Recent Advancements for Atomic Layer Advanced Manufacturing Processes: Microreactor Direct Atomic Layer Processing (µDALP™)

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As the demand for miniaturized and complex devices continues to grow across various industries, the need for innovative and precise atomic layer advanced manufacturing (ALAM) techniques becomes increasingly apparent. One such technique, based on localized Spatial Atomic Layer Deposition (sALD), has gained significant attention for its ability to deposit thin films with atomic-scale precision on large-area substrates.[1] Our company, utilizing proprietary Microreactor Direct Atomic Layer Processing (µDALP™), is at the forefront of pushing sALD's capabilities and broadening its application horizons. The µDALP™ process undergoes the same cyclic ALD process but is only done in a spatially localized area.[2] The microreactor or micronozzle confines the flows of gases used for ALD within a defined µm-scale centric area on the substrate, to deposit the desired material.[3]

ATLANT 3D's recent advancements in our novel µDALP™ technology, has enabled innovation within the thin film deposition field ranging from ALD material development to rapid prototyping and manufacturing. The µDALP™ process enables multiple depositions e.g. depositions with varying film thicknesses, to be deposited onto a single wafer used to calculate a given processes growth rate within only a few hours, compared to days for a traditional ALD process (**Fig 1**). In Addition, innovation of applications including optics and photonics, quantum devices, MEMS, RF electronics, emerging memory technologies, advanced packaging, and energy storage are possible and have been demonstrated using ATLANT 3D's technology.

Discussing the improvements to the µDALP™ process, we have decreased the process resolution, increased material compatibility, and accessible morphologies. Giving one example of recent development in morphologies; films deposited with µDALP™ have conformal coverage of gratings, microchannels, and trenches up to a depth of 25 µm using a Platinum deposition process. **Fig. 1** demonstrates how a given ALD material process (in this case, Pt) can be used with ATLANT 3D technology to deposit localized area conformal coatings of complex surfaces with an aspect ratio of 1:25. Hence demonstrating the versatility and potential of our technology for achieving inherently selective ALD for processing on complex surface morphologies.

This talk aims to shed light on how our breakthroughs in sALD and µDALP™ technology are contributing to the advancement of thin-film manufacturing and scale-up. Fostering a deeper understanding of our technology's capabilities and exploring the possibilities it opens up for various industries.

[1] Poodt P., *JVSTA.*, **2012**, *30*, 010802

[2] Kundrata I., et al., *Small Methods.*, **2022**, *6 (5)*, 2101546

[3] Plakhotnyuk M, et al., *ALD/ALE 2022 [Int. Conf.],* **2022**

Figure 1. Photograph of a set of TiO_2 lines deposited using µDALP™ at differing numbers of cycles (ranging from 100-5000) on a 200 nm SiO_2 substrate. TiO_2 was deposited using TTiP and water.

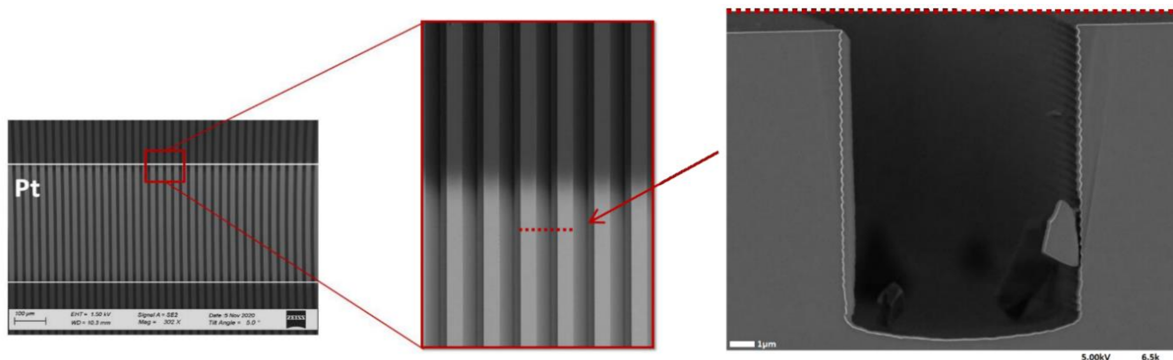

Figure 2. SEM images of conformal deposition of Pt on 20 µm wide, 15 µm deep Silicon microchannels using µDALP™. Aspect ratio of 1:25.