Bottom Up Microsystem Construction Strategies Built Upon 3D Directed Self-Assembly of Metallic and Polymeric Nanostructures

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Recently our group has developed two distinct methods of directed self-assembly of extremely high aspect ratio nanostructures. In one method a periodic micromachined array of vertical pillars is hand-brushed with a liquid polymer or nanomaterial-polymer composite leading to the spontaneous formation of two-point suspended nanofibers air-bridges and trampoline–like membranes (S. A. Harfenist *et al.*, *Nano Lett.* 2004, S. Pabba *et al.*, *ACS Nano* 2007). In some cases fibers as small as 10 nm diameter and exceeding 100:1 aspect ratios have been made with these crude methods of application that are then driven to make precise structures through capillary force driven thinning and self-assembly. In a second method, surfaces patterned with thin films of silver, when dipped into gallium at it melting point, which is near room temperature, can spontaneously grow Ag_2Ga nanowires of constant diameter on the order of 100 nm diameter and up to at least 70 μm in length (M. M. Yazdanpanah *et al.*, *J. Appl. Phys.* 2005). The process is remarkable in that these freestanding needles can be grown individually at selected locations and with a desired orientation with respect to the surface. Additionally the needles are extremely flexible, tough and ruggedly attached to the surface (V. V. Dobrokhotov *et al.*, *Nanotechnol.* 2008). These approaches enable the rapid, often one step addition, of true third-dimensional complexity to substrates, that after initial micromachining, are at best 2.5 dimensional.

Following a brief review of these two methods of directed self assembly, this paper will consider several ways to add increased functionality to the nanostructures through standard additive and subtractive processing. Because the nanostructures already set the limit of resolution, these subsequent processing steps are not critically dependent on extreme resolution patterning systems, which simplify microsystem prototype development. Both the fabrication development of functional elements (e.g. elastomeric and electrostatic actuators, capillaries, optical guides, mechanical and electrochemical sensors) and their planned incorporation into complete bio-microsystems (e.g. microfluidic cell sorters, cell-based biosensors and complete single cell probe and manipulation stations built into a microscope cover slip) will be presented. A final example will describe plans for performing fabrication of point-to-point drawing of nanofibers air-bridges in a rather arbitrary 3D interconnection space, which uses actuated arrays of nanoneedles as a smart brush to draw the polymer fibers.

Oral Presentation Preferred

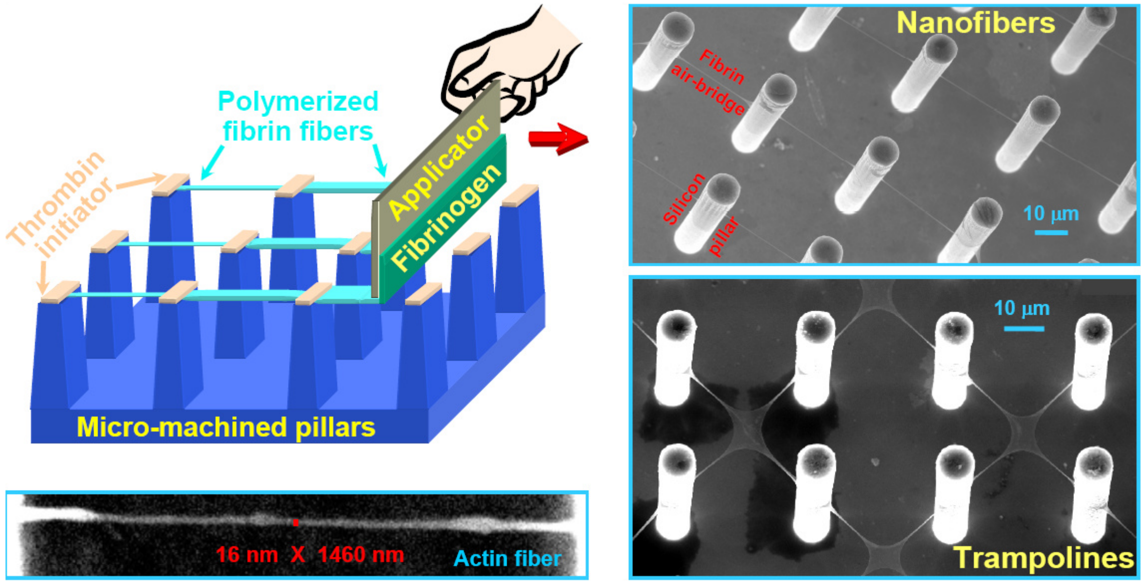

Figure 1. Hand brush on method of directed self-assembly of nanofiber air-bridges and trampolines. The particular reaction shown is for thrombin enzyme-initiated polymerization of fibrin from fibrinogen precursor.

