Nature and the fabrication of novel materials

CONFERENCE REPORT

Self-assembly, inspired by biology, offers an alternative to lithography techniques for nanofabrication. However, the assembly of connected, electrically functional, nanoscale components has yet to be demonstrated, said George M. Whitesides of Harvard University at the Materials Research Society (MRS) Fall meeting in Boston last month. "It is clear that we haven't begun to start to approach nanofabrication in nature."

While that may be the case, much of the work on show at the MRS demonstrated how biomolecules can be used in the assembly of advanced materials. Ioana Pavel and Karen S. Browning of The University of Texas at Austin, with colleague Angela M. Belcher of Massachusetts Institute of Technology (MIT), are using the natural protein factory in cells, the ribosome, to incorporate Au nanoparticles (NPs) into proteins at defined positions. This is not only of interest for generating novel materials, but also to answer fundamental questions about the workings of the ribosome.

In other work, Ganapathiraman Ramanath and coworkers at Rensselaer Polytechnic Institute report successfully functionalizing carbon nanotubes (CNTs) at selected locations with various proteins. Kris C. Wood, Paula T. Hammond and Robert S. Langer at MIT described a drug delivery system capable of targeting therapeutic DNA to liver cancer cells. The system is based on a copolymer that includes a dendritic block with amine groups to bind DNA and a linear, hydrophilic polyethylene glycol (PEG) block for biocompatibility. Ligands that recognize specific cell receptors can be attached to the PEG chain.

Such materials innovation is not a modern phenomenon, however, says Barbara H. Berrie of the National Gallery of Art in Washington. She believes that 16th century Venetian painters such as Lotto and Tintoretto adopted glasses and dyes used by the local glass-making industry as colorants and extenders for paint. These artists, noted for the brilliant colors in their work, looked beyond their usual practices and transferred materials from new technologies to their paints.

Jonathan Wood

A bridge in understanding

CERAMICS

Researchers from Lawrence Berkeley and Lawrence Livermore National Laboratories, the University of California at Berkeley and Davis, and the Air Force Research Laboratory have used atomic resolution imaging to reveal the interface structure and atomic bonding in silicon nitride (Si_3N_4) ceramics [Ziegler *et al.*, *Science* (2004) **306**, 1768].

Si_3N_4 ceramics are of great interest because of their excellent high-temperature mechanical and physical properties, but applications are limited because of their brittleness. These attributes are the result of the crystal structure, local chemistry, and local interface bonding of Si_3N_4. Key to controlling the material's characteristics is the microstructure, which consists of matrix grains randomly oriented and interlocked in a secondary, intergranular phase. But understanding how this phase governs the properties is limited. Alexander Ziegler and coworkers used high-angle annular dark field scanning transmission electron microscopy (HAADF-STEM) and electron energy loss spectroscopy (EELS) to analyse the interface between the grains and the intergranular phase.

By doping Si_3N_4 with rare-earth elements La, Sm, Er, Yb, and Lu, the chemical composition can be changed and, therefore, the atomic bonding in the intergranular phase. The researchers find that each rare-earth element attaches to the interface differently, depending on atomic size. Small atoms, such as Er, Yb, and Lu attach in pairs at specific periodic sites along the interface. Slightly larger atoms, such as Sm, cannot bond in pairs and form a single-atom periodic bonding configuration. Larger atoms, such as La, show no periodicity or site-specific bonding at all. The presence of oxygen at the bonding site also plays a role.

"Determination of the precise rare-earth atom location is a prime factor to understanding the origin of a variety of the material's properties, most importantly grain growth, microstructural evolution, and mechanical properties," says Ziegler. "Such information has been related to the macroscopic fracture toughness, thereby representing a 'bridge in length scales' from subnanometer to meter dimensions."

Cordelia Sealy

New tool for nanoscience

NANOTECHNOLOGY

A high-vacuum fabrication and analysis system under development at the University of Cambridge could be a universal tool for nanotechnology [Egger *et al.*, *Nano Lett.* (2004) doi: 10.1021/nl0486822].

The novel nanofabrication technique is based on dynamic nanostencilling through a shadow mask in a high vacuum. The system has three ultrahigh vacuum (UHV) chambers with vibration dampers to reduce mechanical noise and ion pumps for use during fabrication and imaging. An e-beam evaporator is used for fabrication with a Si_3N_4-coated Si stencil mask cantilever. The mask can be positioned with nanometer precision over a range of 100 μm x 100 μm. A small gap between the mask and sample enables structures in the 80-500 nm range to be fabricated, although structures as small as 10 nm are possible. Analysis tools are also incorporated into the system, including facilities for scanning probe microscopy. The researchers are currently working toward imaging with the same stencil mask, which would have enormous advantages. The dynamic shadow mask system also enables the mask and the substrate to be prepared independently *in situ*; different materials to be incorporated by multiple evaporation sources; and custom-made holes or patterns to be created in the stencil mask. The system allows thickness modulation, which is difficult with conventional lithography, and the interconnection of nano- and macro-scale objects without lithography.

The system could find broad usage for both nanofabrication and surface science research. "It is a unique research tool for making complex nanostructures," says Mark E, Welland.

Cordelia Sealy