Cleanroom in an SEM: in-situ area selective ALD

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A cleanroom is a necessity to fabricate nano-scale devices, because it protects the substrate from contamination as much as possible between the different steps in a fabrication process. A typical cleanroom fabrication process involves: substrate cleaning, lithography, etching (dry etch or wet etch) and deposition (evaporation or sputter). These steps require dedicated instruments in a cleanroom which is expensive to run. Furthermore, it is time consuming to manually switch from one tool to another for the subsequent process. Also, the fabrication area of interest for research is typically small. We envision fabricating a device inside a scanning electron microscope (SEM) i.e., "a cleanroom inside an SEM ". Our goal is to bring in a sample inside the microscope and do the required steps to fabricate a device, including its inspection, in the same tool. This can be done with the addition of miniaturized standard nanofabrication tools inside an SEM, maintaining the vacuum between the different processes and eliminating the need of an expensive cleanroom. In this study, we will concentrate on integrating a thermal ALD tool within the SEM using Platinum electron beam induced deposition (EBID) as the seed layer[1].

Area selective ALD using Pt EBID as a seed layer is a direct write technique which combines the high resolution of EBID with the high purity of ALD. Both Pt EBID and Pt ALD use the same precursor, $MeCpPtMe_3$. For the reactant gas, we have modified an existing gas injection system (GIS) needle to deliver dry air. To validate our design, we patterned Pt EBID seed layers on a silicon substrate followed by thermal ALD at 240°C. After ALD, we observed a contrast change in the secondary electron image of the seed layers, shown in Fig 1. To verify the ALD growth, AFM measurement was carried out on the seed layers both before and after ALD cycles, shown in Fig 2. Even though we have achieved in-situ ALD in the SEM, the duration of a single ALD cycle was 3 minutes. The long duration is due to the closing valve of the GIS, which is located far off from the needle outlet. To bring single cycle duration to a standard thermal ALD cycle duration, we have modified the GIS of the Pt precursor such that the closing valve is near the outlet of the GIS needle. The results of these experiments will be discussed in detail at the conference.

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[1] A.J.M. Mackus, et al. *J Appl. Phys.* 107**,** (2010).

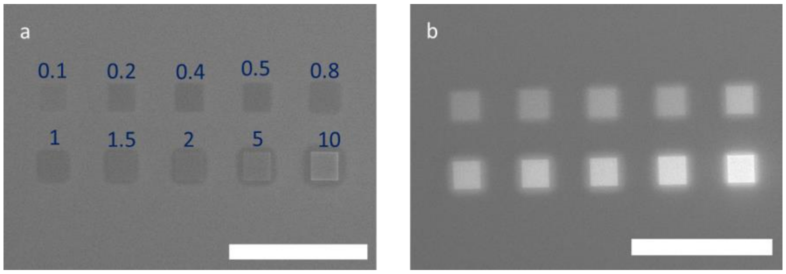

Figure 1(a): Secondary electron image of Platinum EBID seed layers with various doses (the indicated doses are in nC/µm^2). (b) Secondary electron image of the same Platinum EBID seed layers after 17 cycles of ALD, with a clearly observed contrast change. Scale bar is 5 µm.

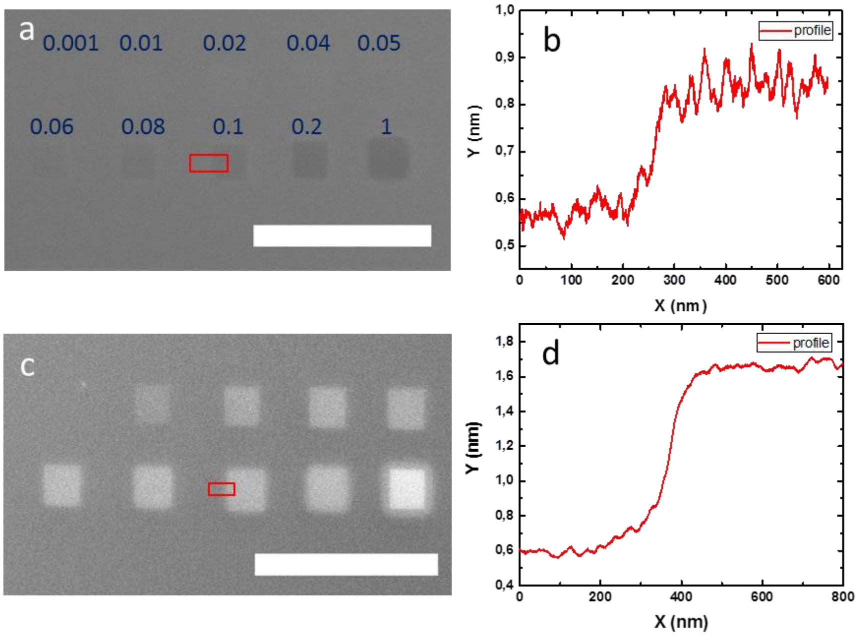

Figure 2(a): Secondary electron image of Platinum seed layers with various doses (the indicated doses are in nC/µm^2). (b) AFM profile over the seed layer in the red region in figure (a), seed layer of 0.3 nm. (c) Secondary electron image of the same seed layers after 17 cycles of ALD, with a clearly observed contrast change. (d) AFM profile of the seed layers after 17 cycles of ALD, in the red rectangle area in figure (c) showing a growth of 0.7 nm. This growth matches with the calculated thickness (growth per cycle at 240°C is 0.04 nm[2]). Scale bar is 5 µm.

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[2] Knoops, H. C. M. et al. *Electrochem. Solid-State Lett., 12, G34, (2009).*