Process and Measurement

Large arrays of stretched DNA

Highly ordered arrays of stretched DNA molecules that are created using a modified molecular combing method and soft lithography have been demonstrated by L. James Lee and Jingjiao Guan at the Ohio State Univ., Columbus. The arrays consist of short nanostrands (average height of 1.48 nm with a range from 0.88 to 3.31 nm) and long nanostrands (average height 1.19 nm with a range from 0.58 to 2.80 nm) over a millimeter-scale area that is transferred onto other flat surfaces using contact printing. Multiple patterns are created using PDMS (polydimethyl siloxane) stamps that contain microwells (5-µm dia; 4-µm deep; 10-µm apart).

In the process, the arrays are created by pressing PDMS stamps into a solution of DNA molecules on a glass coverslip for 5 sec. A small amount of glycerin is added to the solution for transfer efficiency. Without the glycerin, many nanostrands do not transfer or break during transfer.

The stamp is peeled up from one end, which transfers the DNA molecules to the stamp. The molecules orient in the direction that the meniscus of the solution recedes. The stamp is placed on a flat surface for 1 min without the use of external pressure, which transfers the DNA to the surface.

The type of array is determined based on the speed and orientation of the stamp. When the stamp is slowly peeled away from the substrate, long nanostrands of DNA are created—consecutive nanostrands bundle. When the stamp is quickly peeled away, short nanostrands are formed—DNA breaks at the edges of the stamp's microwells.

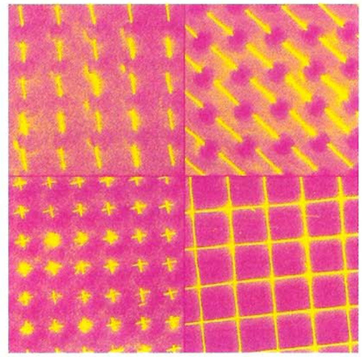

Fig. 1. *Top)* Vertical/diagonal aligned DNA nanostrand arrays. ***Bottom)*** Short/long DNA strands created by double printing. *Source:* Proceedings of the National Academy of Sciences.

Therefore, the nanostrand's length is determined by the geometry of the microfeature on the stamp.

To create crosses of short DNA strands or a crossbar structure of long DNA strands, the process is repeated with the stamp in a different orientation (Fig. 1) .

Potential applications are for the construction of next-generation DNA chips and functional circuits of DNA-based 1-D nanostructures.

The work is described in the Dec. 20, 2005 issue of *Proceedings of the National Academy of Sciences.*

For information, contact L. James Lee at lee.31@osu.edu.

Nanotechnology

Squashable nanotube foams

Films of vertically aligned MWNTs (multi-walled carbon nanotubes) that behave as flexible open-cell foams in which the tubes act as elastic struts have been reported by lead investigator Anyuan Cao at the Univ. of Hawaii at Manoa, Honolulu. The MWNT foams flex and rebound with super compressibility (85%). The films can be reversibly squeezed down to 15% (fatigue resistance) of their original thickness without structural failure, despite zigzag buckling of the tubes. The thickness of the nanotube foams decreased slightly but quickly stabilized and remained constant up to 10,000 cycles. (The thickness of the compressed nanotube films seen at >1,000 cycles, decreased from the original 860 µm to ~720 µm.)

The MWNTs act as elastic compression springs, allowing high compressibility along their axes, but they regain most of their length after the compression is released. The foams' recovery rates (>2,000 µm/sec) are also much faster than the general recovery rates for conventional flexible foams. The nanotube film did not fracture, tear, or collapse under compression, but remained at a constant width during the cycles.

Aligned SWNTS (single-walled carbon nanotubes) are expected to have better performance (strength, resilience). In addition, the compressive strength of the films can be tailored by controlling the wavelength of buckles.

Potential applications are as flexible electromechanical systems, compliant interconnect structures, actuators, and coatings for mechanical damping and energy-absorbing services.

The work is described in the Nov. 25, 2005 issue of *Science.*

Contact Anyuan Cao at anyuan@hawaii. edu.

Nanotechnology and Process and Measurement

Stretchable electronics

A fully stretchable form of a single-crystal Si with micron-sized, wave-like geometries that can be used to build high-performance electronic devices on elastomeric substrates has been demonstrated by John Rogers, Dahl-Young Khang, and colleagues at the Univ. of Illinois at Urbana-Champaign. Several basic electronic components like transistors and diodes can be built using the Si ribbons along with other classes of wavy electronics being possible.

In the process, single-crystal Si or complete integrated devices are fabricated using conventional lithographic processes. Then the top Si and SiO_2 layers of a SOI wafer are etched. The ribbon structures then become supported by the underlying wafer. Then a pre-strained PDMS (polydimethylsiloxane) substrate makes contact with the Si ribbon (Fig. 1), creating a bond.

Peeling back the PDMS with the ribbons bonded to its surface and then releasing the pre-strain causes the PDMS to relax back to its unstrained state, resulting in well-controlled, stretchable wavy structures in the ribbons. The Si takes on a wavy form, which can withstand tension or compression by changing the size and frequency of the waves in the Si ribbons.

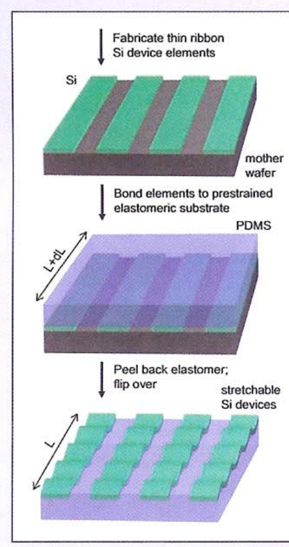

Fig. 1. Process for building stretchable single-crystal Si devices on elastomeric substrates. *Source: Univ. of Illinois, Urbana-Champaign.*

Potential applications are as sensors and drive electronics for integration into artificial muscles or biological tissues, structural monitors wrapped around aircraft wings, and conformable skins for integrated robotic sensors.

The work is described online in the Dec. 15, 2005 *Science Express* Web edition.

For information, contact Yonggang Huang at huang9@uiuc.edu.