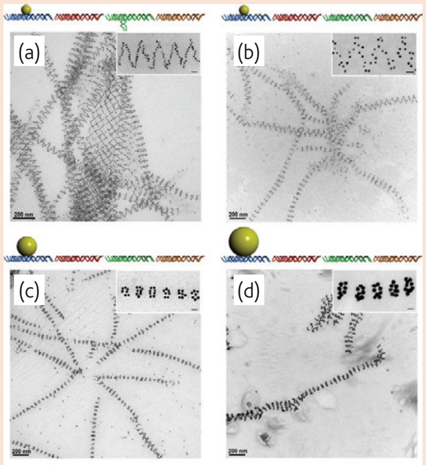
Gold for designer DNA architecture

NANOTECHNOLOGY

DNA is one of the most promising materials for the construction of arbitrarily tailored 3D nanostructures. Researchers from Arizona State University, Tempe, and the Scripps Research Institute, La Jolla, have found a way to trigger self-assembly of DNA tubules [Sharma *et al.*, *Science* (2009) **323**, 112]. "A key prospect of structural DNA nanotechnology is to be able to design and construct nanoscale geometrical shapes in a programmable way. So far the field has demonstrated that we can make 1D, 2D, 3D structures of different shapes. Diatoms, foraminifers, viral capsids etc. are wonderful examples of how self-assembly works in nature," says Hao Yan, the corresponding author. To progress from lower dimensional to 3D structures, Yan and colleagues have attached gold nanoparticles (AuNPs) via a thiol group to DNA double helices. This combination proved convenient as the DNA-gold conjugates are stable and, in addition, provide effective image enhancement for electron microscopy.



These schematic and TEM images are 2D projections of flattened tubular structures formed from DNA tile arrays with various thicknesses of AuNps on A tiles

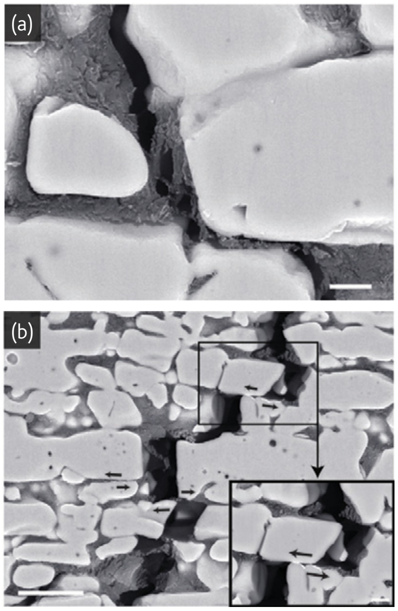
When such modified helices arrange themselves parallel to each other, steric and electrostatic repulsions between neighbouring AuNPs cause curling of the molecular arrangement, which leads to the formation of various tube structures, with the particles on the outside. Depending on the size of the AuNPs and the offset of the parallel strands, a variety of structures are obtained: without any offset, tubes displaying rings of AuNPs are formed, otherwise single, double spiralled tubes, or even double-walled spiral tubes, can be assembled. The manufacturing of tailored DNA architecture mounted with gold or other nanoparticles seems a highly promising lead towards several nanotechnological applications. Nanoelectronics or –photonics come to mind, but Yan can imagine more spectacular devices. "Inductors are but one example that can be made from a spiralling AuNP with a magnetic core, " says Yan. "It would be even more exciting if a designer DNA tube could be used to channel electrical communication through neuron cells. The tube could serve as an interconnect for nanoelectronic devices."

Michel Fleck

Biomimicry to the rescue

CERAMICS

In Nature, the combination of brittle minerals and organic molecules in highly sophisticated structures and designs results in materials (such as bone, wood or nacre) whose mechanicals properties far exceed those that can be achieved by a simple mixture of their components. Producing new high performance materials with enhanced strength and toughness by copying and mimicking nature's hidden marvels is the essence of biomimicry. Biomimicry is a very appealing idea that has yielded only a few practical advances, until a team of researchers from the Lawrence Berkeley National Laboratory and the University of California recently managed to successfully mimic the structure of nacre to create one of the toughest ever produced ceramic [Munch *et al.*, *Science* (2008) 322, 1516]. Through directional freeze casting of ceramic-based suspensions in water (Al_2O_3) and subsequent infiltration with a polymer (polymethylmethacrylate, PMMA), Munch *et al.* produced lamellar ceramic scaffolds. Pressing the lamellar structure perpendicular to its direction of extension and further sintering, result in a collapse of the entire edifice leading to the formation of a 'brick-and-mortar' structure in which the bricks are held together by ceramic bridges. While trying to replicate the microstructural design of nacre to perfection,



In situ imaging of crack propagation in a 'brick-and-mortar' structure. a) evidence of polymer tearing and b) frictional sliding between ceramic bricks

Munch and co-workers have worked towards reducing the lamellae thickness and used some additive to the ceramic slurries in order to modify the viscosity and phase diagram of the solvent, thus leading to ice crystals with a microscopic roughness and bridge density similar to that existing in nacre.

They produced a series of Al_2O_3/PMMA hybrid composites with hierarchical structures spanning multiple length scales. By combining those two relatively ordinary phases (Al_2O_3 and PMMA) the authors have synthesized a bio-inspired ceramic-based material that exhibits a toughness that can be up to 300 times (in energy terms) that of its initial constituents and whose properties match those of engineering aluminium alloys.

While 'these results highlight the tremendous potential of the biomimetic approach' as stated by Munch *et al.*, the next step of this research is to boost the ceramic content of the hybrid material up to 95 vol. % ceramic and decrease the lamellae thickness down to 2-3 nm, to achieve the unprecedented characteristics of nacre and provide additional nanoscale thoughening mechanisms similar to those acting in natural materials.

Maggy Heintz