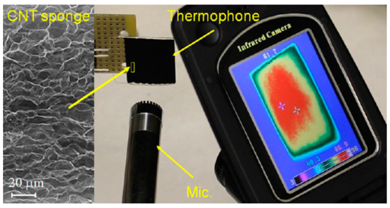
Creating That Hot New Sound

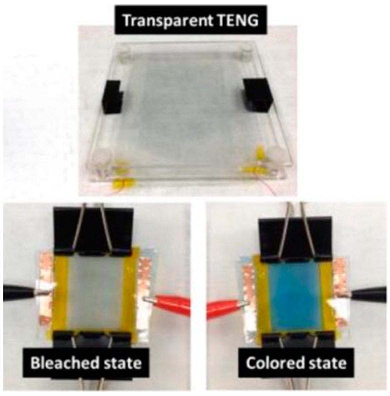
Thermophones are electroacoustic transducers that generate precisely controlled sound waves using heated air from conductors whose temperature varies with the amount of current that passes through them. Recently, researchers have explored the use of various nanostructured materials in such conductors, including carbon nanotubes (CNTs), graphene, PEDOT:PSS and indium–tin oxide (ITO) films, porous silicon, and metal nanowire arrays. Of these, CNT aerogels have shown the most efficient heat exchange with the surrounding medium. This material has been shown to be a suitable thermoacoustic source in environments that include harsh gases and under water and can generate smooth spectra sound over a frequency range from 1 to 10^5 Hz. Despite these attractive qualities, freestanding CNT aerogel sheets have limited accessibility, hampering the advancement of this field.

In a new study, Aliev *et al.* (DOI: 10.1021/nn507117a) investigate potential alternative heat source materials that could provide additional functionality compared to CNT aerogel sheets, are environmentally friendly, and can be made with cost-effective production techniques. These materials include freestanding chemical vapor deposition-grown multiwalled nanotube (MWNT) forests, highly elastomeric graphene sponges, sheets of gold-coated poly(acrylonitrile) nanofibers (PANs), and ITO-coated PAN sheets. Various analyses, including the spectral and applied AC power responses of each material and the effects of heat accumulation on sound generation, suggest that three-dimensional sponge-type nanostructures, such as the freestanding MWNT forests and graphene sponges, had better thermoacoustic performance compared to their planar-structured counterparts. The authors suggest that such materials might be useful for next-generation flexible, lightweight loudspeakers and sonar projectors, noise cancellation and sound therapy devices, and acoustic imaging of biosystems.



Bright Future for Smart Windows

Electrochromic devices (ECDs) can reversibly change their optical properties through electrochemical redox reactions corresponding to an external electric field, a useful quality for applications including displays, switchable mirrors, and electronic papers. In addition, ECDs with nonvolatile memory may also be candidates for energy-saving "smart" windows that can switch between a clear and tinted state, since they can maintain the initiated coloring with no additional power needed. Ideally, such smart windows would be self-powered, a feat that some researchers have suggested could be realized by integrating them with photovoltaic cells. However, this solution would come with unavoidable drawbacks, including having to sacrifice some part of the ECD's surface with solar cells.

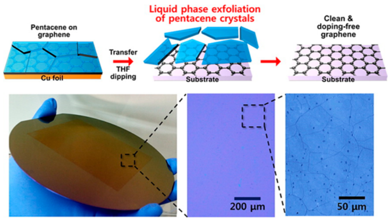


In a new study, Yeh *et al.* (DOI: 10.1021/acsnano.5b00706) show that ECD-driven smart windows could be integrated instead with transparent triboelectric generators (TENGs) that convert mechanical energy from wind and rain into electricity, increasing their utility for windows on buildings or cars. The researchers created their device by layering a single-electrode TENG for scavenging raindrop kinetic energy on top of a contact-mode TENG that can harvest wind energy. Both TENGs were then stacked on top of an ECD composed of Prussian blue nanoparticles as the electrochromic material and zinc hexacyanoferrage nanocubes as the ion storage layer. Tests showed that the TENGs' output current of up to 45 μA, corresponding to an effective power density of 130 mW/m^2, could drive transmittance changes up to 32.4% in the device with no additional power input. The authors suggest that such TENG-integrated ECDs could also lead to applications including self-powered flexible displays and wearable electronics.

