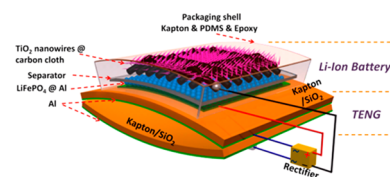


Operating in "Sustainable Mode"

Recent, burgeoning growth in small portable electronics has spurred the need for power sources that are also portable, lightweight, and possibly sustainable. For these new power sources, researchers have focused on optimizing energy generation and storage, typically sequestering these two qualities into two separated units. Although energy generators that harvest energy from the environment offer an excellent and sustainable way to self-power devices, their outputs usually have uncontrollable fluctuations based on changes in ambient conditions. Energy storage devices, such as conventional batteries, offer the advantage of providing a constant voltage. However, their lifetime is limited, necessitating charging or replacement at regular intervals.

To get around both these disadvantages, Wang *et al.* (DOI: 10.1021/nn4050408) developed a device that combines a battery that charges with motion, allowing sustainable energy harvesting while delivering a constant, reliable current. Their device is based on a flexible lithium ion battery (LIB) mounted on top and connected to an arch-shaped triboelectric nanogenerator (TENG). With a layer of Al film on one side of the TENG and a nanorod-roughened Kapton film on the other, contacting these layers through motion produced an alternating current. This current charged the LIB, allowing it to deliver a constant direct current. The researchers demonstrated that this direct current could be used to power a ZnO-nanowire-based UV sensor, both while the battery was discharging to save energy in

"active" mode and while the TENG was continuously charging the battery in "sustainable" mode. The authors suggest that this new sustainable flexible power unit could have numerous applications in future battery technologies.



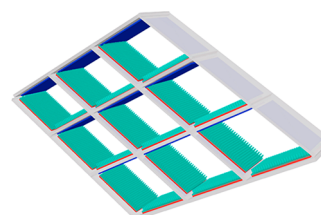
Harvesting Energy a Walk in the Park

Mobile electronic devices are all powered by batteries, which have limited energy storage, add considerable weight, and have a limited lifetime, requiring disposal when they run out of charge. To avoid these drawbacks, researchers are investigating several different ways to scavenge the mechanical energy typically wasted from human motion. One promising way to harvest ambient environmental energy is through triboelectric nanogenerators (TENGs). Although TENGs have promise to be a robust and cost-effective way to translate mechanical energy into power, a key challenge to their use is a relatively low output current.

To overcome this issue, Yang *et al.* (DOI: 10.1021/nn405175z) developed TENGs with

multiple cells that work in parallel, greatly improving the total current output. In each cell, the researchers coated one side of a polyethylene terephthalate substrate with an Al thin film with nanoporous modification that played a dual role as both contact electrode and contact surface. On the other side was a layer of polytetrafluoroethylene film with nanowire arrays, with a copper thin film as a back electrode. With motion, the two surfaces contact each other, producing an alternating current. The researchers show that this new TENG can produce an open-circuit voltage up to 428 V and a short-circuit current of 1.395 mA with the peak power density of 30.7 W/m². To demonstrate its utility, they fashioned their novel TENG

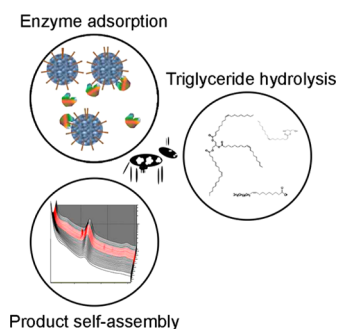
into a backpack, showing that vibrations from normal walking could power 40 light-emitting diodes simultaneously. The authors suggest that this TENG could offer a mobile power source for field engineers, explorers, and disaster-relief workers.



Got Highly Organized Nanostructures?

Milk, the first food of all mammals, is a natural emulsion of proteins, vitamins, salts, and milk fat primarily composed of triglycerides. For milk to be digested, these dietary fats must be hydrolyzed by lipases into fatty acids and monoglycerides that are absorbed by enterocytes. Although researchers have known that monoglycerides and fatty acids can self-assemble into a wide variety of nanostructures when combined in various ratios in water, it has not been known whether these nanostructures form during normal digestion.

