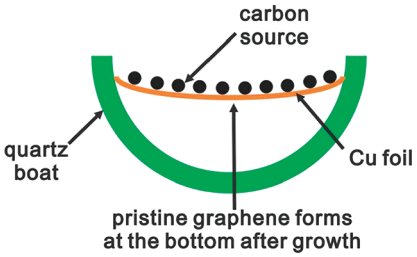
Graphene from Girl Scout Cookies?

■ Graphene, planar sheets of carbon a single atom thick, has been attracting increasing attention due to its extraordinary and potentially useful electrical, mechanical, and thermal properties. Several different methods have been developed to produce this unique material, such as exfoliation, chemical methods, and chemical vapor deposition. Though researchers are working to develop more creative and cost-effective ways to produce graphene, it still remains one of the most expensive materials on Earth because of the high cost of the necessary substrates, catalysts, and purified chemicals needed for current manufacturing methods.

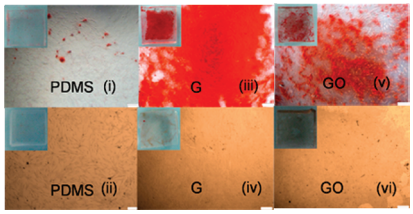
To make graphene a more feasible option for practical applications, Ruan *et al.* (DOI:10.1021/nn202625c) have developed a novel way to produce graphene using common, low-value carbon sources such as food, insects, and waste. Using this new technique, the researchers placed samples of their carbon sources—which included shortbread Girl Scout cookies, chocolate, grass, chips of polystyrene Petri dishes, legs from roaches, and dog feces—on top of Cu foil that rested on a boat-shaped quartz support. They then placed this apparatus inside a tube furnace to anneal with a constant flow of H_2 and Ar gas. Raman and UV−vis spectroscopy showed that high quality graphene, with few defects and high transparency, grew readily on the backside of the Cu foil. X-ray photoelectron spectroscopy confirmed the graphene's pristine nature, showing no heteroatoms in the monolayer samples. Selected area electron diffraction pattern analysis from transmission electron microscopy images showed a definitive hexagonal lattice structure. The authors suggest that these inexpensive or negatively valued materials could be a new solution for producing high-value graphene.



Throwing Stem Cells a Bone

■ Mesenchymal stem cells (MSCs), derived from adult bone marrow, could hold the key for numerous tissue engineering and regenerative medicine applications. These multipotent progenitors have the capacity to develop into various lineages, including adipocytes, osteoblasts, and chondrocytes, with the aid of manipulations such as mechanical interventions, substrate topography, and growth factors. Though researchers have successfully guided MSCs into desired lineages *in vitro* using various combinations of strategies, these methods are generally inefficient, requiring weeks for the preferred cell type to mature. Consequently, more reliable and efficient ways to produce desired lineages will be necessary before stem cell therapies can come to fruition.

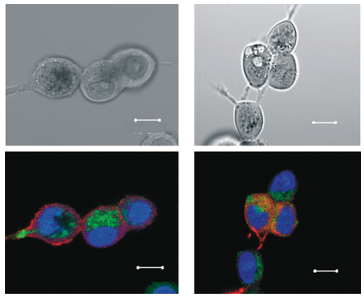
In a step toward this goal, Lee *et al.* (DOI: 10.1021/nn202190c) investigated graphene and graphene oxide (GO), two biocompatible platforms that have recently been shown to interact with stem cells. Though these substrates have been shown to promote adhesion, proliferation, and differentiation, the mechanism behind these effects was unknown. The researchers plated MSCs on graphene and GO films, comparing proliferation and differentiation to MSCs plated on polydimethylsiloxane (PDMS), a material previously shown to facilitate stem cell growth. Imaging tests showed that the MSCs proliferated more quickly and took on different morphology on the graphene and GO substrates than on PDMS. Using various growth factors, the researchers found that cells on graphene more readily differentiated into osteoblasts, and those on GO more readily differentiated into adipocytes. Further tests showed that the growth factors that promoted each lineage had a higher affinity for the responsible substrates. The authors suggest that these materials could eventually play a pivotal role in biomedical applications using stem cells.