A Tidy Transfer for Graphene Grown by Chemical Vapor Deposition

Researchers continue to be intrigued by graphene's extraordinary thermal, mechanical, optical, and electrical properties. Many of these promising qualities were first investigated in mechanically exfoliated graphene derived from natural graphite. Although this method can produce pristine samples, it can be time-consuming, has low yield, and limits samples to a few tens of micrometers. In contrast, chemical vapor deposition (CVD) can produce high-quality, large-area graphene quickly. However, it requires the resulting product to be transferred from the catalytic metal substrate where graphene is grown to where it will be used, a process that requires a supporting layer. Although poly(methyl methacrylate) (PMMA) has long served as the supporting layer of choice, it can leave leftover residue after removal, which causes unintentional graphene doping effects.

Seeking a cleaner way to transfer CVD-grown graphene, Kim *et al.* (DOI: 10.1021/nn5066556) report a method that uses a pentacene ($C_{22}H_{14}$) thin film supporting layer. Although tests showed that thermal removal left behind a pentacene residue on the graphene surface that could alter its properties, chemical desorption with tetrahydrofuran produced undoped graphene without a pentacene residue, a finding confirmed with numerous methods including atomic force microscopy images, Raman spectra, and scanning Kelvin probe force microscopy images. Further, the researchers show the utility of this clean transfer method by using the resulting graphene in field-effect transistors, which had high field-effect mobilities with minimal shifts in the Dirac point voltage. The authors suggest that this method could offer clean, reproducible, doping-free transfer of high-quality graphene.



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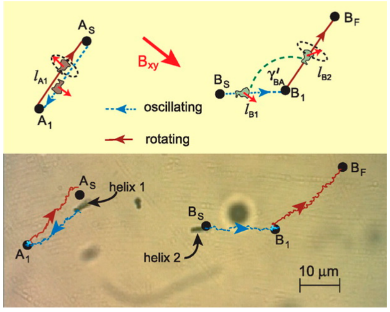
As the Magnetic Nanomotor Turns

Researchers continue to seek new ways to manipulate nanoscale objects in fluidic media precisely and remotely without the need for fuel. Thus, far, the most popular way of manipulating very small objects in fluidic environments is with optical tweezers, which can maneuver and independently position several objects at once. However, this tool requires intense laser beams and close proximity to a focusing lens, rendering it incompatible with living systems, and can only manipulate dielectric objects larger than a few hundred nanometers. Magnetic fields do not hold these limitations, however, and have successfully been used to manipulate various nanostructures; strategies demonstrated thus far, though, can only move collections of objects in the same direction.

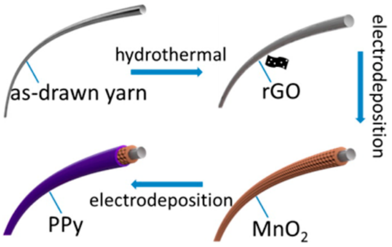
In a new study, Mandal *et al.* (DOI: 10.1021/acsnano.5b01518) report a new method relying on magnetic fields that can independently position several nanoscale objects at once. This novel system uses oscillating magnetic fields to induce corkscrew-shaped nanoparticles topped with polystyrene beads to rock from side to side, resulting in a translational motion due to the particles' asymmetric shape. The nanohelices, coated with cobalt, were distributed in deionized water and subjected to a DC magnetic field, which aligned their magnetic moments, as well as an oscillating field perpendicular to this plane to provide kinetic energy. By varying the magnetic field configurations and actuation time scales, the researchers were able to maneuver multiple nanostructures in different directions and position them at arbitrary locations. The authors suggest that this method could be useful for microfluidic applications that require precise placement of individual components.



Not Your Grandmother's Yarn

Wearable energy storage devices that might power personalized electronics are a growing area of research. However, energy-storing yarns that can act as active supercapacitor electrodes but are also strong enough to withstand weaving and knitting while maintaining a soft, wearable feel remain elusive. Although carbon materials have been successfully woven into fibers, these materials cannot withstand the tensile stress that weaving and knitting machines pose and cannot provide the long-distance electron transport necessary for yarns, a feat that only metallic materials can achieve.

