

Stretchable electronics

Organic-based electronic materials enable the possibility of forming complex electronic circuitry on inexpensive and flexible substrates. In recent years, many different potential uses of these materials have been demonstrated, including



DENSE PACKING

Answering packing problems, such as how many candies can fill a specific volume, seems at first very simple but these are actually non-trivial problems that have fascinated mathematicians and physicists for centuries. So far, the highest possible packing fraction was observed with equal spheres in face-centered-cubic lattices. Salvatore Torquato and colleagues now report in *Science* (A. Donev *et al. Science* 303, 990–993; 2004) experimental and theoretical results suggesting that ellipsoids in the shape of M&M candies can randomly pack more densely than previously thought. The authors believe that the observed higher density is directly proportional to the high number of degrees of freedom per candy, which result in a large number of contacts that stabilize the packing. This finding has many important practical and fundamental implications not only for storage and shipping applications but also for our understanding of scientific issues associated with glass formation, discrete geometry and the properties of granular media and ceramics.

smart textiles and electronic paper. Despite such progress, however, one problem with these materials has resisted solution — they tend to break when stretched. Attempts to develop a conductor that can stretch without breaking have largely focused on increasing the conductivity of an elastic material such as silicone by embedding metal particles within it. Unfortunately, the conductivity of the materials produced by this approach is relatively poor and varies substantially when stretched. But, by incorporating continuous winding patterns of gold wire into an elastomer

polydimethylsiloxane, Darren Gray and colleagues may have found a solution (D. S. Gray, J. Tien & C. S. Chen. *Advanced Materials* <http://dx.doi.org/10.1002/adma.200306107>). This approach takes advantage of the fact that metals are more robust to bending than stretching. The resulting gold coils can be stretched by up to 54% without failure. By increasing the mechanical resilience of these materials, the authors suggest their work could enable electronic circuits to be used both in more delicate and extreme circumstances such as living tissues and high-vibration environments.

Shifting structures

The martensitic transformation of crystalline solids is an important diffusionless phase transformation induced by an external stress, such as a rapid change in temperature. This crystal–crystal transformation also occurs in colloidal systems, where it can be induced and controlled by an external electric field. Anand Yethiraj and colleagues have now conducted a detailed study of the field-induced transition from a close-packed to a body-centred crystal structure in hard-sphere colloidal films (A. Yethiraj, A. Wouterse, B. Groh & A. van Blaaderen *Physical Review Letters* 92, 058301; 2004). The colloidal particles, positioned between two glass plates, sediment towards the bottom of the plates in a close-packed arrangement under the force of gravity. Yethiraj and co-workers used confocal laser scanning microscopy to study the change in crystal structure of the colloidal film under an increasing electric field (oriented perpendicular to gravity). The researchers constructed detailed maps of the changing colloidal crystal structure as a function of height and electric field. A clear transition from close-packed to body-centred tetragonal order was observed with increasing field, but for intermediate field strengths, patches of close-packed and body-centred tetragonal regions coexisted. The distinct intermediate structures were observed only near the solid–solid interface, and were found to be stable over long periods (days). The martensitic transformation may provide a way to sensitively control colloidal crystalline structures and enhance long-range order for photonic-crystal applications.

Active plasmonics

‘Plasmonics’ is a new field of optics that uses propagating plasmon–polariton excitations in nanostructured metal films as information carriers for highly integrated optical devices. Plasmon waveguides consisting of closely spaced metal nanoparticles have already been shown to transmit light (in the form of surface plasmon–polariton excitations) a distance of 500 nm down the nanoparticle chain. Researchers at the University of Southampton have now developed a concept for ‘active plasmonics’, which allows for active manipulation of surface plasmon–polariton (SPP) signals on ultrafast timescales (A. V. Krasavin & N. I. Zheludev *Applied Physics Letters* 84, 1416–1418; 2004).

The authors propose that SPP signals in metallic–on–dielectric waveguides containing a short gallium section could be switched by switching the gallium structure. α -Gallium is uniquely suited for this purpose because it has a low melting point (29.8 °C), above which it transforms to a metastable metallic phase with greatly different optical properties. Using numerical simulations, Krasavin and Zheludev show that ‘melting’ the gallium section in the waveguide (by an increase in waveguide temperature or by external optical excitation) greatly increases the waveguide transmission. The ‘switch-on’ time is of the order of a few picoseconds, and the switch-off time (corresponding to recrystallization of the molten gallium into the α -phase) is expected to be about a microsecond.

Supramolecular nanovalve

Developments in supramolecular chemistry have realized the construction of molecular-scale machines, where the molecular components can make mechanical-like movements in response to stimuli. Researchers in California have now used pseudorotaxane complexes, tethered in pores in a silica film, to create nanovalves that can trap luminescent molecules within the pores and release them on demand (R. Hernandez, H-R. Tseng, J. W. Wong, F. Stoddart & J. I. Zink *Journal of the American Chemical Society* <http://dx.doi.org/doi:10.1021/ja039424u>). The pseudorotaxanes they used are formed from a complex between a linear polymer and a bulky cyclopolymer (in this case a tetracation). The surface of the silica film is first derivatized with the linear polymer, which then acts as gateposts to the pores. After filling the pores with the luminescent molecules, the film is dipped into an aqueous solution of the cyclopolymer, which threads around the gateposts thus blocking the pore openings. When the film is placed in a reducing solution, the complex breaks up, with the tetracations dethreading from the gateposts, thus unblocking the pores and releasing the luminescent molecules. The authors suggest a potential for applications for controlled release of drugs.

