Rational Design of Hyperbranched Nanowire Systems for Tunable Superomniphobic Surfaces Enabled by Atomic Layer Deposition

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The hierarchical assembly of semiconductor nanostructures to form heterogeneous material systems has the potential to advance a range of technologies including electronics, optics, sensors, mechanical resonators, and energy conversion. Semiconductor nanowire (NW) arrays have already been successfully applied in these fields, but challenges such as lack of deterministic control of feature size, shape, and position limits the development of more complex geometries. One example, hyperbranched NWs, have been synthesized for a variety of applications, but the ability to tune the morphology along a spectrum at each level of hierarchy requires further development. Here we demonstrate surface and interface modification via atomic layer deposition (ALD) to control the fabrication and bottom-up solution growth of ordered hyperbranched NW systems.

Existing techniques for the assembly of complex nanostructures generally rely on either nanoscale patterning, or solution based processes. The patterning techniques while slow and costly on planar substrates, often become impossible on high aspect ratio surface geometries. The solution-based approaches offer scalability and lower cost, but the results are often disordered and difficult to tune. ALD is an enabling technique for the control of low-cost, scalable hydrothermal NW synthesis. This process relies on atomic-scale precision of conformal films deposited on nanowire arrays, for which ALD is an ideal process.

We start by demonstrating the control of ZnO NW array properties such as density and orientation by tuning the crystallographic orientation, roughness, and surface stress of ALD films used to seed the NW nucleation.[1] We then show how ALD can be used to overcome the challenges that arise when transitioning from simple NW arrays to complex branched structures. Sub-monolayer deposition of inert blocking layers were used to reduce NW density independent of orientation in order to make room for subsequent branched NW growth. ALD interlayers were then used to prevent epitaxial ALD growth of subsequent seedlayers on the single crystalline NWs. These techniques were all combined to fabricate hyperbranched NW arrays. The array properties were controlled with ALD at each level of hierarchy to produce superomniphobic (repellent to high and low surface tension liquids) with tunable contact angles for different liquids.[2]

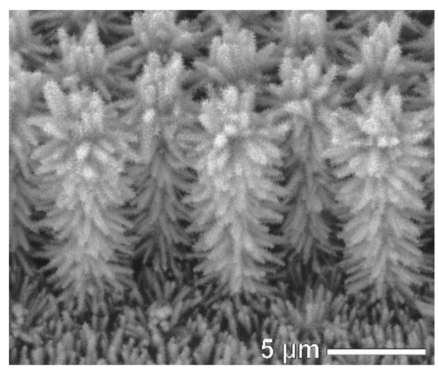

Figure 1: Branched ZnO nanowires on Si microposts.[2]

(1) Bielinski, A. R.; Kazyak, E.; Schlepütz, C. M.; Jung, H. J.; Wood, K. N.; Dasgupta, N. P. *Chem. Mater.* **2015**, *27* (13), 4799–4807.
(2) Bielinski, A. R.; Boban, M.; He, Y.; Kazyak, E.; Lee, D. H.; Wang, C.; Tuteja, A.; Dasgupta, N. P. *ACS Nano* **2017**, *11* (1), 478–489.