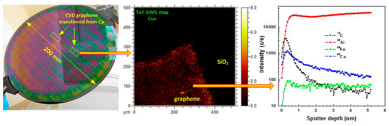
In a new study, Huang *et al.* (DOI: 10.1021/acsnano.5b00860) developed weavable and knittable highly conductive and energy-storing yarns from high-temperature-spun stainless steel 316L thin fibers. These fibers were made into yarns by twist-bundle-drawing, a technique similar to one widely used in the yarn fabrication industry, then coated with reduced graphene oxide, MnO_2, and polypyrrole (PPy) to make them into capacitors. These yarns demonstrated low electric resistivity and were strong enough to withstand commercial knitting and weaving as well as hand knitting, producing a strong and soft cloth. In a three-electrode cell with liquid Na_2SO_4, the yarns demonstrated very fast voltage/current change rates and high capacitances. Coating the yarns with solid poly(vinyl alcohol)/H_3PO_4, the researchers created supercapacitors that outperformed most previously reported yarn-based materials after thousands of charge/discharge cycles at high current densities. These characteristics remained after bending, knotting, and twisting and even making the yarns into woven clothes for a teddy bear and a hand-knitted wristband. The authors suggest that these yarns could be adopted by the modern textile industry for designing wearable electronics.



Chemical Vapor Deposited Graphene Harbors Bad Leftovers

Graphene's extraordinary properties are expected to boost performance of next-generation high-frequency electronic and photonic devices. Thus, far, chemical vapor deposition (CVD) has been the most promising method for fabricating enough large-area, high-quality graphene for commercial applications. However, to serve these purposes, CVD-grown graphene will probably require co-integration with existing semiconductor device manufacturing platforms, including strict purity standards. By nature of this synthesis method, CVD requires graphene to be grown on a metal catalyst surface, with transfer to the desired substrate often facilitated with a support polymer. While much research has been dedicated to studying residual polymer impurities from transfer, significantly less has focused on potential submonolayer metallic contamination of graphene from the metal catalyst surface necessary for growth. Such contamination, even at very low concentrations, can pose a serious threat to Si devices.

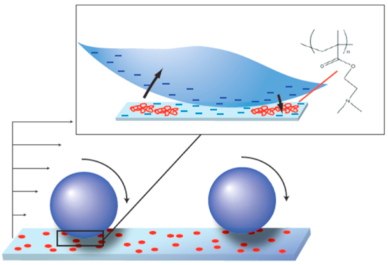
To investigate whether this phenomenon exists, Lupina *et al.* (DOI: 10.1021/acsnano.5b01261) used time-of-flight secondary ion mass spectrometry and total reflection X-ray fluorescence measurements, sensitive techniques capable of detecting even very low concentrations of metal atoms. Applying these methods to graphene transferred from Cu substrates in various ways, using different polymer support films and strategies using different Cu etchants and electrochemical delamination, the authors find that most methods lead to contamination with residual Cu or Fe with concentrations exceeding 10^{13} atoms/cm^2. Annealing experiments show that these impurities are partly mobile with thermal treatments, but some Cu atoms appear to be trapped within the graphene sheets. The authors suggest that significantly more attention should be paid to developing metal catalyst-free paths to synthesize graphene directly on insulators and semiconductors.



Keeping Microparticles Rolling Along

Functionalizing the surface of a microfluidic channel to facilitate the rolling of particles or cells can be a powerful tool for useful applications including selective capture, sorting, and detection. Because rolling involves such intimate contact with the channel walls and contact times are well-defined, it could also offer control over chemical reactions and signaling. Researchers have gained some understanding of how to encourage rolling from studying how cells move in the vasculature. Some studies have successfully mimicked these actions by functionalizing microfluidic channel surfaces with cell adhesion molecules such as selectins or antibodies against cell markers. However, designing completely synthetic systems that aid rolling is a field still in its infancy.

