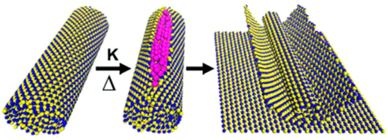
Boron Nitride Nanoribbons from Nanotubes: Divide and Conquer

Boron nitride nanoribbons (BNNRs) are theorized to have interesting electronic and magnetic properties that depend on ribbon width, edge structure, and termination. These properties are also predicted to be further modifiable by chemical functionalization, such as hydrogenation. However, these predictions have yet to be verified because there is not yet a scalable high-yield synthetic method to produce BNNRs with specific width and edge properties. Researchers have had some success in generating BNNRs using boron nitride nanotubes (BNNTs) as a precursor, with one approach longitudinally splitting these starting materials with intercalation of potassium at 300 °C. However, the reported yield of this method was only about 1%.

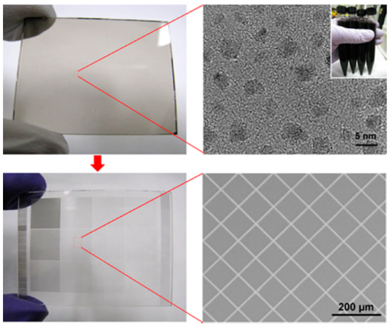
Sinitskii *et al.* (DOI: 10.1021/nn504809n) improved upon this method, increasing the yield to nearly 100% by starting with BNNT precursors generated in a different way. While the original method used BNNTs made by mixing solid boron, magnesium oxide, and either tin oxide or iron oxide powders and heating them, the new method synthesized this precursor by using carbon nanotubes as a sacrificial material to grow BN from boron oxide vapor and nitrogen gas. Using a similar procedure as in the earlier study, which involved adding potassium metal to ampules of BNNTs and then heating the mixture, the researchers successfully generated BNNRs. Various microscopy methods showed that nearly all the BNNTs were split into crystalline nanoribbons with high aspect ratios and straight, parallel edges. Most were either few-layer, with AA′ stacking, or monolayer BNNRs. The authors suggest that this work demonstrates the need for comparison studies of BN nanomaterials synthesized *via* different approaches.



Lighting the Way to Photolithography-Free Ni Electrodes

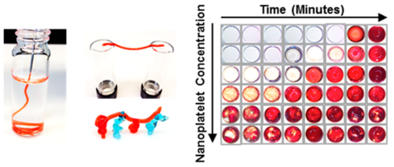
Due to increasing demand for flexible electronics and low-cost fabrication routes, researchers have become increasingly interested in developing photolithography-free electrode fabrication methods. For high-resolution applications, laser direct writing (LDW) is a promising option. This process relies on non-vacuum solution-processable thin film deposition methods using nanoparticle inks to pattern electrodes directly onto various substrates without thermal damage. Most of the target materials used thus far with this method have been noble metals such as Ag and Au. Although less expensive metals such as Cu, Al, and Ni are more desirable, these materials are easily oxidized in air and thus require an inert environment for their use to synthesize metal electrodes, driving up cost.

In a new study, Lee *et al.* (DOI: 10.1021/nn503383z) developed a way to pattern Ni electrodes in ambient conditions using a reductive sintering process. The researchers started by coating glass or plastic substrates with a thin film of NiO nanoparticles. Using LDW, they reduced this material, then sintered it in a desired pattern. After this process, the unsintered parts of the film were easily washed away with a solvent, leaving a shiny, high transmittance Ni electrode. Adhesion tests, including pulling at the electrodes with tape, an ultrasonic bath, and repeated bending of the plastic substrate showed that the electrodes were firmly attached. As a device demonstration, the researchers used these Ni electrodes to create a touch screen panel. The authors suggest that this method can reduce the manufacturing cost toward many applications.



