gies and two monomers with zero energy (see Figure 1d), so that application of a perpendicular electric field results in different potentials at the bottom and top layers. This lifts the degeneracy of the two monomers and induces a bandgap.

The researchers said, "Our work suggests that a tunable bandgap can be induced in thicker graphene samples with ABC (rhombohedral) stacking order, thus providing a still broader class of materials with a tunable bandgap."

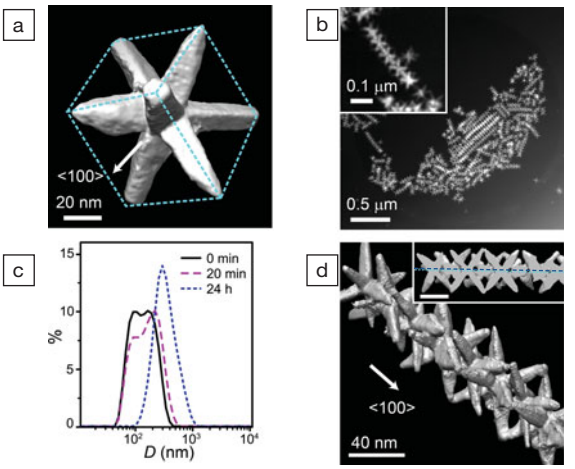
Steven Trohalaki

Octapodal nanocrystals self-assemble into micrometer superstructures

Researchers have created octapodal nanoparticles that self-assemble on a number of levels to ultimately generate micrometer-sized superstructures. Their work opens the door to fast and reversible cation exchange systems, the possibility of building three-dimensional (3D) ion sensors and porous electrodes, and other applications arising from the ability to establish complex geometries of dielectric and conductive materials.

K. Miszta from the Instituto Italiano di Tecnologia in Genova, Italy, J. de Graaf and R. van Roij from Utrecht University, the Netherlands, and their colleagues reported their discovery of this phenomenon in the November issue of *Nature Materials* (DOI: 10.1038/nmat3121; p. 872). By growing eight CdS pods out of a CdSe core, the researchers were able to fabricate monodisperse, colloidally predictable octapods that approached 100 nm in diameter. These octapods self-assembled into linear chains of interlocked octapods up to 400 nm in length in a toluene solvent. After aging the toluene solution for 24 hours, the addition of acetonitrile to the toluene caused the chains to precipitate out into 3D ordered superstructures 2 µm in length, composed entirely of self-assembled chains.

To create these structures, the researchers modified a previous procedure which allowed for unprecedented homogeneity and monodispersity of particles. The team coated the particles with hydrophobic surfactant molecules to improve interactions before immersing them in toluene. The toluene octapod solution (250 µL) was aged for 12–24 hours, and then mixed with 1 mL of acetonitrile. Two to five hours later the researchers transferred the resulting precipitate to a conductive substrate for scanning and transmission electron microscopy analysis. Aggregation in solution was monitored by dynamic light-scattering microscopy. The concentration of octapods in the final solution was on the order of 10^{-8} molar.



Formation of octapod chains in toluene: (a) three-dimensional (3D) reconstruction from scanning transmission electron microscopy (STEM) projections; (b) STEM image after 24 h of ageing; (c) cluster size distribution curves at different ageing times, *D* is the size of the aggregates, % is the percentage of frequency; and (d) 3D reconstruction of a single chain, demonstrating the interlocking sequence along <100> of the cube in (a), with the octapod centers well aligned on the chain axis, as shown by the cut-through of the inset. Reprinted with permission from *Nature Mater*. (DOI: 10.1038/nmat3121).

Benjamin Scheiner

Graphene allows ultrashort pulse generation in solid-state laser

Graphene is a point-bandgap semiconductor with a linear dispersion of electrons with low energy that can be described by the Dirac equation involving relativistic effects. It also possesses large polarizability when illuminated by light, that is, large optical nonlinearity. These unique characteristics, in combination with the ultrafast relaxations of charge carriers (electrons and holes) in this material, in the femtosecond and picosecond time scale, suggest that graphene can be useful as an ultrafast saturable absorber (SA), that is, a material in which absorption of light decreases when the light intensity increases, and in a very short period of time. This property is fundamental for the generation of ultrashort light pulses in laser technology. Furthermore, graphene can be used for this application in a very broad spectral range without requiring modification of the electronic bandgap. F. Rotermund from Ajou University, South Korea, B.H. Hong from Sungkyunkwan University, South Korea, and their colleagues have reported in the October 15 issue of *Optics Letters* (DOI: 10.1364/OL.36.004089; p. 4089) the fabrication of high-quality, large-area graphene SAs and their application for efficient mode-locking of a solid-state laser operating

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near 1.25 μm.