Fighting Cancer with a Golden Touch

■ Polyvalent DNA-functionalized gold nanoparticles (DNA-AuNPs) have many properties that could be useful for drug-delivery applications. Attaching these modifiers to chemotherapeutics increases solubility in aqueous media, even high-salt buffers and serum. DNA-AuNPs also improve resistance to enzymatic degradation, provide contrast for visualization with MRI, and exhibit little cytotoxicity or innate immune response. Perhaps the most useful aspect of DNA-AuNPs is their ability to increase cellular uptake dramatically, previously demonstrated in numerous primary cell types and cell lines, including those with chemoresistance. These qualities could make DNA-AuNPs particularly promising for modifying paclitaxel, a drug used for ovarian, breast, and non-small-cell lung cancers whose potential is limited by its low solubility and eventual acquired chemoresistance in treated cells.

To see whether DNA-AuNPs might solve these problems for paclitaxel, Zhang *et al.*



(DOI: 10.1021/nn201446c) covalently attached paclitaxel molecules to gold nanoparticles using fluorescent antisense oligonucleotide linkers. Tests showed high loading of drug molecules per nanoparticle and more than 50-fold enhanced solubility in a salt-containing buffer compared to free paclitaxel. Fluorescent imaging demonstrated that the DNA-AuNP/paclitaxel combination was successfully internalized in human breast adenocarcinoma and human uterine sarcoma cell lines, the latter of which exhibits chemoresistance to free paclitaxel. Further tests showed that the tethered drug successfully induced DNA fragmentation and apoptosis in both cell lines, suggesting that DNA-AuNPs have the potential to overcome paclitaxel resistance. Even with a decreased dose, which could circumvent side effects, the modified drug had powerful cell-killing ability. The authors suggest that DNA-AuNPs could have significant potential in overcoming the limitations of some cancer chemotherapeutics.

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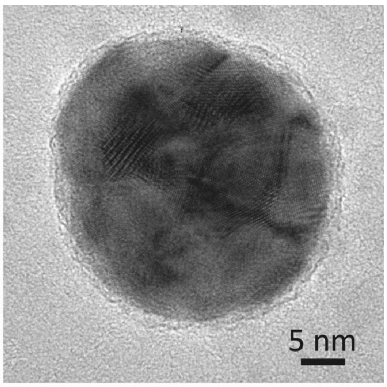
Touch of Ag@TiO_2 = Big Boost in Solar Cell Efficiency

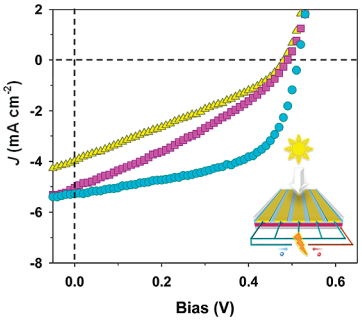
Dye-sensitized solar cells (DSSCs), which consist of a mesoporous thin film overlaid by a monolayer of charge-transfer dye molecules, have high power conversion efficiencies (PCE) that can reach up to 11%. To push this number even higher, researchers have sought strategies that improve light absorption and photogenerated carrier collection. Though increasing photoanode thickness readily increases light absorption, it has a detrimental effect on carrier collection. To solve this problem, some researchers have added metal nanoparticles to DSSCs to improve light absorption through localized surface plasmon (LSP) effects. However, this strategy typically results in recombination of photoelectrons, harming device performance and longevity.

Seeking to overcome these problems, Qi *et al.* (DOI: 10.1021/nn201808g) created nanoparticles composed of a small Ag core with a thin TiO_2 shell. The researchers hypothesized that the thin oxide shell surrounding the metal core would assist in generating a strong localized electric field enhanced by LSP, while preventing recombination and back-reaction from photocarriers and protecting the nanoparticles from corrosion. Tests using these Ag@TiO_2 nanoparticles in solution and in thin films containing ruthenium dye showed that light absorption was significantly enhanced through LSP effects. After incorporating the nanoparticles into DSSC using photoanodes 1.5 μm thick, results showed an increase to 4.4% PCE over 3.1% in devices without these nanoparticles. Similarly, the researchers attained efficiencies as high as 9% in plasmon-enhanced DSSCs with photoanodes as thick as 15 μm, a significant improvement over the 7.8% efficiency found in devices with 20 μm thick photoanodes. The authors suggest that these nanoparticles provide a viable way to increase efficiency in DSSCs through LSP effects.



