Recent Advances for Spatial Atomic Layer Deposition Process: Microreactor Direct Atomic Layer Processing (µDALP™)

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Topic AM2 or AS3:

In parallel to additive manufacturing leading the revolution in traditional manufacturing, the same principles can revolutionize traditional thin film deposition techniques. Where lithography and vapor phase deposition techniques struggle, for example, with rapid iterations for prototyping or incompatibility with the used chemistry, additive manufacturing can shine. Indeed, several approaches are in development for 3D nanopriting[1,2,3].

Atomic Layer Deposition, and in more general Atomic Layer Processing, offers a unique opportunity for localized 3D processing/printing due to its two-step process. While simple in theory, due to well-developed examples of Spatial Atomic Layer Deposition (SALD), in practice miniturization of SALD requires substantial effort into the creation of suitable micro-nozzles. Uniquely, ATLANT 3D has developed proprietary Spatial ALD micronozzles, naming the process microreactor Direct Atomic Layer Processing - µDALP™.

In recent years, the team at ATLANT 3D has been able to significantly develop the technology to reduce the µDALP™ resolution, increase material capabilities, assessable morphologies, and new instruments. 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 (**Figure 1**). Substrates with a surface roughness including Carbon nanograss (**Figure 2**), black silicon and anodized Aluminum Oxide membranes were also conformally coated with roughness up to an aspect ratio of 1:25 again with Platinum and TiO_2. Our results demonstrate how a given ALD material process (in this case, Pt and TiO_2) can be used with ATLANT 3D technology to deposit localized area conformal coatings of complex surfaces with an aspect ratio of 1:25. The µDALP™ technology enables rapid prototyping and manufacturing for an array of applications from sensors (temperature, pressure, gas sensing and capacitive) to optics, all with sensitivities that meet or exceed those of devices made using conventional vapor phase deposition techniques.[4] In addition, rapid localized processing facilitated by ATLANT 3D technology of such devices enables design innovation and optimization not possible with other thin film deposition techniques and lithography.

[1] Kundrata I. et al., *ALD/ALE 2022 [Int. Conf.],* **2022**
[2] de la Huerta C. A. M. et al., *arXiv*, **2020**, 0523.
[3] Winkler, R. et al., *J. Appl. Phys.*, **2019**, *125*, 210901
[4] Kundrata I., et al., *Small Methods.*, **2022**, *6 (5)*, 2101546

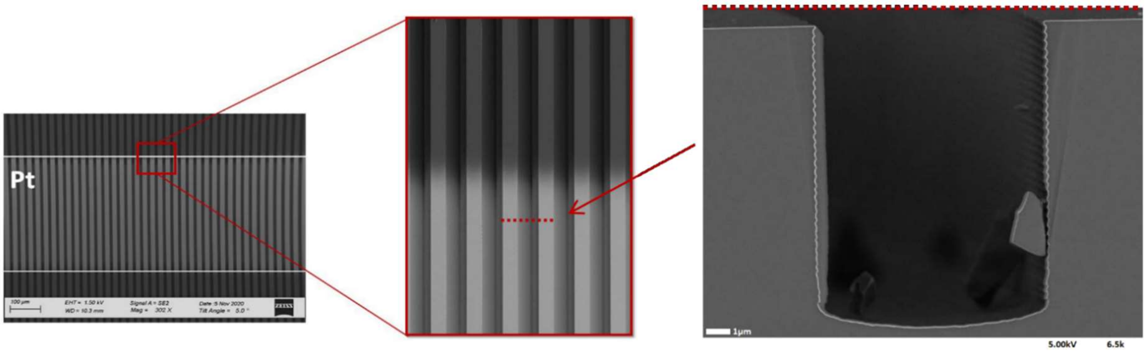

Figure 1. SEM images of conformal deposition of Pt on 20 µm wide, 15 µm deep Silicon microchannels using µDALP™. Aspect ratio of 1:25.

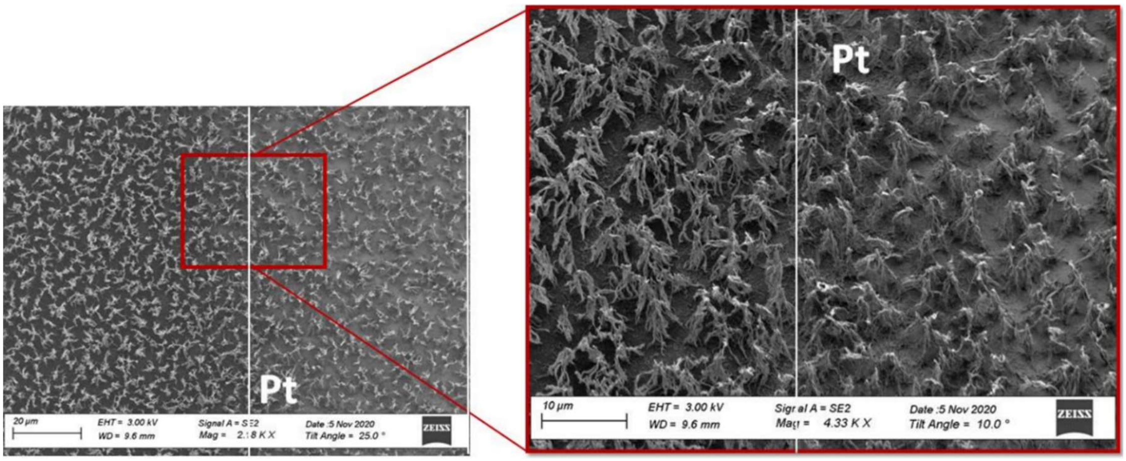

Figure. 2. SEM images showing the edge of deposited Pt line using µDALP™ showing conformally coated Carbon nanograss with an aspect ratio of 1:10.