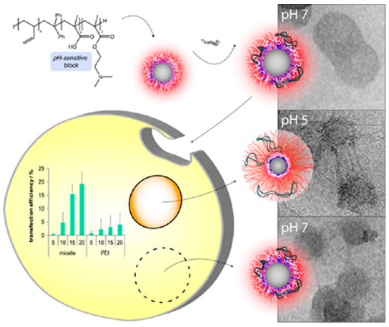
Borrowing from Viruses to Transfect Cells

Researchers from diverse fields have spent decades searching for ways to deliver genetic material into eukaryotic cells effectively with minimal cytotoxicity. Several nonviral transfection agents hold promise, with poly(ethylene imine) (PEI) being held as the gold standard for *in vitro* applications among polymeric materials. However, although PEI can induce high transfection rates, it can also be toxic to cells. Coating PEI particles with poly(ethylene glycol) can make them more biocompatible but reduces transfection efficiency. In addition, most nonviral transfection agents fail to work on cells in suspension. This deficiency hinders research into a variety of diseases, including various immune defects and cancers.

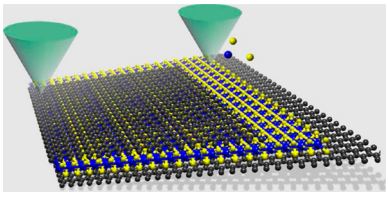
Seeking a better transfection agent, Rinkenauer *et al.* (DOI: 10.1021/nn402072d) developed multicompartment micelles from stimuli-responsive triblock terpolymers, polybutadiene-*block*-poly(methacrylic acid)-*block*-poly(2-(dimethylamino)ethyl methacrylate) (BMAAD). These micelles have a patchy shell, with amphiphilic and cationic regions—a surface reminiscent of some viruses. They can also undergo pH-dependent changes in charge stoichiometry. Tests showed that the novel micelles complexed with plasmid DNA transfected adhered cells better than PEI, even under serum-reduced conditions. In suspended leukemia cells, the BMAAD micelles had a transfection efficiency 5-fold higher than PEI particles. Even at high concentrations, the new micelles showed no detectable cytotoxicity. Further investigation showed that the micelles' high sedimentation rate and patchy surfaces likely play a role in these successes. The authors suggest that this novel system, borrowing part of its strategy from viruses, could represent a powerful new method for transfection.



Saving MoS_2 with a Sandwich

Much like graphene, other two-dimensional (2D) materials, such as transition metal dichalcogenides, have attracted increasing attention due to their unique physical, chemical, and structural properties and potential for applications. To understand these materials' crystallography, reconstruction, stacking order, and other qualities, finding ways to image and to identify every atom in their structures is essential. Most studies toward that end have used transmission electron microscopy and scanning transmission electron microscopy. However, the electron beam in both of these imaging modalities can cause significant radiation damage. This includes "knock-on" damage, in which atoms are displaced from their original positions in the lattice, as well as ionization damage. Finding ways to protect 2D materials from damage during imaging is crucial since it can significantly alter their physical properties.

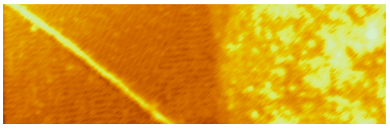
In a new study, Zan *et al.* (DOI: 10.1021/nn4044035) develop a solution for protecting MoS_2 by encapsulating it in a graphene "sandwich", which resists radiation damage through minimization of charging effects and vibrations. Experiments with bare graphene showed that even low beam energies and near-ultrahigh vacuum conditions could not stop the rapid creation of large defects. Applying MoS_2 to a graphene substrate mitigated the damage somewhat but could not prevent it. In contrast, enclosing MoS_2 with a layer of graphene on each side effectively blocked radiation damage, allowing for long scans at high beam energies to obtain accurate chemical information at the atomic scale with high signal-to-noise ratios. The authors suggest that this technique could be used to permit detailed studies of other beam-sensitive materials, including nanomaterials and biomaterials.