To address this question, Salentinig *et al.* (DOI: 10.1021/nn405123j) used time-resolved small-angle X-ray scattering and cryogenic transmission electron microscopy to monitor *in vitro* digestion of milk using enzymes present during physiological conditions in the presence and absence of bile salts. After adding pancreatin to fresh milk,



the researchers found that nanostructures formed hierarchically over time during digestion, gradually proceeding toward more hydrophilic and highly organized geometric structures with substantial surface area. The absence of bile salts promoted the formation of nonlamellar liquid crystalline structures with high internal surface area, such

as cubic phase, which may be important in facilitating digestion of lipids in bile-compromised individuals by allowing more access for lipolytic enzymes. Because bile salts play important roles in solubilizing and transporting digestion products away from the digesting oil droplet to the enterocytes for absorption, people who do not produce bile would be expected to have severely compromised milk digestion. However, the authors assert that their findings suggest one way to explain how these individuals can still effectively digest dairy foods.

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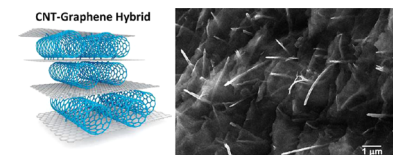
Graphene and Carbon Nanotube Films: The Best of Both Worlds

Some researchers have conjectured that a hybrid film of graphene or graphene oxide (GO) and carbon nanotubes (CNTs) could have advantages beyond the properties of both materials individually. If the CNTs intercalate between individual graphene or GO layers, the resulting films could display high surface areas, mechanical robustness, and high electrical and thermal conduction. To realize these hybrid films, researchers must be able both to produce large area hybrid films without supports or binders and to synthesize homogeneous distributions of CNTs that intercalate between individual graphene or GO sheets. Although some efforts thus far have achieved moderate success with overcoming these challenges,

they have proven both time-consuming and difficult to scale up.

In a new study, Tristán-López *et al.* (DOI: 10.1021/nn404022m) use a novel method to self-assemble films consisting of individual multiwalled carbon nanotubes (MWNTs), nitrogen-doped MWNTs, or boron-doped MWNTs intercalated between sheets of GO. The researchers functionalized CNTs with cationic polyelectrolytes that both prevented CNT aggregation and bound them to GO, which behaves like an anionic polyelectrolyte. When the solvent was removed, the GO sheets formed stacks, sandwiching the CNTs between into films that were later thermally reduced. The resulting films showed unprecedented characteristics,

such as high mechanical stability and low electrical resistivity. Tests showed that they could be used as efficient electron field emission sources. The authors speculate that the novel films could find applications as scaffolds for tissue regeneration, thermal and conducting papers, and laminate composites with epoxy resins.

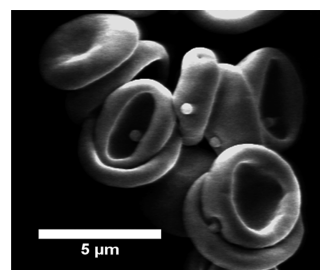


Nanoparticles Hitch a Ride on Red Blood Cells

Numerous studies have shown that encapsulating drugs in nanoparticles can offer distinct advantages over administering the free drug, including better targeting and sustained release. However, this application is limited by nanoparticles' rapid clearance by the mononuclear phagocytic system located primarily in the liver and spleen, which limit the ability for therapeutic doses to reach their intended destinations. To protect nanoparticles from this fate, researchers have used several different strategies, primarily coating nanoparticles with hydrophilic polymers such as polyethylene glycol (PEG), which helps them avoid uptake by macrophages. However, PEG-modified nanoparticles can trigger immune response, making them unsuitable for repeated administration.

