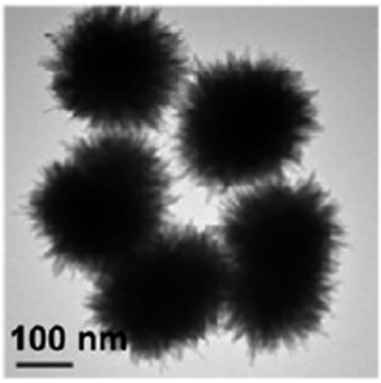
The Dirt on Rare Earth Oxide Dangers

Rare earth oxides (REOs) are being increasingly mined and processed for use in products ranging from magnets to electronics. Consequently, more individuals are being exposed to these materials and their serious health consequences. For example, researchers have documented pneumoconiosis in polishers and rare earth mining workers and systemic fibrosis in patients with renal impairment who receive Gd-based MRI contrast agents. Although these effects are well-known, how rare earth materials induce pathological changes is unclear. Previous research has suggested that rare earth elements are taken up into the lysosomal compartment of macrophages and that rare earth ions have high binding affinity to phosphate groups. However, the precise connection between these findings and the mechanism behind REOs' toxic effects is unknown.

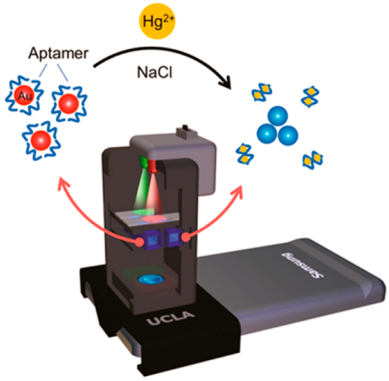
To investigate this question, Li *et al.* (DOI: 10.1021/nn406166n) used a library of 10 commercially available REO nanoparticles to examine effects in phagolysosomal simulated fluid (PSF) and in the lysosomal compartment of macrophages. Compared to REO nanoparticles in water, those in PSF morphed into spiky, sea-urchin-shaped structures or disordered nanowire meshes. Further experiments suggested that it is not this shape change that causes pathological damage. Rather, the REOs collect in lysosomes, which shed REO particles that subsequently complex with phosphate groups and strip them from the surrounding lipid bilayer. This damage in turn triggers the release of a variety of factors involved in inflammation and transformation. The researchers were able to stem these effects by pretreating REO nanoparticles with phosphate. The authors suggest that these results provide both a mechanism for REO damage as well as a method to prevent it.



Phone Attachment Smart Enough To Detect Mercury

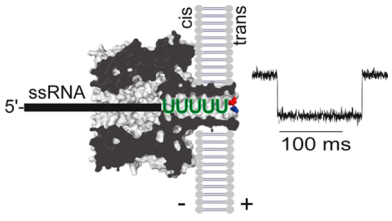
Mercury has long been known as a serious neurotoxin. Thus, developing ways to test for environmental or biological mercury in real time could have a significant impact on human health. Although mercury exposure's neurological effects have been primarily blamed on organic methylmercury, its inorganic form, mercury(II) ions, is far from benign. This form acts as a precursor to methylmercury for bacteria-assisted biotransformation processes and is more nephrotoxic than its organic form. Scientists have used various approaches to test for low nanomolar concentrations of mercury(II) ions. However, these methods all require complex sample preparation procedures, expensive and bulky instruments, and trained personnel.

Seeking a way around these obstacles, Wei *et al.* (DOI: 10.1021/nn406571t) developed an attachment that can sensitively quantify mercury(II) ions in water samples using a smart phone. This device consists of two battery-powered LEDs, green and red, mounted near two rectangular test tubes to hold sample and control solutions. The entire device, mounted on a smart phone's existing camera, weighs less than 40 g. Within the test tubes, the researchers ran a plasmonic colorimetric assay with spherical Au nanoparticles, which produce a characteristic color change from red to purple or blue based on mercury(II)-induced binding. A customized Android app analyzes the gathered data on mercury concentration, giving results with a detection limit of ~3.5 ppb. Using this detection platform, the researchers generated a mercury contamination map of samples gathered from city tap and natural water sources around California. The authors suggest that this cost-effective, portable, and wireless design could make mercury(II) detection in the field a reality.