Graphene Earns Its Stripes

Interest in the two-dimensional (2D) carbon sheets known as graphene continues to be strong due to this material's unique and potentially useful electrical, mechanical, optical, and thermal properties. While a bulk three-dimensional crystal exposes only surface atoms to the environment, 2D materials such as graphene have all atoms exposed, leaving them accessible to unwanted adsorbates. Because graphene is often prepared under ambient conditions, this material in particular is exposed to the water vapor, oxygen, nitrogen, carbon dioxide, and other constituents of laboratory air. These adsorbates can change graphene's properties. Consequently, it is important to understand what happens to graphene in air.

To investigate, Wastl *et al.* (DOI: 10.1021/nn403988y) used various microscopy



techniques to examine epitaxial graphene on SiC(0001) substrates under ambient conditions. Low-energy electron microscopy images showed both monolayer and bilayer regions. Taking images of the same regions with atomic force microscopy revealed that monolayer regions were covered with disordered adsorbates while the bilayer regions were relatively smooth. However, further investigation showed that bilayer regions had a highly ordered self-assembled stripe structure. Based on earlier work that observed similar stripes on highly oriented pyrolytic graphite, the researchers propose that the stripes on graphene are a solid monolayer of aggregated gas molecules from air. These stripes are blocked from forming on the monolayer regions by other adsorbates. The authors propose that because the stripes only occur on the bilayer regions, they could serve as markers of bilayer graphene on SiC(0001) substrates under ambient conditions.

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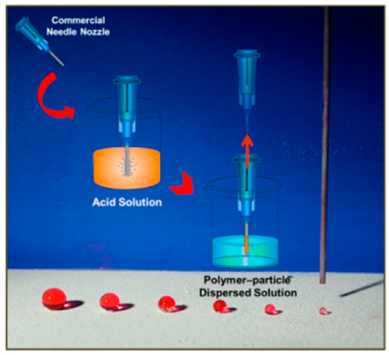
Dispensing the Tiniest Droplets

Finding better ways to dispense ever smaller quantities of liquids has attracted interest from many different fields for its myriad and diverse applications, including drug screening, inkjet printing, and various lab experiments that require delivering precise and minute volumes of drops. Researchers have made several advances toward this goal, achieving smaller drops by shrinking nozzle sizes or including driving mechanisms such as heat ejection or electric-field-directed processes. However, many of these developments have required complex, expensive, or impractical equipment.

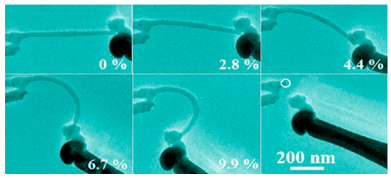
Seeking new inspiration, Dong *et al.* (DOI: 10.1021/nn4048099) looked to natural phenomena that combine surface chemical composition and micro/nanostructures to create special wetting abilities, such as the superhydrophobic rims of lotus leaves that enable them to float on water rather than sink. Based on this concept, the group developed superhydrophobic needle nozzles (SNNs) to control the sizes of dispensed droplets by restricting the spreading of pendulous water droplets. The researchers created the new SNNs using common hydrophobic steel needle nozzles as a base material, first immersing them into an acid solution to achieve a microstructured morphology, then dipping them into a polymer–nanoparticle dispersed solution. By increasing the number of dip-coating repetitions, the researchers decreased the nozzles' inner diameters. Tests showed that the inner diameters most affected the sizes of the dispensed droplets, with the most narrow nozzles dispensing droplets down to the picoliter scale. The authors suggest that this method could be applied to micropipet tips, inkjet or bioprinter heads, or other devices, dispensing very small and precise volumes of liquids without complicated or costly technology.



Breaking News on Boron Nanowires

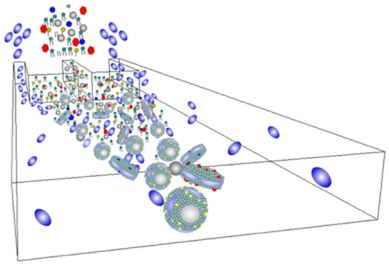
Boron nanowires (BNWs) have a variety of interesting and potentially useful characteristics, including low densities, high elastic moduli, high melting points, large aspect ratios, and high specific surface areas. With recent research successfully developing a protocol for synthesizing BNWs on large scales, this material has potential for applications including lightweight body armors, micro/nanoelectromechanical systems, and cantilever-based nanosensors. Developing fabrication methods has constituted the bulk of research on BNWs thus far, with little attention paid to their elastic behavior. Consequently, understanding this material's mechanical properties lags behind other popular nanostructures, including carbon nanotubes and ZnO and Si nanowires.

