Nanowires with controlled location and direction by surface-guided growth from patterned catalyst

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Semiconductor nanowires (NWs) have been object of intensive studies during the last decade as building blocks for nanotechnology. However, integrating NWs into large-scale functional systems is challenged by limited geometric control at the single-NW level. The geometry of each NW can be described as a vector on a plane by its origin (x,y), direction (ϕ), and length (L). Control of these three parameters should enable bottom-up fabrication of large-scale integrated systems of many NWs. Recently, we demonstrated the guided growth of horizontal NWs with precisely controlled directions and crystallographic orientations determined by the substrate lattice, as well as by a graphoepitaxial effect that guides their growth along surface steps and grooves[1].

In this work we reach the second milestone toward the control of NW geometry by precisely defining the origin for each NW, combined with their surface-guided orientation. Such control is achieved by patterning the catalytic metal used in the vapor-liquid-solid (VLS) growth process. The patterning is done by either electron-beam or nanoimprint lithography, followed by metal deposition and liftoff. This method enables the growth of arrays of discrete unidirectional NWs, whose locations can be arbitrarily defined by the metallic catalyst pattern. Arrays of metal catalyst islands of different shapes and sizes, usually of the order of few tens of nm, were fabricated on sapphire substrates. NWs grown on these substrates by the VLS mechanism emerge from the edges of the patterned areas. By optimizing the shape and the size of the nanopattern, it is possible to achieve single-NW growth from each patterned catalyst island with a yield close to 100 % (Fig. 1). The parallel NWs arranged in periodical arrays provide a convenient geometric platform for functional systems based on many NW. As an example, multiple NW-based top-gate FETs can be fabricated in arbitrary and controlled arrangement, and integrated into circuits of several logical gates.

Our method of patterned guided growth opens up a new approach for integration of NWs into funcional systems, where NWs are grown precisely according to the design. This is opposed to the traditional post-growth assembly approach, where NWs are vertically grown, and then harvested and randomly dispersed on a substrate, forcing the geometry of fabricated nanodevices to be dependent on random location of each NW. We believe that this approach paves the way to more complex sytems based on multiple NWs.

[1] D. Tsivion M. Schvartzman, R. Popovitz-Biro, P. von Huth, E. Joselevich *Science*, 333, 1003, 2011

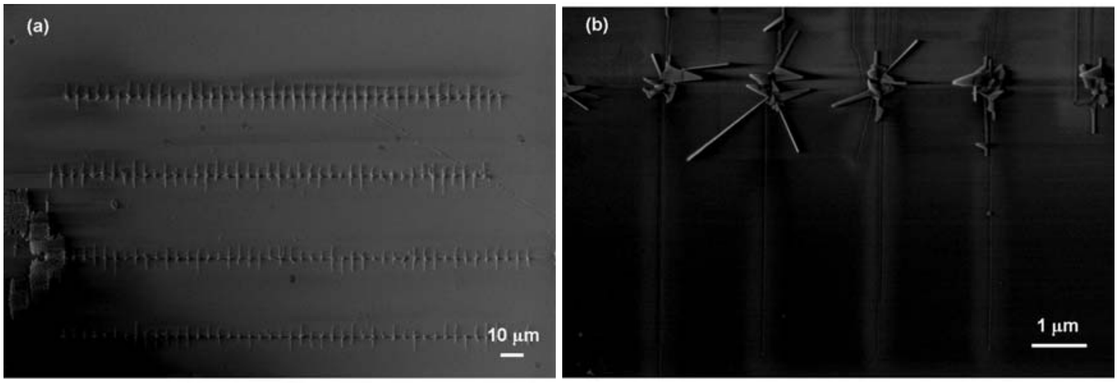

Figure 1. NW arrays horizontally grown on sapphire form nanopatterned catalyst

Figure 2. Integrated NW devices, based on patterned guided growth

Figure 2. Arrays of electrode pair on three parallel NWs, with the constant spacing between them (6