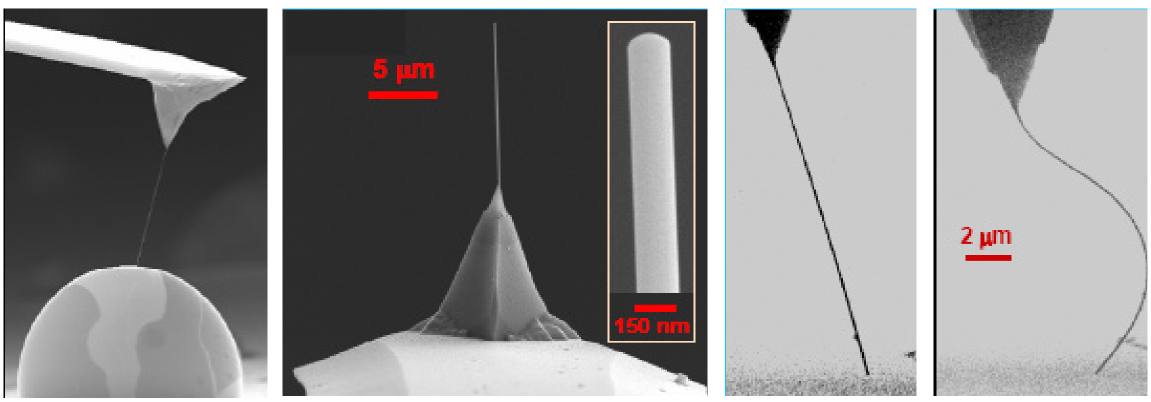

Figure 2. Growth and flexibility of an individual metal alloy nanoneedle. In under 5 min the Ag_2Ga needle was directed to grow on the end of a Ag-coated AFM tip after it was dipped into a 25 ^{o}C melt of gallium.

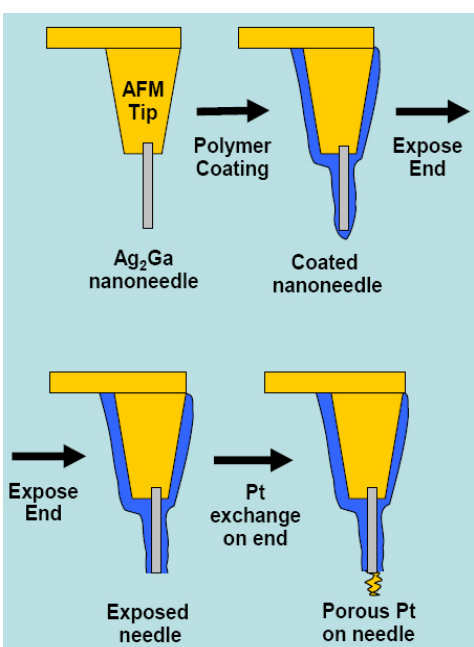

Figure 3. Process flow for templated fabrication of an electrochemical nanoelectrode.

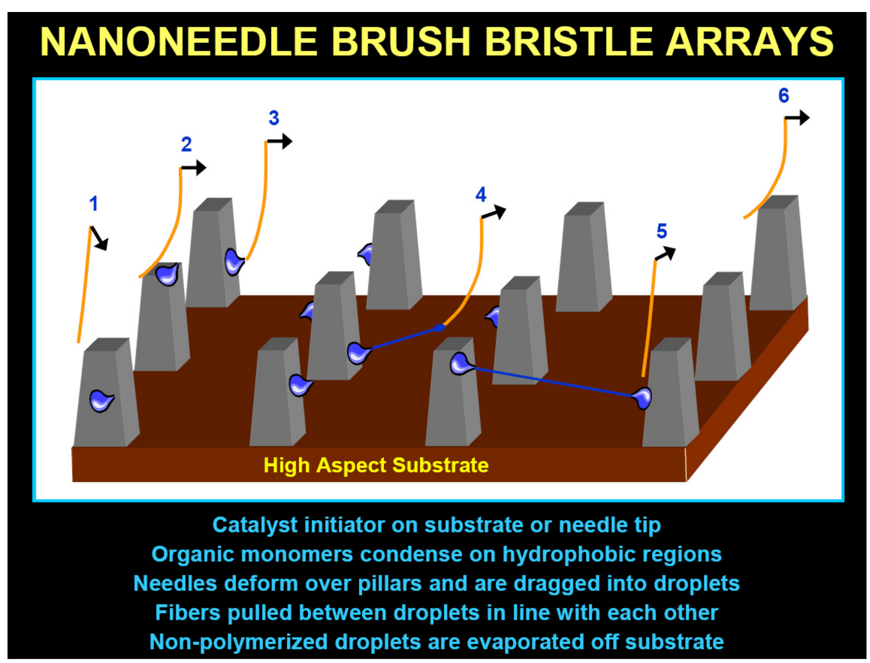

Figure 4. SmartBrush: A proposed process of using arrays of individually actuated nanoneedles to pattern rather arbitrary point-to-point nanofibers air-bridges in a 3D addressing space.