A Color Filter of a Different Color

As worldwide energy demand continues to grow, researchers have sought more inventive ways to scavenge energy from environments. However, thus far little attention has been paid to the significant amount of light energy wasted in displays. For example, the vast majority of color displays use light filters that reflect only a tiny fraction of collected photons, resulting in the bulk of the light being absorbed and consequently never put to use.

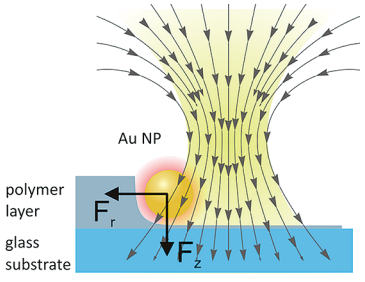


To take advantage of otherwise discarded photons, Park *et al.* (DOI: 10.1021/nn201767e) designed a dual-function color filter that not only displays the desired hue, but simultaneously collects absorbed light in an organic solar cell, converting it into useful electricity. The researchers constructed color filters with two polymer layers, serving as an anode and a bulk-heterojunction (BHJ) photoactive layer, sandwiched between a continuous thick Al film and an Au nanograting layer. This top Au layer was designed to serve a dual function, both modulating the incident light to generate different colors as well as serving as a semitransparent anode for the organic photovoltaic cell. Using BHJ photoactive layers of three different thicknesses, the researchers created devices that displayed cyan, magenta, and yellow colors. Tests showed that these devices had power conversion efficiencies ranging from 1.55% for cyan to 0.60% for yellow. These devices showed reliable performance even while bent, suggesting that they could be applied in large-area flexible displays. The authors suggest that these novel devices could serve as another way to take advantage of otherwise wasted energy.

The Power of a Single Particle

An increasing number of applications rely on the ability to pattern surfaces at the nanoscale with high precision, high throughput, and low cost. Researchers are currently using a variety of methods to meet these objectives, such as optical or mechanical methods. However, though the optical methods offer high resolution and the mechanical methods offer high reproducibility, no method thus far has been able to achieve both objectives.

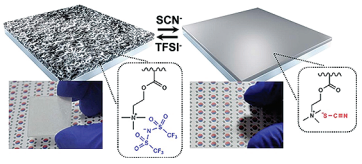
Seeking a new paradigm for nanopatterning, Fedoruk *et al.* (DOI: 10.1021/nn2023045) developed an optically driven nanoburner: a metal nanoparticle simultaneously heated and optically manipulated by a focused laser beam. The researchers tested this concept in proof-of-principle experiments using spherical gold nanoparticles of either 80 or 40 nm in diameter. After homogeneously suspending the nanoparticles in polymer solutions, then spin-coating these studded polymers as films onto glass slides, the team tested the effects of a focused laser beam on individual nanoparticles. Findings showed that the laser heated individual nanoparticles to several hundred degrees, resulting in rapid melting and thermal decomposition of the polymer. Manipulation by the laser beam left pronounced grooves in the film as nanoparticles moved laterally. Using nanoparticles of different diameters tuned the width of the tracks, with 40 nm nanoparticles creating grooves 49 nm wide, and 80 nm nanoparticles creating grooves 98 nm wide. Both types of nanoparticles successfully produced tracks that extended tens of micrometers in length. The authors suggest that their novel nanoburner combines the best of both optical and mechanical nanopatterning methods.



A Smart Window into the Future

As worldwide energy consumption continues to grow, the need to make the best use out of current energy resources has become more urgent. One potential area targeted for conservation is the energy used to heat and to cool buildings. Designing smart windows that control light propagation and absorption is a promising way to prevent unnecessary heating and cooling. Researchers have made several advances toward this target, including synthesizing windows that accomplish optical switching through aligning liquid crystals, dispersing suspended particles, or stimulating redox transduction of chromophores. However, these technologies have a number of limitations, including chemical instability that can undermine longevity, expense, and harsh processing conditions.