Yet Another Use for Protein Nanopores

The addition of uridines onto the 3′ end of RNAs is one way that cells modulate gene expression. This modification plays a critical role in determining the rate of mRNA degradation and the turnover of microRNAs. While this much is known, determining the abundance of this modification and quantifying the number of attached uridines remains a challenge. One potential tool for detecting this post-translational modification is α-hemolysin (αHL), protein nanopores extracted from *Staphylococcus aureus* bacteria. αHL has been widely used for the stochastic detection and analysis of many different kinds of molecules, for example, determining single-stranded nucleic acid length and DNA duplex dissociation and unzipping. These pores have also been used to identify individual bases both within single DNA strands and those enzymatically cleaved from strands. Despite these successes, few studies have focused on using αHL to detect specific RNA sequences.



In a new study, Clamer *et al.* (DOI: 10.1021/nn4050479) tested αHL's ability to detect short RNA 3′-uridylation without amplification. Adding short RNAs with uridines attached to the 3′ end on the *cis* side of a lipid bilayer with an αHL pore in low ionic strength buffer produced long current blockades, a phenomenon absent with the addition of other nucleotides, suggesting that αHL recognized the uridine sequence. Further experiments showed that the mean residential currents and mean dwell times could distinguish the length of uridine tails and could further discriminate between normal and methylated uridine. The authors note that this method may eventually become a useful tool for characterizing biologically important RNA signatures.

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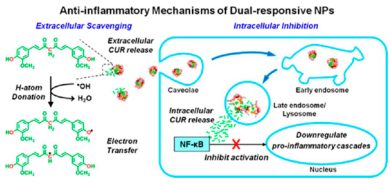
Curry Carriers To Treat Inflammation

One of the immune system's first responses to infection or irritation is inflammation, a condition whose signature characteristics include oxidative stress and reduction of pH. Inflammation has been linked with a variety of health conditions, including cancer, atherosclerosis, asthma, and cystic fibrosis, diseases that are potential consequences to reactive oxygen species' detrimental effects on DNA, proteins, and lipids. One of the major challenges in treating inflammation is delivering drugs that release their cargo selectively to affected areas and, in particular, are capable of cytoplasmic delivery. Stimuli-responsive nanoparticles are one possibility toward achieving this end.

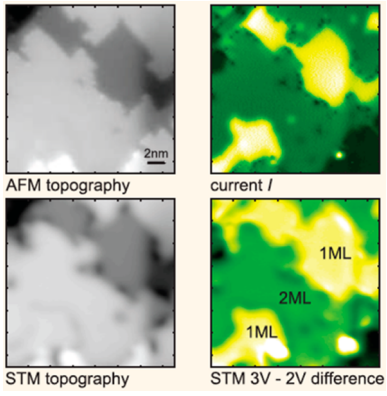
Moving toward this goal, Pu *et al.* (DOI: 10.1021/nn4058787) developed smart nanoparticles that release their cargo of curcumin, a component of the curry spice tumeric that acts as a powerful antioxidant and anti-inflammatory agent, when triggered by reactive oxygen species and acidic pH. These nanoparticles are made of *N*-palmitoyl chitosan that bears a hydrophobic Cy3 moiety. Tests showed that in buffer solution of pH 5.5 containing H_2O_2, the nanoparticles first condense, then swell and disintegrate, allowing their curcumin cargo to escape. Using the encapsulated curcumin and Cy3 as Förster resonance energy transfer (FRET) donors and acceptors, respectively, the researchers confirmed curcumin release in macrophages. Further tests showed that curcumin was gradually released from these nanoparticle carriers over several hours after drug uptake. Administering loaded nanoparticles to a mouse model of ankle inflammation showed that curcumin was effectively released in inflamed tissues and had potent anti-inflammatory activity. The researchers suggest that delivering curcumin through smart nanoparticles could be a promising way to treat inflammation.



Giving Ultrathin Insulating Films a Closer Look

Ultrathin insulating films, particularly those composed of MgO, have long served as gate insulators and tunnel junctions, with more recent use as tunable catalytic surfaces and substrates for magnetic nanostructures. These films provide precise electrostatic coupling and electron tunneling from a conducting substrate to another electrode or adsorbed nanostructures. This coupling strongly depends on the films' thickness and structure, so finding ways to characterize the films at the atomic scale is essential to tailoring them for particular applications.

