# Directed patterning of arbitrary metal oxide nanostructures using polymer template nanoreactors

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Despite the unparalleled success of the lithographic nanofabrication in Si-based systems, nanofabricating other materials by these methods is much more difficult, particularly for functional nanoscale metal oxide structures with sub-100-nanometer-sized features, high aspect ratios, and vertical structural profiles, mainly because of the typically marginal etch selectivity between mask materials and metal oxides during the required reactive ion etching. Alternatively, high aspect ratio nanostructures can be directly grown via bottom-up, patterned growth methods wherein nucleation and growth of nanostructures are localized on patterned metallic catalysts following, for instance, the vapor-liquid-solid or vapor-solid mechanism. However, patterned growth can only generate limited types of vertical structures, such as arrays of nanowires and nanorods. In addition, it is difficult to integrate these as-grown nanostructures into individually addressable devices; they are more suitable for applications in which the collective properties of the whole array of growth structures are important.

In this work, we demonstrate a nanofabrication technique that can pattern functioning metal oxide nanostructures with arbitrarily-chosen designs/morphologies, high aspect ratios, and controlled dimensions/spatial registrations by utilizing lithographically patterned, topographical polymer templates as localized chemical reactors in which gaseous organometallic precursors and water are sequentially perfused and react to form the target metal oxides. Removing the polymer templates by oxygen plasma ashing generates the intended metal oxide nanostructures, for example, ones made of AlOx, TiOx, and ZnO with sub-40-nanometer widths, >5 aspect ratios, and 3-D morphologies controlled by the volumetric shrinkage of the polymer templates during their conversion into the target metal oxides. Our electron microscopy study on the structural and compositional evolutions of the polymer templates during the process reveals that a varying degree of organometal precursor infiltration into polymer templates for different metal oxides determines the amount of material loading, the extent of polymer template shrinkage under oxygen plasma, and, finally, the morphologies of the generated metal oxide nanostructures. We highlight one of the potentials of the technique for a high-throughput fabrication of arbitrary metal oxide nanostructures and devices by fabricating an array of functioning polycrystalline ZnO nanowire field-effect transistors (FETs) with controlled dimensions and spatial registrations.

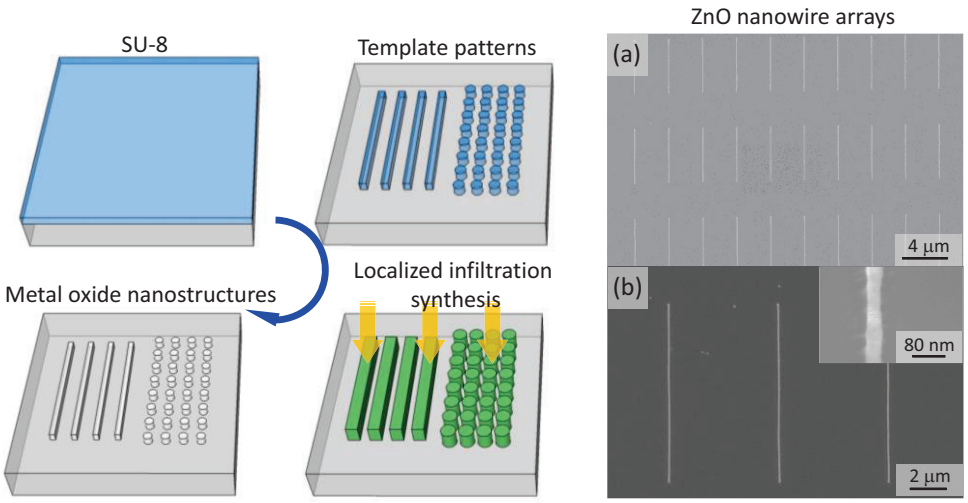


**Figure 1 Process flow of nanopatterning using polymer template nanoreactors. SU-8 resist template patterns formed by electron beam lithography are infiltrated with metal oxide precursors. The remaining resist is removed by oxygen plasma, leaving inorganic metal oxide nanostructures. ZnO nanowires (right) can be patterned to specific width, length, arrangement and registration.**