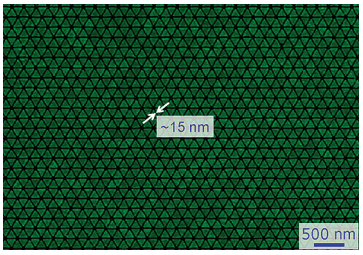
Seeking a new design paradigm, Lee *et al.* (DOI: 10.1021/nn202328y) developed a new type of smart window that relies on polyelectrolytes and the exchange of counterions to tune transparency. The researchers spray-casted polyelectrolytes with quaternary ammonium groups onto glass slides. When these optically clear slides were immersed into solutions containing lithium bis(trifluouromethane) sulfonimide salt, chloride ions in the polymer gels were gradually replaced with bis (trifluoromethane)-sulfonimide ($TFSI^-$) ions, leading to a complete loss of optical transparency. Immersing the same opaque slides in a sodium thiocyanate salt solution reversed this loss as $TFSI^-$ ions were replaced by thiocyanate (SCN^-) ions, returning transmittance to 90.9%. Various microscopy techniques suggest that $TFSI^-$ ions cause the polyelectrolytes to develop an opaque microporous structure, while the SCN^- ions lead to a smooth, transparent structure. The authors suggest that smart windows based on this polyelectrolyte design could eventually be applied in building windows, cars, or even roof tiles.



Mind the Ultrasmall Gap

Plasmon resonance is intensified in nanostructures separated by nanoscale gaps. Research has shown that as the size of the gap decreases, the gap's energy-focusing effect increases. This effect could be advantageous for a variety of applications in fields as varied as nonlinear optics, heat-assisted magnetic recording, and high-sensitivity chemical detection. Though much work has been done to understand this phenomenon, researchers still have no reliable way to fabricate structures with these nanogaps. Approaches tried thus far have drawbacks that prevent their use for real-world applications, such as limited yield or few possible varieties in patterns.

To overcome these obstacles, Duan *et al.* (DOI: 10.1021/nn2025868) developed a new, reliable way to synthesize metal films of



any pattern with ultrasmall gaps of less than 10 nm. The method relies on a high-resolution electron-beam lithography process using hydrogen silsequioxane (HSQ) as a negative-tone resist. The researchers spin-coated a thin HSQ layer onto a silicon substrate, then patterned the surface using an electron beam. After development to remove the unexposed HSQ, the surface was coated with Au. A lift-off process was then used to remove the columns of exposed HSQ, leaving behind Au patterns with gaps as small as 5 nm. Tests confirmed that the technique was versatile, producing patterns including hexagonal nanodisks, squares, and triangles. Optical extinction spectra showed that these patterns displayed tunable plasmonic activity and were useful for detecting molecules with surface-enhanced Raman scattering. The authors suggest this method could have wide-reaching effects beyond plasmonics, including creating nanochannels for nanofluidics or gaps in metal for molecular electronics.

Shining a New Light on Laser Cooling

The intriguing phenomenon of laser cooling, in which counter-propagating laser beams retard atomic motion and thereby lower temperature, has recently become an intense focus of atomic physics research. Laser cooling has allowed researchers to investigate a variety of questions, including those concerning many-body physics with ultracold gases and Bose–Einstein condensation. Researchers are currently using this tool to probe quantum phenomena of complex particles and matter at the macroscale. Yet, even with these advances, researchers still struggle to apply laser cooling to any matter beyond alkali-like atomic species.

Seeking to expand laser cooling beyond current limitations, Ridolfo *et al.* (DOI: 10.1021/nn2022364) used a series of calculations and simulations to show how systems exhibiting a Fano line shape, such as hybrid nanostructures incorporating a metal nanoparticle and a quantum dot, can be laser-cooled below the conventional Doppler cooling limit using a typical Doppler cooling scheme. The researchers found that variations in radiation pressure cross-section around the Fano resonance can lead to optical cooling through a velocity dependent scattering force. Depending on the Fano factor associated with the resonance, this cooling can occur for either red or blue detuning of the laser frequency. Applying these findings to model systems containing a quantum dot coupled to either a single silver nanoparticle or a silver nanoparticle dimer, the researchers estimated that laser cooling can be accomplished down to the milli-Kelvin range with cooling times of a few seconds. The authors speculate that these findings can be applied to any large system that includes a quantum emitter with a Fano line shape.