Multi Cycle and Material Deposition for Spatial Atomic Layer Deposition Process

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Spatial Atomic Layer Deposition (sALD) offers a unique opportunity for localized deposition due to its physical separation and isolation of precursor and co-reagent dosing.[1] While simple in theory, due to well-developed examples of sALD, in practice miniaturization of sALD requires substantial effort into the creation of suitable micro-nozzles.[1] Uniquely, ATLANT 3D has developed proprietary sALD micronozzles, called microreactor Direct Atomic Layer Processing - μDALP™.

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. Similarly, to spatial ALD, the creation of this monolayer then hinges on the movement of the substrate.[1,2]

Since sALD and the μDALP™ process are based on physical separation, it is theoretically compatible with any ALD material process however requires development as ALD processes are highly tool dependent.[3] As such, the material capabilities can match traditional ALD and exceed other patterning techniques, such as lithography, which can be costly and time-consuming, especially for rapid prototyping required for innovation.[4,5]

sALD using the μDALP™ technology also vastly increases the efficiency and innovation potential of material and precursor development. Using a small amount of precursor (due to low flow rates required) multiple film thicknesses can be deposited onto a single wafer used to calculate a processes growth rate within only a few hours, compared to days for a traditional ALD process (**Fig 1**). Multiple depositions can also be performed at varying temperatures for the calculation of temperature dependent growth rate (for "ALD window"), and film characteristics all within a few hours on a single sample. The μDALP™ process has also been used to demonstrate the selective deposition of different materials on the same substrate without the need for masking shown in **Fig 2.** By facilitating the more efficient development of ALD processes, μDALP™ sALD can help to enable continued and more efficient growth of the ALD industry and the development of new and innovative technologies. Multi-material sALD also enables unseen potential for versatile patterning and complex geometry formation, applicable to efficient, iterative, and low-cost device and sensor development.

[1] Poodt P., *JVSTA.*, **2012**, *30*, 010802
[2] Kundrata I., et al., *Small Methods.*, **2022**, *6 (5)*, 2101546
[3] Barry, S. T. *Chemistry of Atomic Layer Deposition*; De Gruyter
[4] Kundrata I., et al., *ALD/ALE 2022 [Int. Conf.],* **2022**
[5] Plakhotnyuk M, et al., *ALD/ALE 2022 [Int. Conf.],* **2022**

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

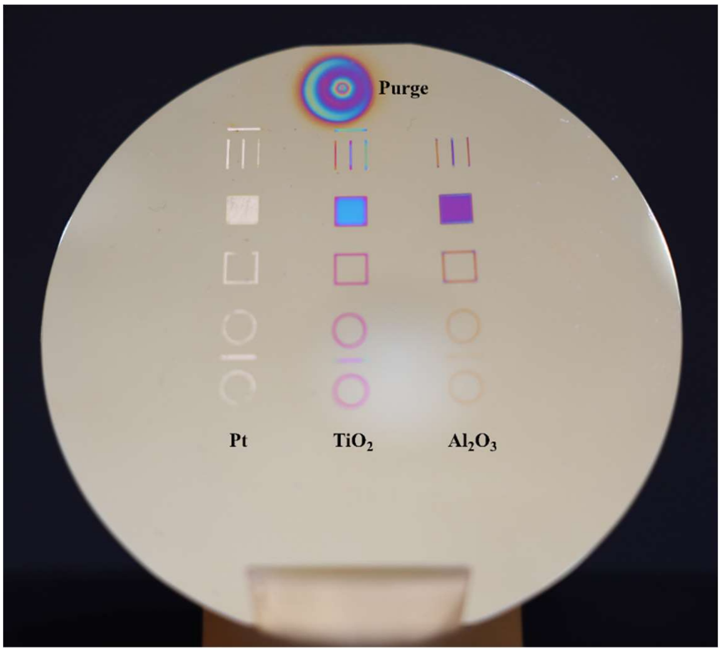

Figure 2. Photograph of 200 nm SiO_2 silicon wafer substrate with 3 different deposited materials using µDALP[TM] technology in < 5hr and done without any masking or additional processing. Thin films from left to right are Pt, TiO_2 and Al_2O_3 using $MeCpPtMe_3$ + Ozone, TTiP + water and TMA and water respectively. The circular pattern at the top is a purge region used to flush out precursor between material switching.