Selective area ALD deposition with nanolithography using SAM as a resist

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Conventional semiconductor processing requires chemicals for develop, lift-off or etching. However, if we can deposit materials onto the desired region only, i.e. fabricate 3D structure directly, we can minimize cost and duration of patterning.

In this presentation, self-assembled monolayers (SAMs) have been investigated as soft mask materials for electron beam lithography (EBL). We have evaluated selective atomic layer deposition (ALD) of dielectrics in conjunction with patterned octadecyltrichlorosilane (OTS) SAMs as a surface modifier on top of SiO_2/Si substrate. OTS pattern created by EBL with different e-beam dose was characterized by AFM, as in Fig 1. After dielectric deposited by ALD, the pattern was characterized by AFM and SEM, refer to Fig 2-3. Furthermore, cross-sectional TEM sample was created by focus ion beam (FIB) lift-out method, and the sample was observed by TEM, shown in Fig 4. Although EBL patterns on OTS can be scale down to under 100nm, selectively grown TiO_2 patterns generated after ALD process will be much wider than the patterned OTS. This implies that not only functional groups of OTS on the e-beam exposed area, but also those in the adjacent domain are also damaged. We explore the limitation of scaling down of selective ALD with EBL patterning. These findings highlight the significance of functional group of SAMs to those scattered electrons with high accelerated energy. We design a new approach to pattern SAMs using low energy electrons for nano-scale lithography applications. The feasibility will be discussed in this presentation.

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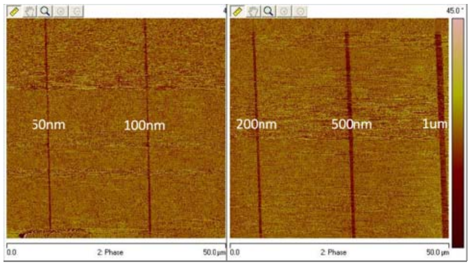

Fig 1. AFM (phase) image of OTS patterns created by EBL with e-beam dose from 1nC/cm up to 20nC/cm, which shows the line width is highly dependent on e-beam dose.

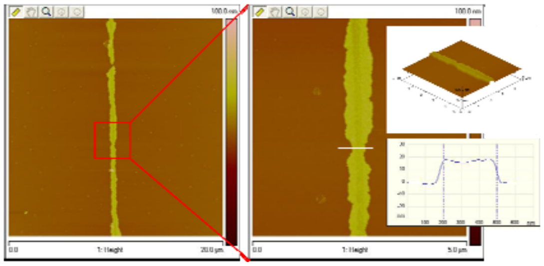

Fig 2. AFM (height) image of TiO_2 patterns created by selective ALD shows the smallest dimension we can get is ~300 nm, which is much wider than actual e-beam exposed area.

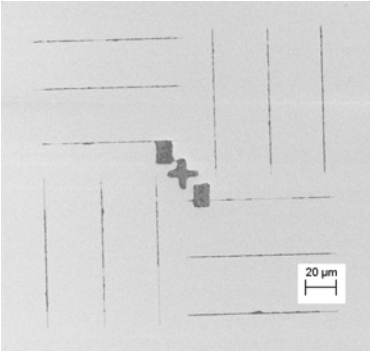

Fig 3. SEM image of TiO2 patterns created by selective ALD shows that except the e-beam exposed and adjacent area, all the rest are prevented to be deposit by ALD precursor because of OTS’s functional group –COOH (cross pattern with numbers are location markers for EBL).

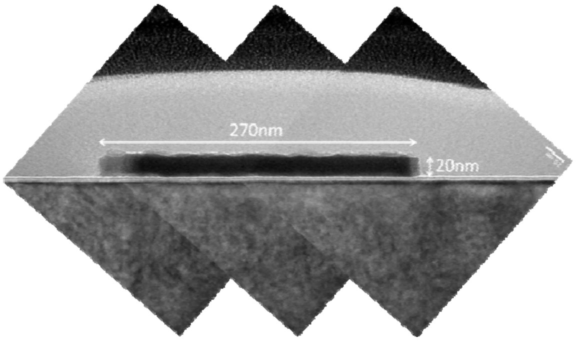

Fig 4. Cross-sectional TEM image of TiO_2 patterns created by selective ALD shows the width of TiO_2 pattern is ~270nm and the height is ~21nm, which matches the data we get from AFM image. (Scale bar is 20nm).