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Commissioning of photo-ALD capability at Max IV SPECIES APXPS end station for time-resolved APXPS studies

Content

ALD is a thin film deposition technique based on sequential, saturative and irreversible reactions between gaseous precursors and a solid surface. The cyclic and surface-controlled nature of ALD provides superior film conformity and atomically accurate film thickness. However, areal control of ALD film growth remains challenging. Thus, ALD film patterning currently requires multiple litho/deposition/etch steps. This top-down patterning gets extremely challenging as feature sizes shrink to nm-scale. Thus, device yield is reduced by inevitable misalignment, and multiple processing steps cause etch damage. Bottom-up patterning where materials are deposited directly as-patterned, would be ideal. Selective ALD (S-ALD), i.e. ALD with areal control, would enable this. S-ALD is often attempted by passivating the non-film growth areas with self-assembled monolayers or polymers. This has shown limited performance with the conventional ALD chemistries: after a few nm of deposition, selectivity is lost and film grows everywhere. In photo-ALD photons supply energy to the deposition reactions. Simply shadowing the non-film growth areas facilitates S-ALD. These recent findings demonstrate the high potential of photo-ALD to address many challenges in microelectronic manufacturing and other application fields. Photo-ALD of metal oxides from alkoxides as a single precursor has been an established technique. In photo-ALD, a photoinduced step most initiates the elimination. The OH is reactive towards the following $\text{Ti}(\text{OiPr})_4$ pulse, which deposits TiO_2 film. Unreacted $\text{Ti}(\text{OiPr})_4$ adsorbates on the shadowed areas of the surface, in contrast, are not reactive and no film deposits.

The evolution of surface chemistry with respect to UV exposure is crucial for the understanding of the photo-ALD process. Understanding the substrate role, also allows for a greater understanding of the overall photo-ALD process allowing for the discovery of new photo-ALD processes and substrate/photo-ALD precursor pairs. APXPS allows for the ideal platform to investigate the surface reactions occurring during the photo-ALD process in a time-resolved manner during pulses and UV exposure. At SPECIES APXPS end station we developed photo-ALD capability for the current ALD APXPS cell. By attaching a UV lamp to the end station, we can now carry out photo-ALD reactions in the specialised ALD APXPS cell.

Herein we present proof of principle study of TiO_2 ALD demonstrating the evolution of the $\text{Ti}^{3+}/\text{Ti}^{4+}$, and over core levels the during TTIP deposition and UV exposure allowing the surface mechanisms to be elucidated. We compare this data with more traditional TiO_2 using water instead of UV. In addition, we demonstrate the photo-ALD of both HfO_2 and Cu both using time-resolved APXPS. These results are the first measurements of operando photo-ALD. Along with our initial results we will present the set up and control employed at the SPECIES APXPS end stations to allow for operando photo-ALD measurements.

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