A New Shot To Clot

One of the leading causes of battlefield death is internal hemorrhaging. A variety of agents have been developed to induce clotting and to establish hemostasis through several different mechanisms, including dehydrating the injury site, concentrating clotting factors, delivering clotting agents, or forming a physical barrier against bleeding. However, most of these hemostats are only useful for external injuries, in which hemostatic agents can be applied while simultaneously applying pressure. Although researchers have developed other agents for treating internal bleeding, including injectable solutions of clotting factors, these pose the risk of producing unwanted coagulation elsewhere in the circulatory system. Thus, developing new hemostatic therapeutics that are injectable and mechanically stable and that introduce both quick and local clotting is an urgent need.



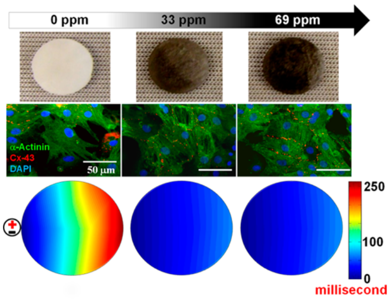
In a new study, Gaharwar *et al.* (DOI: 10.1021/nn503719n) report the development of a novel injectable hemostat: a shear-thinning nanocomposite hydrogel. To make this potential coagulant, the researchers mixed exfoliated synthetic silicates that functioned as nanoplatelets with a gelatin stock at room temperature. Initial tests with a 22-gauge needle showed that the resulting hydrogels could be injected and form self-supporting structures. The researchers also showed that the silicate nanoplatelets improved the gelatin's thermal stability, giving it the potential to remain at a wound site without flowing into adjacent areas. In whole blood, this hemostat significantly decreased clotting time by as much as 77%. In an *in vivo* liver bleeding model, the researchers show that the new hydrogel compared favorably to a commercial hemostat in inducing clotting. The authors suggest that this novel agent could be a welcome addition for treatment of incompressible wounds.

10.1021/nn505687f

Nanotubes Patch the Broken Heart

Part of the pathology of the congenital heart defect known as tetralogy of Fallot is a hole between the lower chambers of the heart. To treat this problem, surgeons usually place a patch or baffle across the right ventricular outflow tract in an area that typically consists of contractile tissue in healthy individuals. Although an ideal patch would support cell–cell interactions and propagate electrical signals, the porous polymeric matrices most often used for this purpose lack these qualities, increasing the frequency of arrhythmias. Researchers have sought to improve these patches by incorporating various structural features and novel materials, including carbon nanotubes (CNTs). Patches with integrated CNTs showed improved cell adhesion, changes in cell morphogenesis and signaling, reduced degradation, and altered mechanical properties. Although these qualities are promising, these patches all had relatively high CNT concentrations, which could be toxic to cardiomyocytes and other tissues.

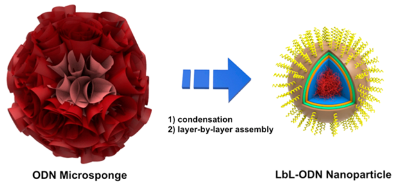
In a new study, Pok *et al.* (DOI: 10.1021/nn503693h) show that it is possible for cardiac patches to benefit from substantially lower concentrations of CNTs. The researchers generated gelatin–chitosan hydrogels with concentrations of CNTs as low as 10 ppm, an amount suggested by previous studies to be nontoxic. Tests showed that these CNTs acted as electrical bridges between cardiomyocytes in culture, improving electrical coupling, synchronous beating, and cellular function. Further examination showed that these hydrogels had excitation conduction velocities similar to native heart muscle, with CNTs being pivotal for this effect. The researchers suggest that these qualities make these novel engineered tissues excellent candidates to patch cardiac defects, including tetralogy of Fallot.



Sopping up Cancer with Microsponges

Antisense oligonucleotides and other nucleic acids have extraordinary potential to treat a broad range of cancers, infectious diseases, and other health problems. However, these promising therapies face a significant challenge in implementation from the body's natural nucleases, which can digest nucleic acids before they reach their target. Although packaging these therapies in nanocarriers can improve their stability, this can lead to further challenges, including avoiding toxicity from the carriers themselves, being able to load the carriers effectively with high enough amounts of drug to be effective, and avoiding the body's natural filtration systems that remove nanoparticles from circulation.

