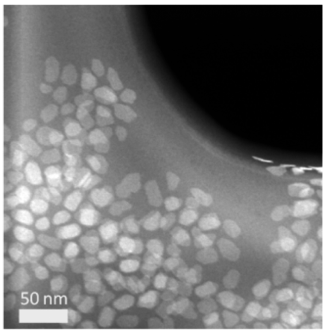
Bright Future for Colloidal Nanoplatelets

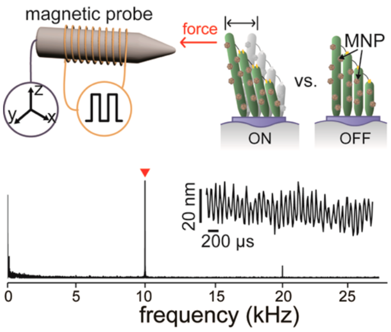
Colloidal quantum dots have long been considered a promising component for achieving full color lasers, but they have severely limited optical gain. Various shaped nanocrystals, including nanorods and tetrapods, can achieve more efficient optical gain than quantum dots but are also limited. Recently, researchers developed colloidal nanoplatelets (NPLs), which have a variety of optical and electronic properties that are superior to those of quantum dots, including narrower spontaneous emission spectra, suppressed inhomogeneous emission broadening, and giant oscillatory strength. CdSe/CdS core/crown NPLs, with a laterally grown shell, are particularly attractive due to their excellent photophysical properties. However, the optical gain of these NPLs has yet to be examined.

In a new study, Guzelturk *et al.* (DOI: 10.1021/nn5022296) investigate the optical gain performance of four monolayer thick CdSe cores and three different CdSe/CdS crown/core NPLs with different crown sizes using one- and two-photon absorption pumping. Their results show that the core/crown NPLs showed enhanced optical gain compared to core-only ones, with low one- and two-photon absorption pumped amplified spontaneous emission (ASE) thresholds in the crown/core NPLs, presumably due to their increased absorption cross section and more efficient interexciton funneling from the crown to the core. Their ASE thresholds were lower than the best reported optical gain of colloidal nanocrystals emitting in the same spectral range, while the NPLs' gain coefficient is four times larger than that of colloidal quantum dots. As proof of principle, the researchers used these NPLs to fashion a vertical cavity surface-emitting laser. The authors suggest that colloidal NPLs are excellent components for optical gain and lasing applications.



Now Hear This: Magnetic Control for Hair Cells

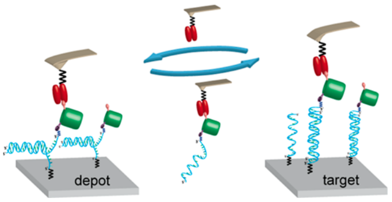
Many biological systems, including those that sense touch and sound, rely on mechanotransduction. This conversion of a mechanical stimulus into electrochemical signal occurs when motion exerts a mechanical force on an ion channel in a sensory cell, causing a conformational change that opens the channel and allows ions to enter. Researchers have long been interested in better understanding and controlling the mechanotransduction process, but they have lacked tools with noncontact and precise spatiotemporal capabilities. For example, traditional tools such as glass or piezoelectric probes that directly contact cells impose a mechanical load and can create hydrodynamic artifacts on fluid-immersed tissue.



Seeking a new option for inducing and studying mechanotransduction, Lee *et al.* (DOI: 10.1021/nn5020616) looked to magnetic fields. The researchers designed a cube-shaped magnetic nanoparticle (MNP), $Zn_{0.4}Fe_{2.6}O_4$, that has a high magnetization value enhanced by Zn^{2+} doping while also exhibiting colloidal stability. Using a custom electromagnet probe, the researchers tested their MNPs on hearing hair cells from North American bullfrogs. When electric current was applied to the probe in the vicinity of a selected hair cell coated with MNPs, it deflected the hair bundle by tens of nanometers. This stimulus could be pulsed at up to 10000 Hz, suggesting that this system could be used to study auditory mechanotransduction across a broad range of species. Further investigation showed that hair bundle deflection with this system led to a sharp rise in intracellular Ca^{2+} ion concentration, suggesting a mimic of natural mechanotransduction. The authors suggest that these MNPs could offer a way to study mechanotransduction in other sensory systems, as well.

