

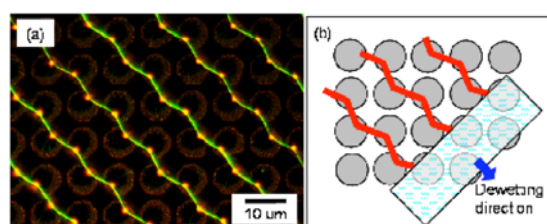
## Fabrication of DNA Nanowire Arrays and Nanochannel Array for DNA Manipulation

One-dimensional nanostructures, characterized by their extremely small cross-sectional size and large surface-to-volume ratio, hold tremendous potential to build next-generation sensors with high sensitivity and reaction rates, and devices capable of single-molecule manipulation. Among them, nanowires offer a strategy for ultra-sensitive detection of DNA and other biological entities. To build a nanowire sensor, these extremely small nanostructures need to be assembled into a well-designed architecture. Lack of robust and low-cost techniques for nanowire assembly is currently hindering the advancement of this field.

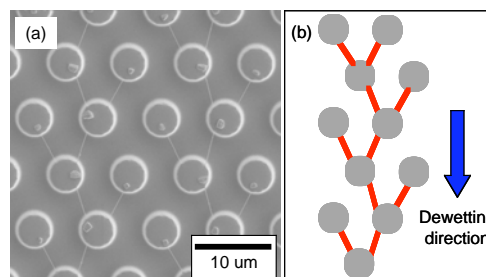
We have developed a method capable of generating arrays of functionalized DNA and polymer nanowires by dewetting a micropillar array with a DNA solution. Compared to other methods, this approach is fast, easy, robust, inexpensive and intrinsically capable of generating highly ordered nanowire arrays over large surface areas. During the last year, we have greatly extended this method in controlling the pattern of the nanowires and creating nanowire arrays with much higher densities. Nanochannels constitute another class of powerful tools for biosensing. They have been used to study single DNA dynamics, detect DNA-protein interaction, map genes on single DNA molecules, and separate DNA. Remarkably, a nanopore-based sensor can potentially sequence the entire human genome within a time scale of hours. However, the application of this technology is significantly limited because expensive and time-consuming nanolithographic methods are generally required for fabricating the nanochannels. During the last year, we have developed a polymer nanofabrication technique for preparing nanochannels by using DNA nanowires as templates. Compared to other methods, this technique can quickly generate a large and uniform array of nanochannels at low cost.

The same method described in our previous report was employed here to generate DNA nanowire arrays. Briefly, a polydimethylsiloxane (PDMS) stamp with micropillars on its surface was gently placed on a small drop of DNA solution seated on a glass slide and peeled off immediately, resulting in the formation of a well-defined array of DNA nanowires on the micropillars. Straight DNA nanowires were typically generated on micropillars with a 2D cubic lattice when the dewetting direction was in parallel to a lattice axis. In this study,

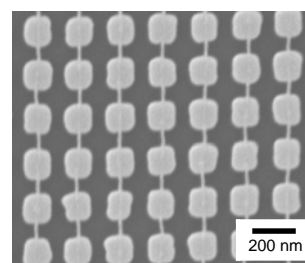
dewetting was controlled in a diagonal direction relative to the cubic lattice of micropillars, leading to a formation of nanowires with a zigzag pattern, as shown in Figure 1. We also fabricated a micropillar array with a hexagonal lattice. A branch-like nanowire pattern was obtained on the micropillars, as shown in Figure 2. For many nanowire devices, high wire density is desirable to achieve higher performance, lower manufacturing cost, and even new physical phenomena. We applied our technique to nanopillars (150 nm wide and 220 nm in center-to-center distance) and generated DNA arrays, as shown in Figure 3.



**Figure 1.** (a) Fluorescence image of zigzag-like DNA nanowires on micropillars and (b) schematic representation of nanowire pattern and dewetting direction. DNA was labeled with green YOYO-dye. Red-colored nanocrystal quantum dots were mixed in the DNA solution and led to the formation of orange bright aggregates on each micropillar.



**Figure 2.** (a) Scanning Electron Microscopy image of branch-like DNA nanowires on PDMS micropillars with a hexagonal lattice and (b) schematic representation of the nanowire pattern and dewetting direction.