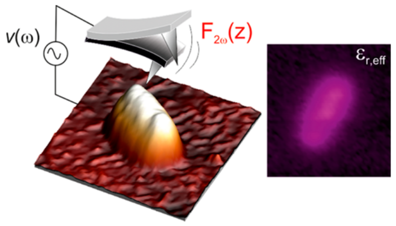
To avoid these issues, Roh *et al.* (DOI: 10.1021/nn502596b) developed a novel way to package antisense oligonucleotides as microsponges. The researchers used rolling circle amplification to generate long, single-stranded antisense oligonucleotides for anti-luciferase. In the course of this reaction, the strands coalesced into microsponge structures that each contained several thousands of repeated oligonucleotide copies. By adding cationic polymer and salts, the researchers displaced the magnesium pyrophosphate crystals that made up the microsponges' scaffolds, shrinking them into nanocomplexes. They then further modified the particles using layer-by-layer assembly, adding layers of DNA, polyethylenimine (an endosomal escape agent), and polyethylene glycol (which stabilizes the particles in blood and sheathes them from immune discovery). Tests show that these modifications facilitated *in vitro* and *in vivo* delivery of the antisense oligonucleotides, which effectively inhibited gene expression. The researchers suggest that this packaging offers an effective means to deliver antisense oligonucleotide therapy to treat cancer and other conditions.



Electrifying Bacterial Investigations

Numerous spectroscopic studies have suggested that bacterial response to electric fields depends on a variety of factors, including bacterial shape and size, internal structures, and electric conductivity and permittivity of their cell components. These findings have led to several new technologies, including tests to detect pathogenic bacteria or even the presence of bacterial cells, to count and to differentiate bacteria, to determine bacterial viability, to distinguish among mutants, and to separate bacteria from other cells. Most of these investigations were carried out by averaging populations containing millions of cells. However, being able to capture the electrical characteristics of single cells has important advantages, including the ability to capture a population's heterogeneity and to take measurements from a mixed sample without separations.

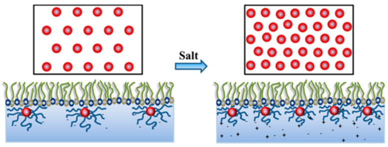
In a new study, Esteban-Ferrer *et al.* (DOI: 10.1021/nn5041476) used electrostatic force microscopy (EFM) to quantify the electrical polarization properties of single bacterial cells. As proof of principle, the researchers chose to examine two types of Gram-negative bacteria (*Salmonella typhimurium* and *Escherichia coli*) and two types of Gram-positive bacteria (*Lactobacillus sakei* and *Listeria innocua*) in both dry air and ambient conditions. The researchers found that the effective dielectric constant was about the same for all four bacteria studied in dry air. However, under ambient conditions, this number nearly doubled for the Gram-negative bacteria and more than tripled for the Gram-positive ones. Further examination showed that these values included contributions from both the envelope and core of each bacterium, reflecting the long-range nature of electrostatic forces. The authors suggest that these findings open the possibility for analytical studies based on bacterial electric polarization properties.



Making Tunable Nanoparticle Arrays

■ The ability to create two-dimensional nanoparticle arrays with tunable interparticle distances is useful for a variety of applications, including photovoltaic devices, metamaterials, optically tailored coatings, and magnetic storage media. There is also fundamental importance in understanding the physical parameters that influence nanoscale object assembly, including the components that make up these nanoscale objects and their interactions with the environment. Of particular interest is elucidating the interactions of nanoparticles with lipid membranes, which has practical implications in nanotoxicology and nanomedicine.

