# Direct surface structuration and functionalization using localized Atomic Layer Deposition

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Precise designs of micro- and nanostructures are sought after for many devices and applications such as thin films transistors, diodes, electrocatalysts, solar cells, sensors, or membranes. Additive and subtractive technologies are nowdays areas of extensive research. In particular, additive approaches permit the controlled stacking of layers made of different materials. However, they display limitations either in thickness of the deposited material, in lateral resolution, or structuring scale. Combining control of at least one dimension at the nanometer level with large-scale patterning is still challenging in the direct write approach. Atomic Layer Deposition (ALD) is a technique of choice for depositing thin films with a thickness control at the atomic scale. In particular, direct patterning can be realized using spatial ALD (SALD). [1–3]
Herein, maskless deposition of uniform and homogenous oxide thin films is successfully demonstrated with a lateral resolution tuned from millimeters to hundred micrometers range (Fig1b) while keeping a film thickness in the range of a few to hundreds of nanometers with a control at the nanoscale. A modified open-air SALD head (Fig1a) is employed to fabricate complex oxide patterns on various substrates. [4] The co-reactant being kept in the surrounding atmosphere *i.e.* water from relative humidity in the present case, a simple injection head that consists of three concentric nozzles with only one precursor outlet has been designed. An easy and reversible modification in the diameter of the metal precursor outlet that permits direct patterning with different lateral sizes is demonstrated. This maskless SALD approach also enables controlled surface functionalization. In particular, using alkyl silane, it is possible to locally modify the surface properties (hydrophilic/hydrophobic character...). This is particularly of interest to control water condensation and drop displacement (Fig. 1c).

## References

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[2] P. Poodt *et al.*, physica status solidi (RRL) – Rapid Research Letters **5**, (2011), 165.
[3] M. Aghaee *et al.*, Plasma Processes and Polymers **16**, (2019), 1900127.
[4] L. Midani *et al.*, ACS Appl. Nano Mater. **4**, (2021), 11980.

## Figure

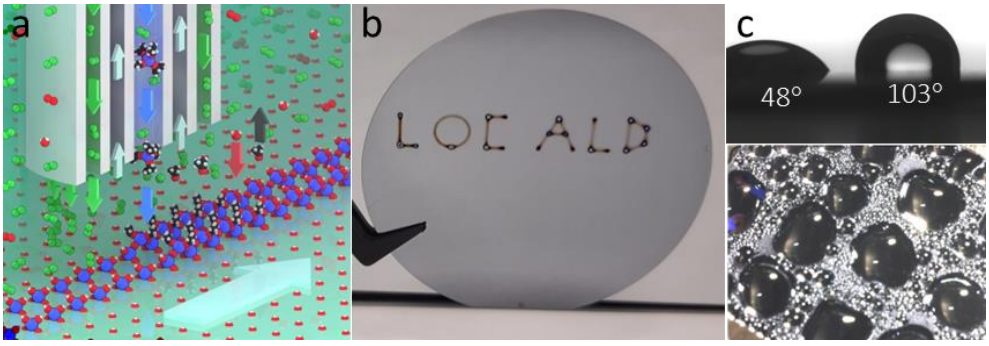


**Figure 1:** a) Scheme of localized ALD principle and b) photograph of a 76 nm thick $TiO_2$ pattern deposited on Si wafer with sub-millimetre lateral resolution. Photographs of c) drops and water condensation on surfaces locally functionalized by an alkyl silane.