To address this discrepancy, Liu *et al.* (DOI: 10.1021/nn404316a) used *in situ* high-resolution transmission electron microscopy to study the mechanical properties of individual BNWs in several different scenarios. Clamping individual nanowires between an atomic force microscope cantilever and a tungsten tip using an electron-beam-induced carbon deposition technique, the researchers subjected BNWs to tensile, compression, and bending tests. Through these tests, the researchers found the mean fracture strength, maximum strain, and average Young's modulus while discounting the effects of the thin oxide layer covering the nanowires. The bending strain and stress values, specific fracture strength, and specific elastic modulus were significantly higher than other materials known for their excellent mechanical properties, including ZnO, Si, GaN, InN, W, and Au nanowires. The authors suggest that these qualities make BNWs a promising choice for lightweight reinforcing fillers, potentially giving this material a future place in applications including airplane wings, bridges, masts, and bicycle frames.



Making High-Density Lipoproteins from Scratch

Lipoproteins are natural nanoparticles that ferry cholesterol and triglycerides throughout the body. As such, they play key roles in enhancing or mitigating the risk of atherosclerosis and other vascular diseases. High-density lipoprotein (HDL) is a key component in "good cholesterol", transporting cholesterol away from atherosclerotic plaques to the liver, which eliminates it from the body. Based on this promising quality, researchers are investigating directly infusing reconstituted HDL (rHDL) to treat cardiovascular disease. Reconstituted HDL has also been explored for a variety of other potential medical roles, including as a vehicle for targeted delivery of diagnostic or therapeutic agents, such as contrast agents for medical imaging, therapeutic nucleic acids, or drugs. However,



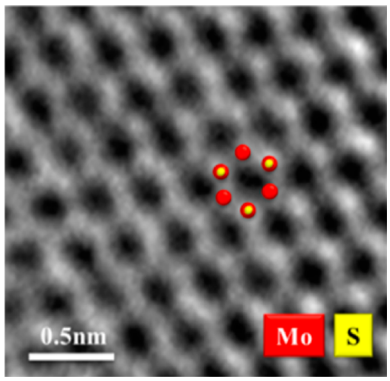
rHDL has challenges that hinder its practical use in the clinic, including a time-consuming, laborious, and complicated reconstitution process.

Seeking a better way to accomplish the same goals, Kim *et al.* (DOI: 10.1021/nn4039063) developed HDL-mimicking nanomaterials (μHDL) using a microfluidics platform. With a single-layer, 3-inlet microfluidic device, the researchers mixed together phospholipids and apolipoprotein, finding the optimum ratio to create nanoparticles similar in size to natural HDL. Tests showed that μHDL has similar bioactivity to natural HDL, with macrophages attaching to and taking up the synthetic particles at similar rates as they do with native HDL. The same microfluidic self-assembly method was used to incorporate a variety of additions into the μHDL, including a hydrophobic drug and gold, iron oxide, and quantum dot nanocrystals and fluorophores for various imaging applications. The authors suggest that μHDL could offer a powerful and facile replacement for rHDL for a variety of biomedical applications.

Shining New Light on MoS_2 Nanosheets

High interest in the two-dimensional (2D) sheets of carbon known as graphene has ignited a burgeoning interest in other 2D materials, including MoS_2. Monolayer MoS_2 has a direct band gap and dramatically higher photoluminescence quantum efficiency compared to bulk MoS_2, giving this unusual material the potential for a variety of applications in the fields of photonics and optoelectronics. Research into this material's nonlinear and ultrafast optical properties is pivotal to make MoS_2 photonic devices a reality.