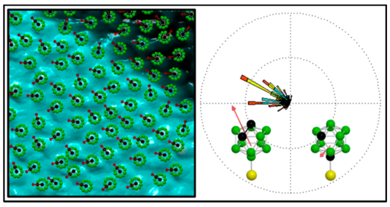
In a new study, Kalasin and Santore (DOI: 10.1021/nn505322m) take steps toward this goal by engineering surfaces that encourage microparticle rolling. After lining silica surfaces with various densities of nanopatches composed of single, flattened coils of the cationic polymer poly(dimethylaminoethyl methacrylate) (pDMAEMA), the researchers tested the effect on silica microspheres flowed through the channels. Experiments showed that whether particles rolled on the surface, arrested, or flowed freely depended on a combination of a variety of factors, including spatial distribution of the pDMAEMA nanopatches, the rate of fluid flow, and particle size. These variables all depended on each other, with no "one size fits all" rule able to ensure particle rolling. The authors note that this study adds insight into particle rolling that could eventually facilitate the creation of regenerative surfaces, improved surface polishing and cleaning methods, and new drug delivery methods, as well as improve understanding of particulate contamination in soils.



Dipole Coverage without Defects

For decades, researchers have studied self-assembled monolayers as a means to construct well-defined monomolecular films, both for fundamental study and for applications ranging from nanotechnology to the life sciences. Carboranethiols are one type of self-assembling molecule, forming identical monolayer lattices on Au$\{111\}$ substrates regardless of isomer. Consequently, these bound, upright, rigid, three-dimensional carbon–boron–hydrogen cage compounds are good systems to study the effects of intermolecular interactions without varying monolayer structure.

In a new study, Thomas *et al.* (DOI: 10.1021/acsnano.5b01329) use multimodal scanning tunneling microscopy to study the intermolecular interactions that lead to this ordered assembly. Measuring both topographic and local barrier height modalities simultaneously, the researchers compare and contrast monolayers of *o*-9-carboranethiolate and *m*-1-carboranethiolate, comparing local molecular dipole orientations across monatomic substrate steps. Their results revealed dipole alignment for both carboranethiol monolayers that extends across substrate step edges and molecular domain boundaries. Simulations suggest that these findings can be attributed to favorable intermolecular dipole–dipole interactions that cause these molecules' dipoles to align spontaneously along a common direction when the temperature is sufficiently low. This favorable alignment energy leads to stable, locally ordered regions of molecular dipoles. The authors suggest that better understanding of these systems could lead to advances in molecular machines, dipolar rotors, and functionalized coatings for device frameworks.



Pumping It Up: WS_2, MoS_2, and MoS_2/Graphene Aerogels

Graphene and graphene analogues, such as layered dichalcogenides, have inspired researchers with their potential for a wide range of applications such as catalysis, energy storage, lubricants, sensors, and electronics. Graphene, which was once limited to two-dimensional sheets, has recently been manipulated into various three-dimensional (3D) forms. However, reports on graphene analogues have typically focused on nanoparticles and powders, and few studies have demonstrated aerogels or monolithic assemblies of these materials.

In a new study, Worsley *et al.* (DOI: 10.1021/acsnano.5b00087) change this paradigm by describing the synthesis of MoS_2 and WS_2 aerogels with densities far below the theoretical densities for these materials, as well as a hybrid MoS_2/graphene aerogel with high specific surface area and electrical conductivity. The researchers crafted the ultra-low-density MoS_2 and WS_2 aerogels using freeze-dried precursor solutions of ammonium thiomolybdate and ammonium thiotungstate. They annealed these solutions in hydrogen, creating the aerogels. Despite having densities as low as 0.4% and 0.5% of the full density of MoS_2 and WS_2, respectively, the aerogels had Young's moduli of about 35 MPa and plasticities similar to memory-shape foam. Various characterization methods showed that these aerogels were composed of sheets that were more locally aligned in the WS_2 aerogels than in the MoS_2 ones. Expanding on these findings, the researchers used a similar method to create a graphene aerogel incorporated with a homogeneous distribution of MoS_2. Tests showed that this material was an effective conductor and an efficient H_2 evolution reaction catalyst. The authors suggest that their synthesis method could lead to a new class of ultralow density materials for catalysis and energy storage.