

# Direct Atomic Layer Processing for Spatially Selective Multi-Material Nanofabrication

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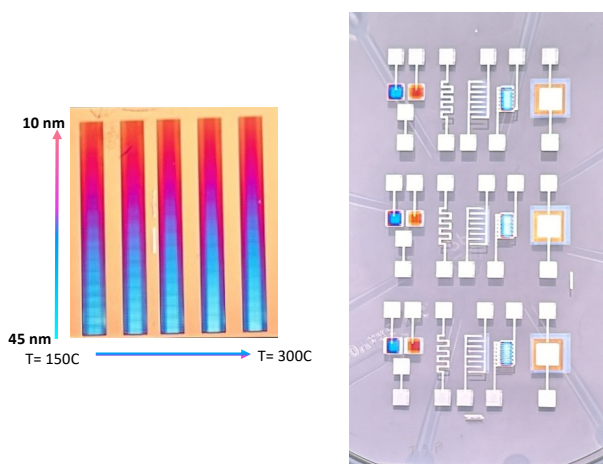
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## Abstract

Progress in advanced electronic, photonic, and quantum devices is increasingly constrained by the rigidity of conventional thin-film deposition techniques. While ALD and PVD offer excellent uniformity and material quality, they lack the flexibility required for rapid, localized, and multi-material experimentation at the nanoscale.

ATLANT 3D introduces **Direct Atomic Layer Processing (DALP®)**, a novel nanofabrication technology enabling digitally controlled, spatially selective deposition of multiple materials with atomic-scale precision. DALP allows different materials to be deposited sequentially and locally within a single process flow, enabling rapid prototyping of complex material stacks, heterostructures, and interfaces without lithographic patterning between steps.

This contribution presents the DALP process architecture and its relevance to combinatorial materials exploration and device-level nanofabrication. **When coupled with data-driven experimental design, DALP enables accelerated materials discovery by rapidly exploring composition, interfaces, and process parameters at the nanoscale.** Examples include multi-material nanoscale structures for advanced semiconductor and functional material applications, where precise interface control and fast iteration are critical. DALP expands the accessible design space of nanoscale fabrication and provides a new pathway from materials research to scalable device development. **Figure 1 below illustrates representative DALP-fabricated material libraries and wafer-scale multi-material test structures, demonstrating controlled thickness modulation, spatial selectivity, and device-level compatibility.**



**Figure 1.** (left) DALP-fabricated  $\text{TiO}_2$  deposition library exhibiting controlled thickness variation from approximately 10 nm to 45 nm across patterned stripes, achieved through systematic modulation of process conditions, including substrate temperature (150 °C to 300 °C). The optical contrast reflects thickness-dependent interference effects across the library. (Right) Wafer-scale integration of DALP-deposited Multimaterial films into electrically addressable test structures, demonstrating compatibility with device fabrication workflows and enabling direct electrical and functional characterization of thickness- and process-dependent material behavior.