Protein–DNA Chimeras: Tagged for Success

To understand protein networks at the individual molecule level, researchers first need ways to target and to localize each network's constituents precisely. As a means to this end, researchers recently developed the single-molecule cut and paste (SMC&P) technique. In SMC&P, molecules are picked up from a depot area and assembled one by one at a selected position in a "construction site" in the target area. After initially applying this technique only to DNA, researchers eventually expanded its application to proteins, using zinc finger fusion proteins as the transport mechanism. However, this system has several drawbacks, including significantly alterating the protein of interest, poor solubility, and the noncovalent nature of its DNA interaction.



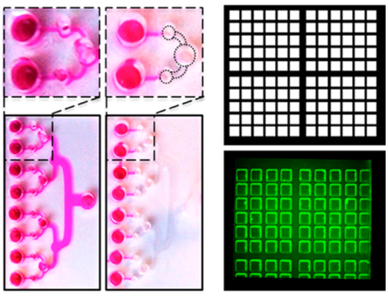
Seeking a better system that might also couple proteins to DNA, Pippig *et al.* (DOI: 10.1021/nn501644w) employed the ybbR-tag. This 11 amino acid sequence, when assisted by the phosphopantetheinyl transferase Sfp, enables site-selective attachment of coenzyme-A-modified DNA to proteins of interest. Expressing green fluorescent protein (GFP) with the ybbR-tag, the researchers reacted the construct with coenzyme A-modified transfer-DNA, then incorporated this chimera into SMC&P experiments. Tests showed that transport efficiencies with this combination were extremely efficient, with the GFP remaining intact and fluorescent throughout the procedure. Fluorescence measurements suggest that only individual molecules could be transported with a select atomic force microscope cantilever. Demonstrating this chimera's utility, the researchers used SMC&P to assemble the pattern of a snowflake over 552 transfer cycles. The authors suggest that this method provides a useful strategy for coupling proteins and DNA.

10.1021/nn503690f

Layer-by-Layer Films, without the Waste

Researchers have long been interested in layer-by-layer (LbL) assemblies—the alternate absorption of materials onto surfaces using complementary interactions, one individual layer at a time, to form nanometer-scale thin films. The resulting ultrathin coatings exhibit a range of interesting properties and have found applications in areas as diverse as reactive membranes, drug-delivery systems, and electrochemical and sensing devices. Various innovations have enabled the implementation of promising LbL systems at speeds and throughputs needed for commercial products and processes. However, as of yet, there is no viable way to assemble large libraries of LbL films.

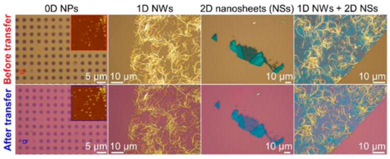
Moving toward this goal, Castleberry *et al.* (DOI: 10.1021/nn501963q) developed a novel technique that uses capillary flow within a microfluidic device to create LbL films, making high-throughput assembly of vast libraries of these materials possible. The researchers' device consists of an array of microchannels formed by bonding a polydimethylsiloxane mold to an oxygen-plasma-treated substrate. Each microchannel has a main channel, where material from solution absorbs onto the substrate, and three openings: an inlet well, a capillary flow break well, and an exit well. Using this design, the researchers created a simple library of bilayer poly(acrylic acid) and poly(allylamine hydrochloride) films, changing the properties of individual films by varying the pH of the starter solutions. Additionally, by cultivating cells with microstructures within the same platform, the investigators assayed biological properties of the films, including cell adhesion and proliferation. The authors suggest that this new way of synthesizing LbL films could provide a facile way to create libraries without the need for large reservoirs of material.



Nanostructures Make a Clean Getaway

The ability to transfer synthesized nanostructures from one substrate to another is key for the large-area integration and multidimensionality required by many applications. Researchers have already developed several different transfer techniques, including kinetic-controlled transfer printing with a poly(dimethylsiloxane) (PDMS) stamp, lift-off by etching, and stripping/peeling mediated by poly(methyl methacrylate). However, these methods have process-specific drawbacks that make them unable to be generally applied to different circumstances.