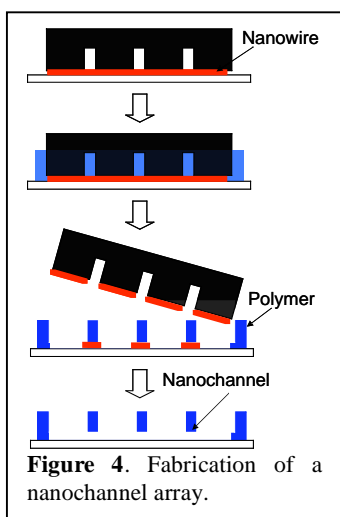


**Figure 3.** Scanning Electron Microscopy image of DNA nanowires on PDMS nanopillars.

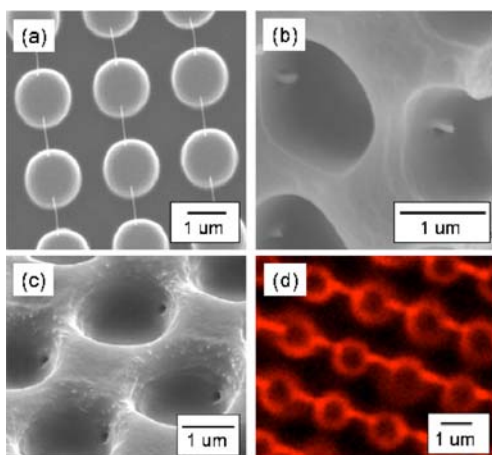
We can convert the DNA nanowires to polymer nanochannels, as shown in Figure 4. The DNA

nanowires on micropillars were first coated in gold by either sputter coating or E-beam evaporation (Figure 5(a)). The coating thickness can be easily controlled to define the diameter of the nanowires. The

gold-coated nanowires on PDMS micropillars were placed on a solid substrate, such as a glass slide. Liquid resin was used to fill the space between the micropillars using capillary flow. The liquid resin was then solidified by

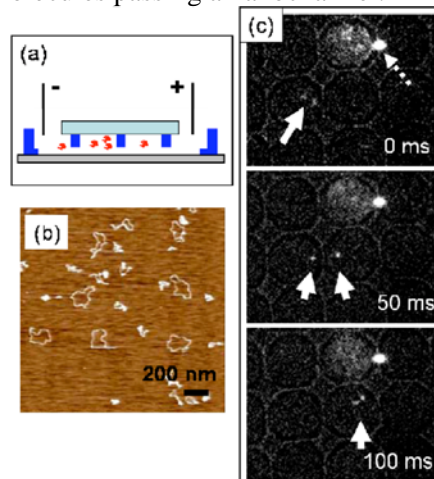


UV-induced polymerization. As a result, the nanowires suspended between micropillars were embedded in the solid polymer. The PDMS stamp was then removed, leaving the nanowires in the matrix of the cured polymer. Moreover, microwells were formed because of the replication of the micropillars. The two ends of the gold-coated DNA nanowires were exposed to the microwells, as shown in Figure 5(b). The nanowires were removed by soaking the chip in gold etchant. As a result, nanochannels formed, as shown in Figure 5(c). The width of the nanochannels was ~100 nm, determined by the width of the nanowires. The openness of the nanochannels was confirmed by filling the nanochannels with a fluorescent dye, rhodamine (Figure (d)).



**Figure 5.** SEM images of (a) the gold-coated DNA nanowires between 1 μm-wide micropillars; (b) ends of nanowires embedded in cured polymer; and (c) openings of nanochannels between microwells. (d) Fluorescence micrograph of nanochannels filled with rhodamine.

We used the nanochannels to manipulate DNA. The experimental setup is shown in Figure 6(a). The plasmid DNA (Fig. 6(b)) solution was loaded into the microwells, which were then covered by a piece of PDMS block. Electrical voltage was then applied. We found that DNA could pass through the nanochannels when the DAN concentration in the microwells was low. In contrast, DNA tended to be trapped in the nanochannels when the concentration was high (Fig. 6(c)). Figure 6(c) shows a time-series fluorescence micrographs of the translocation of two DNA molecules passing a nanochannel.



**Figure 6.** (a) Experimental setup of DNA manipulation by a nanochannel chip. (b) Atomic force microscopy image of plasmid DNA used in the experiment. (c) Time series fluorescence images of DNA translocation through a nanochannel. An aggregate of multiple fluorescence-labeled DNA molecules in a nanochannel is pointed by a dashed arrow. DNA molecules moving through nanochannel are indicated by the solid arrows.

A Computational Fluid Dynamics (CFD) simulation is being undertaken in our center to understand the effect of the dewetting pattern, micropillar lattice pattern, and pillar size on nanowire formation. Nanochannel devices will be developed to study DNA dynamics in nanoscale confinement and produce nanoparticles for gene delivery.

#### Publications

1. J. Guan, B. Yu, L. J. Lee, *Forming Highly Ordered Arrays of Functionalized Polymer Nanowires by Dewetting on Micropillars*, **Advanced Materials** (2007) 19: 1212.
2. J. Guan, N. Ferrell, B. Yu, D. J. Hansford, L. J. Lee, *Simultaneous Generation of Hybrid Arrays of Micro/Nanoparticles and Nanowires by Dewetting on Micropillars*, **Soft Matter** (2007) 2: 1369. Cover article.
3. J. Guan, L. J. Lee, *Fabrication of Nanochannel Array for DNA Manipulation and Analysis*, in preparation.