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.

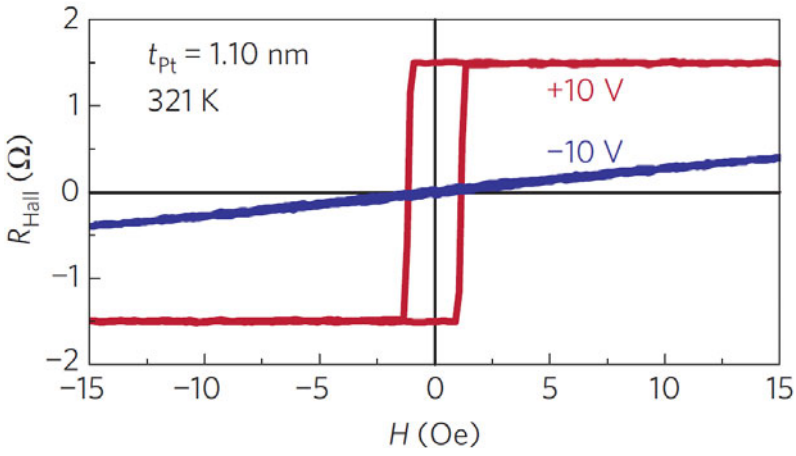
The researchers consider that graphene can be further applied for other bulk solid-state lasers in the wide spectral region due to its unique band structure and superior nonlinear optical properties with modulation depth being tailored through appropriate layer-by-layer stacking of monolayer graphene.

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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change in Curie temperature could be related to the local density of states on the surface of the Co layer. Assuming that the surface is perfectly (111)-oriented, first principles calculations have shown that a charge modulation equal to approximately ±0.012 electrons/Co atom can be induced by the applied gate voltage. However, these calculations also predict that the Curie temperature should decrease with increasing electron number, which is in disagreement with the observed results.

The research team therefore offers a number of alternative explanations for their experimental observations, including the possible intermixing of the Co and Pt layers, as well as the formation of a two-dimensional ferromagnet. The latter case is particularly significant, as it implies that the ferromagnetic ordering is tied to the dimensionality of the system.

These results may lead to a better understanding of the mechanisms of thin-film magnetism and could even lead to the design of an electrically switched "field effect" magnet.

Steven Spurgeon

News

Materials Researchers

John Cahn receives Kyoto Prize

Courtesy NIST

John Cahn, Emeritus Senior Fellow of the National Institute of Standards and Technology and affiliate professor at the University of Washington, received the 2011 Kyoto Prize in the category of advanced technology. He was cited for "outstanding contribution to alloy materials engineering by the establishment of spinodal decomposition theory." Cahn developed the theory of spinodal decomposition in alloy materials by incorporating the strain energy term into the free energy of the alloy system. It has made it possible to predict the optimal microstructures of alloy materials and to maximize their functions. The theory has led to the establishment of a design guideline for the development of alloy materials and contributed to the progress of both materials science and the materials industry. □

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