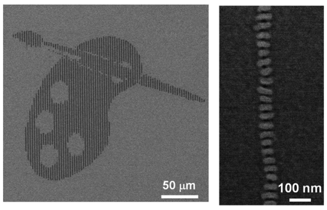
In a new study, Li *et al.* (DOI: 10.1021/nn501779y) provide a novel transfer method that could be applied to transfer a variety of nanostructures between substrates. The researchers spin-coated a polymer onto nanostructures of various types, including nanoparticles, nanowires, and nanosheets, predeposited onto a Si substrate coated with SiO$_2$. After scratching off strips of polymer at the edges to expose the hydrophilic SiO$_2$ and bringing a thick PDMS film into contact with the polymer, the researchers introduced a small drop of water at the edge. This drop of water penetrated between the hydrophilic substrate and hydrophobic polymer attached to the nanomaterials, effectively pulling them off. After the film with the attached nanomaterials was placed onto the target substrate, the PDMS was peeled off on a hot plate and the carrier polymer was removed with dichloromethane. Examinations showed that the nanomaterials were transferred in a pristine state, and the researchers were able to create various heterostructures, including graphene—MoS$_2$, graphene—WSe$_2$, and MoS$_2$—WSe$_2$. The authors suggest that this method could prove to be a facile way to transfer many nanostructures between substrates and form a variety of heterostructures.



A Brush with Greatness

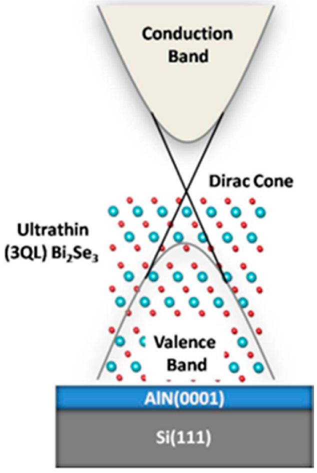
Researchers have long taken advantage of the properties of block copolymers (BCPs) to self-assemble on substrates to form nanoscale patterns. These patterns can then be used as templates for nanolithography, membrane technology, electronic devices, and metamaterials. The orientation of domains that form in BCP films are largely determined from interfacial interactions with the substrate. One way to establish a preferred orientation is by altering the substrate's wetting behavior through grafting random copolymer brushes that include monomers present in the BCP. Most applications of BCPs require precise spatial control of surface interactions down to tens of nanometers. To accomplish this, conventional lithographic techniques can selectively remove brush coatings or cross-link these coatings to prevent brush grafting. However, these methods can cause difficulty in forming pristine surfaces or patterns with more than a single brush chemistry.

Seeking a better approach, Onses *et al.* (DOI: 10.1021/nn5022605) developed a novel method to graft copolymer brushes by directly printing them onto surfaces. The researchers applied patterns of inks consisting of copolymers with different compositions of styrene and methyl methacrylate, P(S-*ran*-MMA), to target surfaces. These patterns then affected the self-assembly of BCPs of poly(styrene-*block*-methyl methacrylate) (PS-*b*-PMMA). Through various experiments, the researchers confirmed that they could print the copolymer in complex patterns in feature sizes down to about 50 nm, changing the substrate's wetting behavior in a way that forced perpendicular assembly of BCP domains. The authors suggest that this method not only provides a useful way to steer morphologies of BCP nanostructures but also to study the effects of chemical transitions on self-assembly processes.



Topological Insulators Trim the Fat

■ Researchers have grown increasingly interested in three-dimensional (3D) topological insulators (TIs), materials that have a bulk excitation gap and gapless surface metallic states in the form of spin-polarized, or helical, Dirac cones. Although TIs are interesting from both a theoretical and applied standpoint, use of these materials has been limited due to several drawbacks, including excess sensitivity of surface states under ambient conditions, residual bulk conduction caused by defects, and thermal excitations in the small bulk band gaps. The latter two problems can be minimized by growing TIs with better quality and large band gaps, such as Bi_2Se_3, and by producing TIs as ultrathin films to enhance the surface state contribution. However, making ultrathin epitaxial TI films with the same properties of their 3D counterparts has its own challenges. Experimental and theoretical work shows that as thickness dips below 6 quintuple layers (QL), Bi_2Se_3 films show an energy gap opening before eventually falling into a trivial insulator state.

