separated in some cases by only a few fractions of a nanometre.

To investigate the local heat transfer and its spatial variation at the nanoscale, one must ideally switch to a point-like sensing probe, which is currently impossible experimentally. Using a sharp tip to measure the heat transfer also causes problems because the theoretical description of this scheme is complicated and undeveloped; a conducting tip can lead to a field enhancement, and this must be covered by an appropriate theory. Future work should aim to reduce separations to only a few nanometres and investigate spatially resolved heat transfer (that is, energy transfer) on the 'true nanoscale'.

The recent activity of several groups worldwide illustrates the increasing relevance of research into thermal near-field radiation. The subject still poses significant challenges to both fundamental and applied physics, ranging from the study of non-local effects in dielectric media to active thermal management in nanostructures. Although 40 years have passed between the first investigations into thermal near-field radiation[4] and the precision measurements reported here[1], the next decisive steps will likely be taken much sooner. ❐

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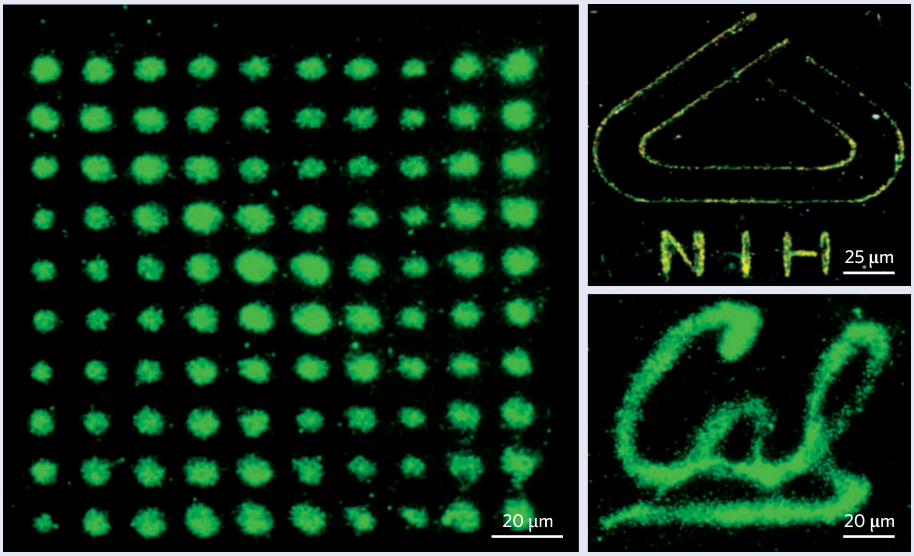
OPTICAL MANIPULATION

Nanopatterning made easy

The ability to write a pattern of nanoparticles using a 'pen' may ease the fabrication of opto- and nano-devices significantly. The realization of such a 'nanoparticle pen' has now been achieved by a group of scientists from the University of California in Berkeley, Lawrence Livermore National Laboratory and Lawrence Berkeley National Laboratory, USA (*Nano Lett.* **9,** 2921–2925; 2009).

Current nanoparticle patterning techniques typically involve process durations of several minutes to several hours, complicated set-ups or high optical intensities exceeding 10^5 W cm^{-2}. Now, Arash Jamshidi and co-workers have developed a low-power light-actuated method for creating dynamic patterns of nanoparticles (such as gold and silver), nanowires and carbon nanotubes in real time. The scheme is capable of operating on the timescale of seconds over an area of thousands of square micrometres, and requires a light intensity of <10 W cm^{-2}.

Their 'NanoPen' uses optoelectronic tweezers integrated with an optofluidic platform to write patterns of nanoparticles directly. The scheme consists of a 1-µm-thick layer of hydrogenated amorphous silicon (a-Si:H) that is covered by a 100-µm-thick layer of deionized water solution containing the nanoparticles to be patterned. The water and the a-Si:H layer are sandwiched between two layers of indium tin oxide (ITO) that serve as transparent electrodes.



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An a.c. voltage (10–20 V peak-to-peak voltage and 10–100 kHz frequency) is applied to the ITO electrodes while an optical pattern is projected onto the a-Si:H layer using a scanning laser source, a spatial light modulator or a commercial projector. The light pattern generates electron–hole pairs in the a-Si:H layer, thus locally increasing its electrical conductivity and transferring the a.c. voltage in the illuminated regions to the liquid layer above. The result is a non-uniform electric field distribution in the liquid layer that can be used to manipulate the nanoparticle positions.

To demonstrate the effectiveness of the scheme, the team used a suspension of gold spheres (90-nm diameter) and, using a commercial light projector, wrote various patterns (including a 10 × 10 array of dots, miniature logos and letters) over areas of 140 µm × 110 µm to 160 µm × 140 µm. Patterning over larger areas is possible using a digital micromirror display device as a projector.

Once the patterning process is complete, the team say that in principle the liquid solution can be removed to leave a permanent surface pattern. It is expected that the approach could find applications in photonic circuitry manufacture, nanostructure synthesis, photovoltaics and surface-enhanced Raman spectroscopy.

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