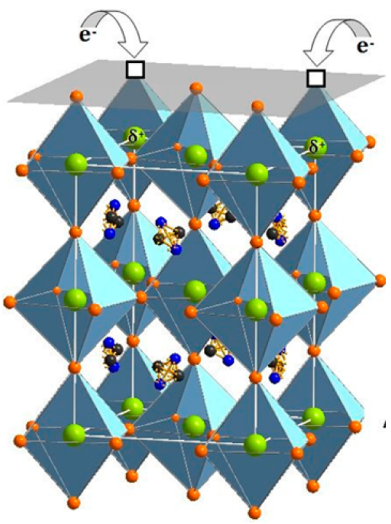
Srivastava *et al.* (DOI: 10.1021/nn5042416) investigated a novel way to make tunable nanoparticle arrays using DNA-coated nanoparticles (DNA-NPs) on positively charged lipid layers at the water–air interface. The researchers coated Au nanoparticles with single-stranded DNA of nonhybridizing sequences, promoting interparticle repulsion. They then placed these DNA-NPs on liquid interfaces with varying ratios of two different lipids, one neutral and one cationic, over water. Grazing incidence small-angle X-ray scattering and X-ray reflectivity measurements both suggested that this setup caused the nanoparticles to form highly ordered hexagonal close-packed lattices with the DNA-NPs pulled closely toward the interface, with the DNA coating the particles likely being deformed. After the researchers increased the salt content of the liquid interface, further investigation showed that the DNA-NP layer became denser, with the nanoparticles farther away from the interface. The authors suggest that these observations, effects they attribute to electrostatically induced confinement of the nanoparticles at the lipid interface, could be important for a broad range of nanoscale interfacial systems.



Lewis Bases Let the Sun Shine in

■ Organic–inorganic metal halide perovskites have become popular choices for absorber materials in solar cells in recent years. The best-known members of this group are methylammonium trihalogen plumbates with formulas of $CH_3NH_3PbX_3$, where X is a single halogen or halogen mixture. These materials have been incorporated into a variety of photovoltaic device designs with solar power conversion efficiencies over 15%. However, like most other ionic materials, these semiconductors contain undercoordinated ions at crystal surfaces and grain boundaries between individual crystals. These qualities lead to an excess of charge building up at the crystal surface, which negatively effects solar cell performance by causing an accumulation of photogenerated positive carriers within the hole-transporter phase at the heterojunction.

Seeking a way to improve the performance of these materials, Noel *et al.* (DOI: 10.1021/nn5036476) used Lewis bases to passivate the perovskite surface. Working with the mixed-halide lead-based perovskite $CH_3NH_3PbI_{3-x}Cl_x$, the researchers treated films of this material with thiophene or pyridine. Results show that these treatments significantly raised the photoluminescence quantum efficiency of the films at all excitation intensities, particularly low excitation intensities for the pyridine-treated films. Similarly, the researchers found that photoluminescence lifetimes increased by an order of magnitude for both treatments. When the researchers incorporated the treated films into photovoltaic devices, they observed increases in power conversion efficiency from 13.1% for untreated devices to 15.3% with thiophene passivation and 16.5% with pyridine passivation. The authors suggest that Lewis base passivation could also be useful for improving the performance of other perovskite-based optoelectronic applications.



Making FinFETs Flexible

■ Silicon electronics have become a nearly indispensable part of daily life since the introduction of the first microprocessors in the early 1970s. The vast majority of current electronics are based on silicon micro- and nanofabrication processes, a reflection of silicon's unparalleled performance for relatively low cost. However, with the growing interest in ultramobile computation and implantable and wearable electronics, silicon is showing its shortcomings. Despite its tremendous advantages, silicon's brittleness and inherent lack of flexibility limits its use. To work around this weakness, researchers have looked to other options, including polymer-based electronics, using carbon nanotubes or graphene, or transferring silicon nanoribbons onto flexible polymer substrates. However, each of these materials has its own intrinsic drawbacks.

Looking for a new way to create flexible electronics, Torres Sevilla *et al.* (DOI: 10.1021/nn5041608) developed a novel method to preserve the silicon in FinFETs, currently the most advanced transistor architecture used in state-of-the-art microprocessors, by thinning it with a soft-etch process. The researchers started by constructing conventional FinFETs using silicon-on-insulator wafers. Coating the applied components with a thick photoresist, the researchers then thinned the back of the substrate using anisotropic etching. To make sure that they did not under- or overetch the substrate, the researchers completed the etching process in four different steps, measuring thickness between each step. The result was a substrate thinned from 800 down to 50 μm. Tests showed that this thinning allowed a minimum bending radius of 1.5 cm without a significant loss in electrical performance. The authors suggest that this technique could lead to flexible, high-performance circuitry that could be used in future ultramobile applications.