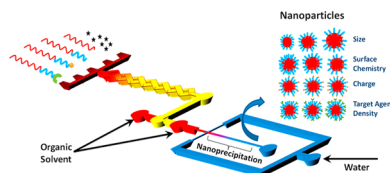
Seeking a way around this conundrum, Anselmo *et al.* (DOI: 10.1021/nn404853z) tethered nanoparticles to red blood cells, allowing the nanoparticles to hitchhike to the lungs in mouse models while avoiding uptake by the liver and spleen. The researchers used electrostatic and hydrophobic interactions to attach spherical polystyrene nanoparticles to red blood cells. The tiny hitchhikers did not harm the cells, and the attachment was reversible, merely leaving indentations on the cells' surfaces once they were removed. Tests showed that attaching nanoparticles to red blood cells significantly increased time in blood circulation, allowing the nanoparticles to accumulate in the lungs, where they were likely sheared from the red blood cells through the force of circulation. Although accumulation in the lungs dropped over 24 h, the researchers

were able to extend this time through adding the anti-ICAM-1 antibody to nanoparticle surfaces. The researchers suggest that cellular hitchhiking could offer a new way to improve the pharmacokinetics and delivery of nanoparticles while avoiding immune clearance.



Microfluidics for Fighting Cancer

Researchers are increasingly investigating nanoparticles as potential drug delivery vehicles. With the ability to encapsulate thousands of pharmaceutical molecules per nanoparticle and target delivery to destinations throughout the body, nanoparticles could theoretically be used to treat a variety of health problems including cancer, inflammation, and infectious diseases. However, few formulations have reached clinical translation. Optimizing these materials with biophysicochemical parameters particular to treating each disease type while simultaneously offering molecular targeting, immune evasion, and controlled drug release remains a challenge. In addition, few technologies exist that are capable of synthesizing nanoparticles with a wide range of properties in a reproducible manner.



Seeking a solution, Valencia *et al.* (DOI: 10.1021/nn403370e) developed a microfluidic platform that rapidly synthesizes different nanoparticle formulations in highly reproducible batches, making it possible to optimize parameters for various disease-treating needs in a scalable fashion. Their device consists of a multi-inlet mixing unit and synthesis unit that operate in continuous flow mode. The mixing unit combines several different nanoparticle precursors

dissolved in organic solvent through different inlets, giving the capacity to blend these precursors at different ratios. In the synthesis unit, the resulting precursor mixtures are rapidly mixed with water, resulting in the self-assembly of nanoparticles through nanoprecipitation. Using this method, the researchers were able to synthesize 45 different nanoparticle formulations of different sizes and surface compositions quickly. Experiments *in vitro* and *in vivo* identified the formulations most likely to evade macrophage uptake, to have the longest blood half-life, and to target prostate cancer cells. The authors suggest that this new approach could potentially speed the discovery and clinical translation of nanoparticle therapeutics.

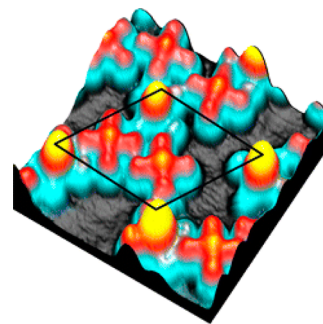
Hexagonal BN on Ir(111): That Is a Moiré

■ Ultrathin layers of hexagonal boron nitride (h-BN) laid on top of a metal support form a moiré structure caused by the lattice mismatch between the two materials. This “nanomesh” consists of a series of strongly interacting pores separated by weakly interacting wires. Recent research has found that these structures typically exhibit strong moiré corrugation and work function modulation. The combination of these two attributes allows molecules to be confined spatially to the pores of the moiré superstructure, suggesting that h-BN monolayers can act as a guide for growing nanostructures. However, researchers know little about the degree of electronic coupling of molecular states and the underlying metal substrate.

