Enhanced Area-Selective ALD Using Patterned Self-Assembled Monolayers

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Area-selective atomic layer deposition (AS-ALD) is a process that deposits a thin film on desired device areas but not on the entire substrate[1]. This bottom-up fabrication process could eliminate lithography and etch steps and could further be used for self-aligned accurate pattern placement[2]. To achieve AS-ALD on a surface, polymers[2] and self-assembled monolayers (SAM)[3] have been used to block nucleation and growth of a variety of inorganic ALD films within a defined area. In this study, we used a fluorinated self-assembled monolayer (SAM) (tridecaflouro-1,1,2,2-tetrahydrooctyltrichlorosilane (FOTS)) to enhance the area selectivity in AS-ALD.

FOTS is a water repellant SAM coating. The coated surface contact angle with water is shown in figure 1. Its super hydrophobic nature can enhance water blocking in thermal ALD. In addition, FOTS SAM is more thermally stable than the carbon hydrogen-based SAM coating such as octadecyltrichlorosilane (ODTS), which was used for AS-ALD process in the past. The enhanced thermal stability leads to a broader temperature range within the ALD process.

Al_2O_3 deposition was carried out by alternating trimethylaluminum (TMA) precursor and water steps at 300 °C on an oxidized silicon substrate without further chemical surface activation. Figure 2 shows that a thin Al_2O_3 layer was selectively deposited on the exposed SiO_2 area, however, the FOTS areas were uncoated. The area selective Al_2O_3 deposition process was used on nanoscale FOTS patterned surfaces (600 nm pitch gratings), as shown in figure 3.

Further Al_2O_3 deposition contrast study between FOTS and ODTS SAM protection shows that FOTS patterned sample is better on both Al_2O_3 deposition thickness contrast and surface smoothness than the ODTS patterned sample (figure 4). In contrast to ODTS, the enhanced deposition contrast on FOTS patterned samples can be attributed to its super-hydrophobic property and thermal stability.

References

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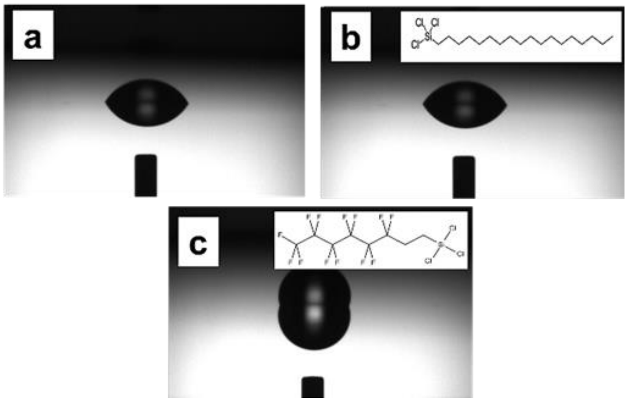

Figure 1. Water contact angle data showing (48 ± 1)°, (62 ± 1)°, and (102 ± 1)° on respective (a) SiO_2, (b) ODTS and (c) FOTS surfaces.

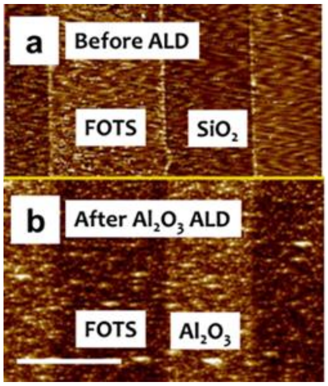

Figure 2. Topographic atomic force microscope (AFM) images of thermal Al_2O_3 coating on a SiO_2 surface with patterned FOTS regions. Scale bar represents 5.0 µm.

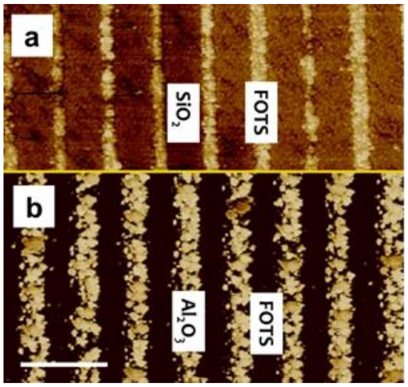

Figure 3. AFM phase images of SiO_2 surfaces with patterned, 600 nm pitch FOTS lines (a) before and (b) after ALD Al_2O_3 coatings. Scale bar represents 1.0 µm.

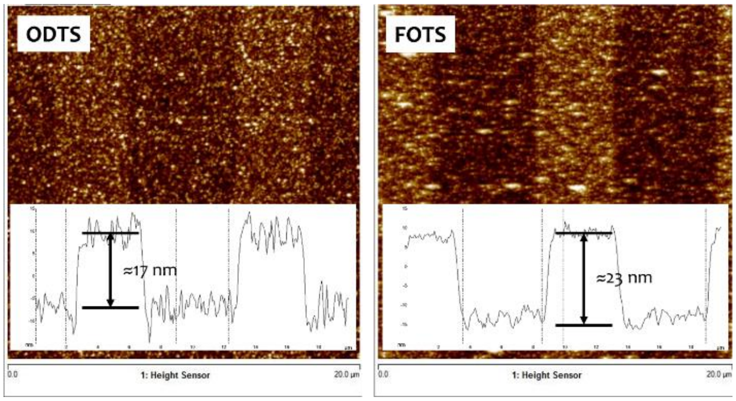

Figure 4. AFM height images of thermal Al_2O_3 coatings on ODTS and FOTS SAM patterned SiO_2 surfaces.