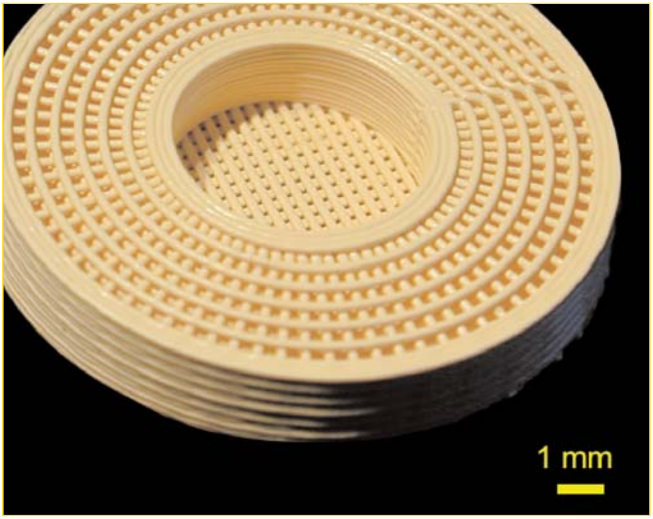
Self-supporting inks



Optical image of a structure constructed using robocasting. (Courtesy of Jennifer Lewis.)

Three-dimensional structures have been fabricated using colloidal inks by researchers at the University of Illinois and Sandia National Laboratories [*Langmuir* (2002) **18**(14), 5422-5428]. The structures include self-supporting or spanning elements and were built up layer by layer using a technique called robocasting. Such structures could find application in advanced ceramics, sensors, composites, tissue engineering scaffolds, and photonic bandgap materials.

Robocasting involves the robotic deposition of inks through a nozzle. In this case, the properties of the concentrated colloidal ink were crucial. "Such inks must first flow through a very fine deposition nozzle and then quickly 'set' to maintain their shape while simultaneously bonding to the underling layer," explains Jennifer A. Lewis, who led the group. This fluid-to-gel transition requires the tuning of the interparticle forces. The researchers used a change in pH to give the desired strength and shape retention in the deposited features, even when unsupported.

A three-dimensional lattice and a radial structure were assembled using the optimized colloidal inks. The features are as small as 100 μm and span gaps as large as 2 mm.

The group hopes to develop inks to print materials with even finer features. They also hope to dispense multiple inks simultaneously to build structures with variations in their composition.

Nano-emitter

Richard Smalley and colleagues from Rice University report observing fluorescence across the bandgap of semiconducting carbon nanotubes [*Science* (2002) **297**, 593-596]. By treating raw nanotubes with a sonicator, followed by centrifugation, individual tubes in aqueous micellar suspensions are produced. By preventing the aggregation of nanotubes into bundles, Smalley's team was able to detect fluorescence in the 800-1600 nm range.

In a more practical vein, Otto Zhou and colleagues from the University of North Carolina, Chapel Hill, together with Applied Nanotechnologies, Inc., have incorporated carbon nanotubes into a cold-cathode device [*Appl. Phys. Lett.* (2002) **81**(2), 355-357]. Intense electron beams generated by the nanotubes bombard a metal target to produce X-rays.

Lithography with single molecules

The bottom-up approach to fabricating nanometer-size electronic devices requires molecular building blocks to recognize each other correctly and self-assemble.

Biomolecules are attractive candidates, offering binding specificity and accurate enzymatic processing.

Scientists at the Technion-Israel and Institute of Technology, Haifa, used these properties of DNA and RecA protein in a process they call molecular lithography. They have created conductive wires with insulating gaps by coating parts of a DNA molecule with metal according to its sequence [*Science* (2002) **297**, 72-75].

This DNA-templated formation of nanowires uses aldehyde-derivatized DNA incubated in $AgNO_3$ solution. The reduction of Ag ions by the aldehyde forms tiny Ag aggregates along the DNA skeleton. The idea of 'molecular lithography' lies in patterning the Ag deposition by protecting areas of the DNA according to its sequence.

"The realization of sequence-specific molecular lithography constitutes an important step toward integrated DNA-templated electronics," say the authors. The group made use of the biological process of homologous recombination.

The DNA template for the wire was mixed with RecA and a short DNA probe with the same sequence as part of the template. In short, the information encoded in the sequence of the DNA probe determines where the RecA protein is located on the template. Metallization of the DNA-protein complex then gave a wire with an insulating gap where the RecA was bound.

RecA serves as a resist for the molecular lithography.

Christof M. Niemeyer, in an accompanying article [*Science* (2002) **297**, 62-63], optimistically adds, "The joint venture of biotechnology and electronic engineering promises plenty of excitement from future developments."