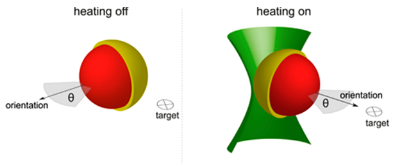


In a new study, Tsipas *et al.* (DOI: 10.1021/nn502397x) show that obtaining ultrathin epitaxial Bi_2Se_3 is indeed possible by growing films of thicknesses down to 3QL. Growing Bi_2Se_3 films in a one-step mechanism at 300 °C, the researchers show that these layers bond strongly with an AlN substrate without forming interfacial reaction layers and a perfect registry with the substrate. Angle-resolved photoelectron spectroscopy shows that these films maintain their 3D TI properties even at 3QL, even exhibiting top surface gapless metallic states in the form of a Dirac cone. The authors suggest that this system presents an attractive design for future TI devices.

Giving Microswimmers a Light Nudge

■ When microswimmers or self-propelled particles start to interact at higher densities, they tend to align and to form flocks, swarms, and other complicated patterns—collective motions that are not well understood. The reason for this gap in understanding is partly due to a lack of control over the active particles themselves. Finding a way to exert control could allow detailed study of active microswimmers' interactions. Although optical tweezers and other external force fields can influence these particles' motions, they also change the hydrodynamic flow field of microswimmers and, consequently, their hydrodynamic interactions. Thus, whatever method is developed to control these active particles must preserve their natural hydrodynamic field.

In a new study, Bregulla *et al.* (DOI: 10.1021/nn501568e) present a novel way to initiate locomotion and steer microswimmers toward a target by nudging them with light. The researchers' system uses Janus particles in which a polystyrene bead is capped on one side with gold. When irradiated with a laser, the energy absorbed by the gold cap is converted into heat, distorting the counterion cloud around the colloidal particle and creating an osmotic pressure difference that drives the particle forward with the polystyrene side ahead. Using four Janus particles of different diameters, the researchers found that by switching on the laser only when the particles were facing the target, they could effectively localize them at well-defined positions. Positioning errors were smaller with smaller beads, which required less intervention to overcome rotational Brownian motion. The authors suggest that photon nudging could offer a ready way to navigate microswimmers in complex environments.



A Closer Look at Catalysis on an Insulator

■ Researchers have recently demonstrated covalent coupling reactions catalyzed by solid metal surfaces, opening the exciting and rapidly evolving field of on-surface chemical synthesis. One example of this is the synthesis of porous graphene based on the molecular precursor 5,5′,5″,5‴,5⁗,5′′′′′-hexaiodocyclohexa-*m*-phenylene (I_6-CHP), which dissociates all its iodine atoms on a variety of metal substrates. Although the catalytic activity of this reaction is so high that studying site-specific interactions between the reactant and substrate seems irrelevant, the situation is expected to be different when it takes place on an ultrathin surface-supported insulating layer, such as monolayer hexagonal boron nitride (h-BN).

In a new study, Dienel *et al.* (DOI: 10.1021/nn501906w) performed this experiment, following the reaction details using low-temperature scanning tunneling microscopy (STM). Distributing I_6-CHP at low coverage onto h-BN on a Rh crystal, the researchers observed flower-like molecules occupying dents in the corrugated h-BN structure. Rather than settling into the middle of each dent, the I_6-CHP molecules instead attached to the rims in a preferential orientation, with a carbon atom on top of a boron atom rather than on top of a hollow site. After inducing dehalogenation, they saw alternating iodine atoms dissociating around the molecule and halting after removal of only three. Only at higher annealing temperatures and I_6-CHP coverage was complete dissociation and bonding between adjacent molecules possible. The authors suggest that better understanding of reactions like this one could help advance the design of electronic nanostructures on insulating substrates with reduced catalytic activity.