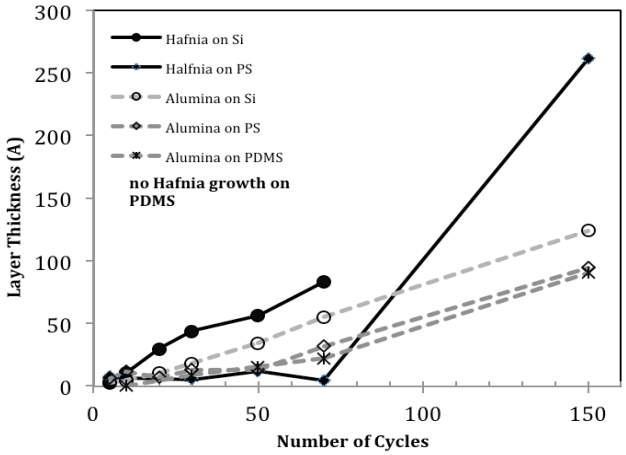
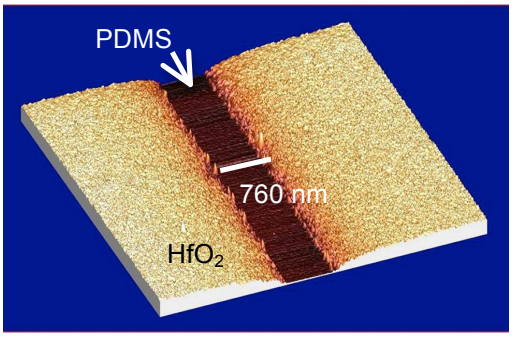


Figure 1: HfO_2 and Al_2O_3 ALD thickness, measured by ellipsometry, on 3 surfaces. Growth of alumina on all surfaces is linear. Growth of HfO_2 on PS shows a growth delay while there is no growth on PDMS. The processes are water based at a temperature of 135 °C.

Figure 2. AFM image of HfO_2 deposition on surface patterned with PS and PDMS. The line is coated in a PDMS brush. HfO_2 growth occurred outside the patterned line on the PS surface. The process was 300 cycles long, water based, at a temperature of 220 °C.



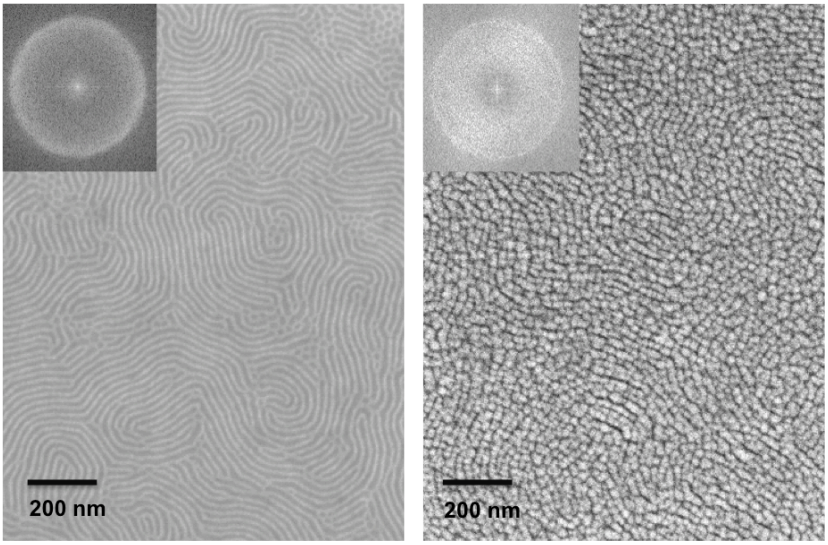


Figure 3. SEM images of left, a patterned PS and PDMS brush layer and right, HfO_2 deposition on the brush layer. The ALD layer is 15 nm thick. Outer ring on FFT insets correspond to a 20 nm period before and after deposition. Deposition temperature was 135 °C.