Toward this end, Baumann *et al.* (DOI: 10.1021/nn4061034) used a combination of scanning probe methods both to determine the local film thickness of ultrathin MgO films grown on a Ag(001) substrate and to resolve the film's three-dimensional structure and the topography of the buried MgO–Ag interface.

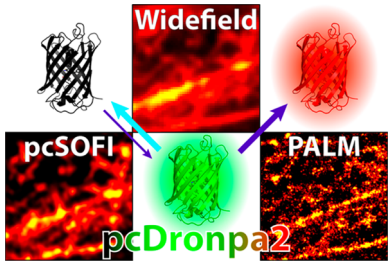


The researchers relied on scanning tunneling microscopy (STM) and conductive atomic force microscopy (AFM). Conductive AFM is itself a combination of STM and standard AFM, in which the tunneling current is recorded while scanning the tip with constant force over the surface. Using these two methods together, the researchers made some surprising discoveries about the complexity of MgO on Ag(001). For example, they discovered terraces with a height of about 5 nm between steps at the insulator–metal interface. The MgO layers avoided creating polar step edges over these terraces by using a carpet-like growth mode, draping smoothly over the Ag steps without introducing edges in the MgO layers. At submonolayer coverage, MgO formed embedded islands on the metal surface. The researchers suggest that this technique for studying thickness and structure could be extended to other thin insulating films.

Photoswitchable Dronpa Goes Photoconvertible

Using fluorescent proteins (FPs) as labels for fluorescence microscopy has revolutionized cell biology. The diverse FPs currently available have a variety of useful properties, including photoactivation, photochromism, and photoconversion. These subclasses of FPs have allowed a range of super-resolution methodologies, each with different strengths and weaknesses. For example, photoactivated localization microscopy (PALM) has high spatial resolution but poor temporal resolution and requires high signal-to-noise ratios. In contrast, photochromic stochastic fluctuation imaging (pcSOFI) has lower spatial resolution but higher temporal resolution and is more tolerant to imaging conditions. Though using such complementary imaging techniques can allow different observations for the same sample, it also places different demands on fluorophores. For example, PALM achieves its highest resolution with green-to-red photoconvertible FPs, but pcSOFI needs labels with reversible photochromism.

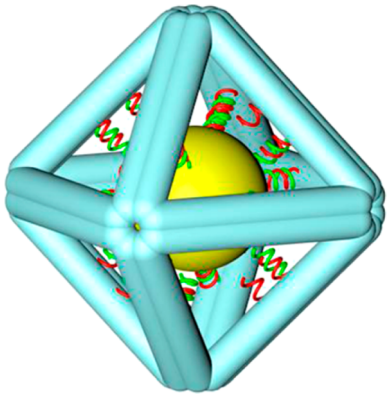
Seeking a more versatile label, Moeyaert *et al.* (DOI: 10.1021/nn4060144) developed a green-to-red photoconvertible mutant of the photoswitchable well-studied FP Dronpa protein. The researchers first selected a brighter Dronpa by observing bacterial colonies with randomly mutated Dronpa genes. A second round of random mutation identified a photoconvertible mutant. Through rational design, the researchers created a third mutant with higher photoconversion efficiency, which they dubbed pcDronpa2. Experiments showed that pcDronpa2 was an effective label for the same sample of cells using both pcSOFI and PALM. The authors suggest that this novel FP paves the way toward multimodal super-resolution imaging.



Fine Dining: DNA Nanocages Swallow Au Nanoparticles

■ Host–guest interactions are a pivotal part of many biological phenomena, such as those involved in enzyme–substrate dyads. Finding ways to mimic these processes at the nanoscale could be a boon for a variety of applications, creating novel structures that confer properties of both members of the pair. One intriguing duo is Au nanoparticles (AuNPs) and DNA nanocages. AuNPs have demonstrated their utility in plasmonics, magnetics, and catalysis, while self-assembled DNA nanocages have shown the ability to serve as host scaffolds and to encapsulate and to deliver cargo.