To learn more, Schulz *et al.* (DOI: 10.1021/nn404840h) used scanning tunneling

microscopy and scanning tunneling spectroscopy to investigate organic molecules on a nanomesh of h-BN on Ir(111). After evaporating cobalt phthalocyanine (CoPC) onto this surface, the researchers found that these molecules selectively adsorb only onto the moiré superstructure's pores at low coverages. At higher coverages, CoPC coverage extended onto the moiré wires, forming locally square packed regions. Using differential conductance spectroscopy, the researchers found molecular resonances with narrow line widths, modulated by the adsorption site. Further investigation suggests that this arrangement modifies the CoPC charge state, as well, leading to local and periodic doping. Even higher coverage led the additional molecules to settle preferentially into the moiré pores, forming CoPC dimers. The authors suggest that

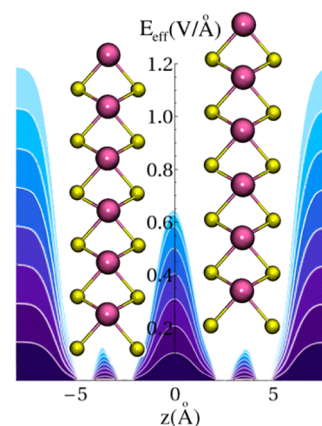
these findings demonstrate that monolayer h-BN can act as an ultrathin insulating layer for adsorbed molecules as well as a template for nanoscale self-assembly.



Electrically Tuning the Dielectric Constant

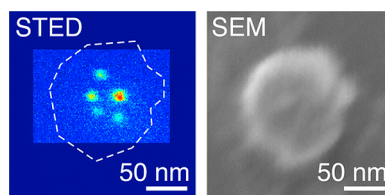
■ MoS₂ has an attractive set of features that could make this material play a starring role in a new class of nanodevices. Its sizable band gap overcomes the limitations of graphene's zero band gap, opening the possibility for developing field-effect transistors with lower power dissipation than conventional transistors, optoelectronics devices in flexible electronics, and thin-film solar cells that absorb visible light. MoS₂'s thickness heavily influences these properties, affecting charge distribution as well as the electronic structure through the band gap and electric field screening that depends on the dielectric constant. Though determining the dielectric constant's intrinsic value has important implications for improving the performance of MoS₂-based devices, different experiments have found a large range of values.

In a new study, Santos and Kaxiras (DOI: 10.1021/nn403738b) investigate the effects of an electrical field on MoS₂'s dielectric constant. Using first-principles electronic structure calculations, the researchers found that, at low external fields, the dielectric constant assumes a nearly constant value of about 4. However, this value increases linearly at higher fields depending on the layered material's thickness, with the dielectric constant of thicker structures being more susceptible to electric fields. Beyond a critical value, the electrical field can weaken the bonds between MoS₂ layers, allowing them to become easily separated. The authors suggest that these insights both open the possibility of designing new devices with a tunable response as well as a novel method for exfoliating MoS₂.



Going STEDy with Nanodiamonds

■ Nitrogen vacancy (NV) centers in nanodiamonds, a point defect that consists of a nitrogen atom substituting for a carbon atom in the lattice and an adjacent vacancy, are promising candidates for bioimaging and sensing. NV centers have stable photoluminescence, and the negatively charged NV center enables optically detected magnetic resonance measurements of electron spin. They are also sensitive to magnetic and electrical fields, as well as temperature, giving them potential for a wide range of bioapplications. Consequently, mapping NV centers within individual nanodiamonds and gathering spin information on individual NVs have become important goals. Though stimulated emission depletion



(STED) has proven useful for imaging NV centers in bulk diamond, several studies have predicted that this method would fail for nanodiamonds.

Contrary to these expectations, Arroyo-Camejo *et al.* (DOI: 10.1021/nn404421b) find in a new study that STED microscopy can resolve NV centers in nanodiamonds at high resolution. Applying this method to

nanodiamonds of different shapes ranging in size from 40 to 250 nm, the researchers identified individual NV centers at a resolution of about 10 nm. In single nanodiamonds with up to 20 different NV centers, STED microscopy could discern individual NV centers down to distances of 15 nm. Extended numerical simulations theoretically confirmed these experimental findings. The authors suggest that even though nanodiamonds' size and shape affected the NV distribution in the resulting image and the NV centers' positions can affect the effective resolution, the findings show that STED microscopy is as useful for imaging NV centers in nanodiamonds as in bulk diamonds.