Nanotechnology Highlight

Robotic Assembly of Functional Nanostructures (9871775)
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Robotic Manipulation at the Nanometer Scale

An interdisciplinary team at the Laboratory for Molecular Robotics (LMR) of the University of Southern California has developed reliable and accurate techniques for manipulating nanometer-scale objects by using a Scanning Probe Microscope (SPM) as a robot. SPM manipulation will be an important process for protyping and small-batch fabrication of nanodevices for the foreseeable future. The SPM was invented only a couple of decades ago but has had a major impact on science and technology, and is one of the primary tools that underly the current research impetus on nanotechology. SPMs are normaly used as microscopes to image samples, often at molecular or even atomic resolution. However, it has been known almost since its invention that an SPM can also be used as a manipulator to modify a sample. Atomic manipulation has been demonstrated at several laboratories, but it normally requires operation in ultra high vacuum (UHV) and at temperatures approaching the absolute zero (< 4 K).

The LMR team has focused on manipulation of objects with dimensions on the order of a few nanometers, which are comparable to those of macromolecules such as small proteins. The phenomena underlying manipulation at the nanoscale have been investigated, and custom software for manipulation, inspired by the mobile robotics field, has been developed to compensate for the many spatial uncertainties inherent in SPM operation. LMR's procedures do not require stringent environmental conditions: operation is at room temperature, in air or in a liquid. Liquid operation is especialy interesting since it opens the door to applications in the biological sciences.

The figure below shows results that can be routinely obtained at LMR. It is a pattern of 15 nm gold nanoparticles positioned on a grid with a 100 nm pitch. The vertical scale has been exagerated, for clarity. The particles are approximately spherical but appear as bumps in the figure because the SPM's tip shape broadens the images of the sample's features. The presence of a particle at a grid point can be interpreted as a logical "1", and its absence as a "0". Thus, the three rows in the figure represent the letters "LMR" in the ASCII code that is widely used in information processing. This example illustrates a potential application of nanoparticle manipulation to digital storage, at a density that is several orders of magnitude higher than that of current compact disks.

Nanoparticle patterns have many other applications that are being investigated at LMR. They include (i) tunneling structures such as single-electron transistors, which can be used in computing and sensing; (ii) components of NEMS (Nano Electro Mechanical Systems), which can be built by joining nanoparticles by chemical means after they have been positioned by manipulation; (iii) wiring for electronic circuits, built by combining manipulation with self-assembly; (iv) three-dimensional layered nanofabrication, which involves nanoparticle manipulation and self-assembly of sacrificial layers; and (v) optical nanowaveguides. The long-term goal of this research is to develop sensors, actuators and full-fledged robots at the nanoscale. In turn, these will fuel advances in physically-coupled nanowebs, which are networks of very large numbers of very small sensors and actuators. Nanowebs are expected to have a revolutionary impact on such fields as medicine and environmental monitoring.

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