Seeking a way to combine these two components, Zhang *et al.* (DOI: 10.1021/nn406039p) developed DNA nanocages that "swallow" AuNPs, engulfing them into their inner cavities to form stable complexes. The researchers designed the DNA nanocages as a family of symmetric DNA wireframe polyhedra, with tetrahedra, octahedra, and

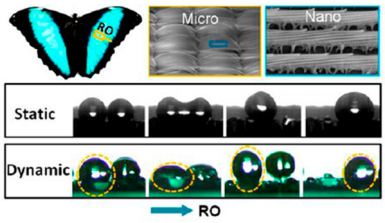


icosahedra. Two unpaired, single-stranded tails dangled from the middle of each strut on these structures. Separately, the team functionalized AuNPs with thiolated DNA single strands with sequences complementary to these tails. After incubating these two components together overnight, the DNA nanocages encapsulated the AuNPs. Using a variety of characterization methods, including gel electrophoresis, atomic force microscopy, dynamic light scattering, and cryogenic electron microscopy, the researchers show that the DNA tetrahedra and octahedra enclosed single AuNPs, but the icosahedra were able to swallow up to six. Further experiments showed that by adding excess single-stranded DNA complementary to the tails on the DNA nanocages, the nanocages released their cargo, making this interaction reversible. The authors suggest that DNA nanocage–AuNP hybrids could have significant potential for nanotechnology and materials science.

Lifting the Fog on Dynamic Drop Transport

■ A variety of biological materials, including cactus spines, spider silk, and desert beetle backs, have attractive fog drop transport abilities. By mimicking these special surfaces, researchers have already made many important contributions to academic and industrial applications. However, the vast majority of research on directional fog drop transport has been on static surfaces. Few reports have identified materials that can transport fog drops in both static and dynamic states.

In a new study, Liu *et al.* (DOI: 10.1021/nn404761q) show that the wings of *Morpho deidamia* butterflies, which have already demonstrated directional fog transport under static conditions, display the same phenomenon while in motion due to an asymmetric ratchet effect caused by micro- and nanostructures on their surfaces. The surfaces of these wings are covered with overlapping scales about 200 μm long and 150 μm wide. On the surfaces of these scales are parallel ridges with nanotips tilting toward the wing's outer edge. The ridges themselves are composed of about six layers of stacked cuticle lamellae, each made of lattices that give the ridges a porous structure. The asymmetric ratchet-like structures these features impart cause fog droplets to grow on the wing's superhydrophobic surface and coalesce, then roll toward the wing's edge when larger than the size of a scale. The researchers found that fog drops on dynamic wings are also propelled toward the wing's edge, with an optimal vibration frequency of 35 Hz. The authors suggest that a similar design could be used to develop materials that directionally transport fog drops in dynamic and static conditions.



Molecular Fingerprinting a New Way

■ In the past several years, researchers have used molecular electronics as a novel way to investigate quantum transport phenomena. This tool has shown some promise for practical applications, such as third-generation DNA sequencing using nanopores and nanochannels. However, most approaches thus far have limited utility for other important sequencing tasks, such as identifying the methylated DNA that could signal the start of cancerous transformation in cells.

Seeking a molecular electronics approach capable of this critical task, Rajan *et al.* (DOI: 10.1021/nn4062148) used a novel method that generates a two-dimensional conductance spectrum by controlling both the bias and gate voltages applied to an armchair graphene nanoribbon (AGNR). They found that by stacking a molecule of interest onto a narrow and otherwise pristine narrow AGNR, the resulting electron transmission generates characteristic dips and peaks representing electronic levels and coupling due to Fano resonances. This spectrum can then be used for molecular fingerprinting. The researchers show the utility of their method by distinguishing between naphthalene and thymine. They also show that this two-dimensional (2D) conductance spectrum can distinguish between all four DNA nucleobases, making it potentially suitable for DNA sequencing. Lastly, they show that this method can distinguish between methylated and unmethylated DNA, possibly providing an alternative to the commonly used bisulfite treatment and amplification method currently used for recognizing methylated nucleobases. The authors suggest that these findings could open a new field of Fano resonance-driven 2D molecular electronics spectroscopy, which could be as advantageous as 2D NMR over one-dimensional NMR spectroscopy.