They can therefore be used in biological applications to transport biochemical nutrients or growth factors for tissue engineering. Incorporation of lithographically defined pores can also be used to locally release chemicals. The researchers also created a reconfigurable metamaterial suggesting that these self-assembling devices could prove useful as 3D electromagnetic devices.

Mousumi Mani Biswas

Nano Focus

Hollow spacers lead to new possibilities in superlattice design

Highly ordered arrays of nanoparticles hold the promise of functionality determined by the periodic arrangement of their constituent nanoscale building blocks. The rational assembly of DNA-functionalized nanoparticles has proven an effective method for generating well-defined crystalline lattices, but is limited in the number of geometries. C.A. Mirkin, E. Auyeung, J.I. Cutler, and their colleagues at Northwestern University have recently improved the capabilities of this method, allowing them to create lattices with previously unobserved symmetries. As reported in the January issue of *Nature Nanotechnology* (DOI: 10.1038/NNANO.2011.222; p. 24), Mirkin's group demonstrates the utility of three-dimensional hollow spacers, or spherical nucleic acid (SNA) nanostructures, that take the place of DNA-functionalized gold nanoparticles, enabling the researchers to expand the library of superlattices they are able to create as well as to make novel structures not previously observed in nature.

The hollow spacers are made using gold nanoparticles as a template and offer the potential of superior control over the superlattice structure. The technique utilizes gold nanoparticles functionalized with alkyne–modified DNA, which can be employed to generate a rigid network by cross-linking the densely packed alkyne units. The gold particle cores within the DNA shells are then dissolved, generating hollow spherical nucleic acids (SNAs) nanoparticle conjugates which are nearly identical in size to their gold nanoparticle counterparts. They also exhibit many of the same unique chemical and physical properties, including the ability to participate in cooperative binding events, which is a necessary requirement for their use in this programmed assembly application. However, the spacers do not scatter x-rays and are observed as blank positions in x-ray scattering experiments.

The research team demonstrates the utility of hollow SNA nanostructures by first changing the molar ratio of the gold nanoparticle units to spacer particles, and secondly by changing the size of the gold and spacer nanoparticles. Initially, a body centered cubic (bcc) system was formed using two sets of gold nanoparticles of equal size (molar ratio 1:1) and with complementary sticky ends (5′-AAGGAA-3′ for the first group and 5′-TTCCTT-3′ for the second group). By replacing one of the gold nanoparticle groups with a hollow spacer group, the researchers were able to form a simple cubic system.

Alternatively, a 2:1 ratio of 20 nm and 10 nm gold nanoparticles was used to create AB_2-type crystal superlattices. By substituting the gold nanoparticles in this system for spacers, the researchers demonstrated simple hexagonal (10 nm spacer) and graphite-like symmetries (20 nm spacer). Finally, AB_6 symmetry was created using a 1:6 ratio of 20 nm to 10 nm gold nanoparticles. When the 20 nm spacer was substituted for 20 nm gold nanoparticles, a completely new symmetry group was observed that the team dubbed "Lattice X."

The researchers said that the improved structural diversity provided by their hollow particle approach will lead to the development of new functional materials that can be used in a wide variety of applications ranging from plasmonics to catalysis.

Kevin P. Herlihy

Hydrogen at room temperature is squeezed to become a metal

Hydrogen, one of the most basic and well-studied elements, still has surprises in store. At pressures exceeding several million atmospheres, hydrogen is predicted to become metallic, superconducting, and may even exhibit superfluidity.

In the November 13, 2011 online edition of *Nature Materials* (DOI: 10.1038/NMAT3175), M.I. Eremets and I.A. Troyan at the Max Planck Institute for Chemistry describe experiments in which molecular hydrogen undergoes transformation to dense hydrogen and then a conductive, metallic state under the megabar pressures exerted by a diamond anvil cell (DAC).

The hydrogen sample first becomes opaque at a pressure of about 220 GPa, and is a semiconductor, as shown by photoconductivity measurements where the samples conduct on illumination with a He-Ne laser (photon energy of 1.96 eV). As the pressure is increased, the width of the bandgap decreases, and the samples can conduct without illumination. Finally, the bandgap closes at an applied pressure of about 270 GPa. Eremets and Troyan propose that a first-order phase transformation to a metallic, monatomic liquid state occurs at that pressure, since the resistance drops precipitously and exhibits little pressure dependence at higher applied pressures. This metallic state was confirmed by cooling the sample down to about 30 K, and noting that the resistance remained low (in contrast with a nonmetal, which insulates at sufficiently

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