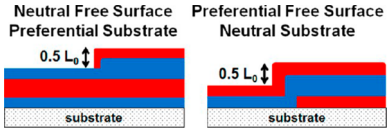
Toward this end, Wang *et al.* (DOI: 10.1021/nn403886t) examined the ultrafast nonlinear optical property of MoS_2 nanosheets in dispersions. The researchers used high-yield liquid-phase exfoliation to produce 2D monolayer and few-layer MoS_2 flakes, dispersing them in three different organic solvents. Scanning transmission electron microscopy and high-resolution transmission electron microscopy as well as Raman spectroscopy confirmed the high quality of the flakes and the mono- or multilayered configuration. Using an open-aperture Z-scan system in conjunction with a mode-locked Ti:sapphire laser operating at 800 nm with 100 fs pulses, the researchers investigated the nanosheets' ultrafast nonlinear optical properties. Their results show that the MoS_2 nanosheets had significant saturable absorption for the femtosecond pulses. Comparison with graphene dispersions showed that the MoS_2 dispersions exhibited much stronger saturable absorption responses under the same excitation conditions. The MoS_2 nanosheets maintained their high nonlinear performance in the different solvents. The authors suggest that these properties position MoS_2 as a contender in the development of nanophotonic devices such as mode-lockers and optical switches.



Exploring Interfaces with Block Copolymer Films

Thin films spun from block copolymers (BCPs) have promise for a wide range of interesting applications, including as membranes and as part of lithographic patterning processes for future generations of semiconductors and hard disk drives. Most of these applications require very precise control of the BCPs' morphology and orientation so that they are perpendicular to the substrate. Both the BCPs and their substrates must be taken into account to achieve this goal. Consequently, significant research has been devoted to better understanding the role of interfaces in BCP thin film self-assembly.

Contributing to this knowledge base, Kim *et al.* (DOI: 10.1021/nn403616r) explored three scenarios involving different combinations of neutral interfaces with two lamella-forming block copolymer thin films, PS-PEI78 and PTMSS-PLA: one in which both the free and substrate surfaces are nonpreferential; one in which the free surface is nonpreferential and the substrate surface is preferential; and a third in which the free surface is preferential and the substate surface is nonpreferential. The researchers found that PS-PEI78 annealed on a nonpreferential polymer mat produced perpendicular lamellae independent of film thickness, the result of a neutral substrate and neutral free surface. However, neutral PS-PEI78 annealed on a nonpreferential PS brush forms islands and holes with 0.5 times the natural period of the polymer. The same topography was produced with the inverse experiment, when PTMSS-PLA, with a preferential free surface, annealed on a neutral substrate. The authors suggest that these "half" islands and holes provide a powerful methodology for evaluating the neutrality of BCPs and interfacial modifiers.



A Fast Path to Fresnel Zone Plates

The core element behind X-ray microscopy is the Fresnel zone plate (FZP), a diffractive optic capable of focusing high-energy electromagnetic radiation. Simple FZPs consist of concentric sets of alternating transparent and absorbing rings. These structures behave like a simple lens, focusing X-rays. Typically, FZPs are constructed using electron beam lithography. However, this method involves many complicated, time-consuming steps, which drive up the cost and feasibility of this technology.

Seeking a faster and more facile route to FZPs, Keskinbora *et al.* (DOI: 10.1021/nn403295k) used ion beam lithography instead. The researchers generated a FZP of 50 μm diameter, 50 nm outermost zone width, and approximately 110 nm thickness using a focused Ga^+ ion beam generated by a general purpose dual beam focused ion beam system. Starting with an X-ray transparent amorphous silicon nitride membrane on silicon, the researchers coated this substrate with a thin gold layer using electron beam evaporation to act as an absorbing material. They patterned a FZP into this layer with ion beam lithography in a process that took only 13 min, compared to the hours required for making some FZP structures with electron beam lithography. Tests showed that despite the short milling time, this FZP was high quality, imaging nanostructures with sub-29 nm widths with clear resolution and with an ultimate cutoff resolution of 24.25 nm. The authors suggest that this technique could increase the accessibility of high-resolution optics to a wider community of researchers working on soft X-ray microscopy.