The researchers synthesized monolayer graphene by chemical vapor deposition of a mixture of methane and hydrogen gases on Cu foils. They then spin-coated a layer of polymethylmethacrylate (PMMA) on the grown monolayer graphene, and etched the underlying Cu foil before transferring the supported graphene layer onto a quartz substrate and removing the PMMA layer with acetone. The size of the graphene layer transferred onto the substrate was over 1.2 cm^2 × 1.2 cm^2. This method could be extended using a layer-by-layer stacking approach to fabricate a bilayer graphene saturated absorber.

The linear transmission of the monolayer graphene was measured to be 97.6% at around 1.25 μm. The researchers detected two different behaviors in the decay curves for the saturable absorption: an instantaneous response of 155 fs followed by a slower recovery time of 1.45 ps. They associated the fast decay with collision between charge carriers lying in the same band together with the emission of phonons, while the slow component was associated with relaxation of electrons and holes lying in different bands and the decrease of energy of long lifetime phonons (cooling of hot phonons). The researchers also estimated other important parameters for monolayer and bilayer graphene SAs necessary to generate ultrashort laser pulses (laser mode-locking). These included saturation fluences that determine the pulse energy required for extracting most of the energy stored in the gain medium of the laser; modulation depths that represent the maximum change in absorption which can be induced by the incident light at a particular wavelength; and nonsaturable losses that are the unwanted part of the losses.

The researchers considered that the values they measured for graphene were well suited to achieve stable mode-locking of bulk solid-state lasers. They demonstrated laser mode-locking with graphene SAs in a Cr:forsterite laser, delivering 94-fs pulses with a spectral bandwidth of 20 nm near 1.24 μm. These results yielded a time-bandwidth product of 0.37, which is close to the Fourier limit. The researchers achieved stable mode-locked operation for hours with an average output power up to 230 mW at 75 MHz, without the appearance of multiple pulsing and Q-switching instabilities, and without visible damage to the absorber.

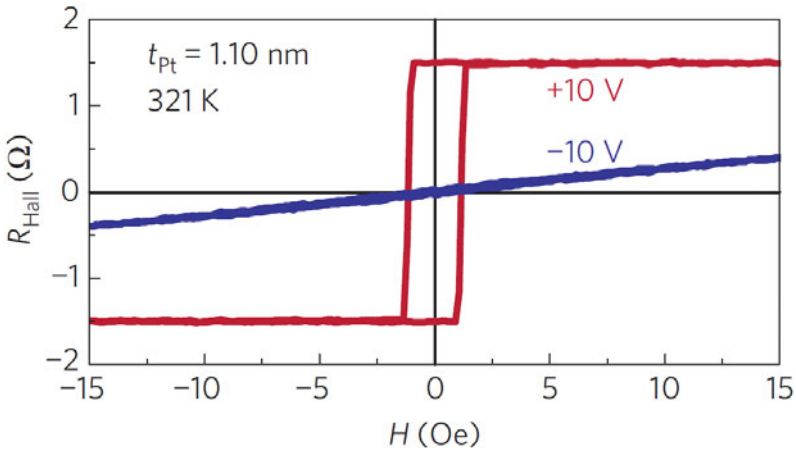
The researchers consider that graphene can be further applied for other bulk solid-state lasers in the wide spectral region due to its unique band structure and superior nonlinear optical properties with modulation depth being tailored through appropriate layer-by-layer stacking of monolayer graphene.

Joan J. Carvajal

Room-temperature electrical control of ferromagnetic ordering in cobalt demonstrated

Designers of magnetic memories have long sought to control the ferromagnetic ordering temperature with the application of an electric field. Such control would enable the design of more efficient, multifunctional memory technologies, but coupled magnetic and electrical order is only observed in a handful of compounds and typically only at very low temperatures. Now, D. Chiba of Kyoto University and the Japan Science and Technology Agency, S. Fukami of NEC Corporation, and their colleagues have demonstrated room-temperature control of the ferromagnetic Curie temperature of cobalt, as reported in the November issue of *Nature Materials* (DOI: 10.1038/nmat3130; p. 853).

The team applied a ±2 $MVcm^{-1}$ electric field across a MgO/Co/Pt/Ta heterostructure—with an ultrathin 0.4 nm Co layer—and measured the resulting magnetic hysteresis using the anomalous Hall effect. The researchers found that it is possible to tune the coercivity of the Co layer at ~20 K below the Curie temperature by applying a positive or negative bias. Closer to the Curie temperature (~320 K) they show that it is even possible to switch the material from a ferromagnetic response to a linear response with no coercivity by reversing the polarity of the applied bias. The researchers said that this



Magnetization curves under applied electrical bias for a Co/Pt multilayer. A switch from ferromagnetic (+10 V) to linear behavior (–10 V) is clearly visible. Reproduced with permission from *Nature Mater.* (DOI: 10.1038/nmat3130). © 2011 Macmillan Publishers Ltd.

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