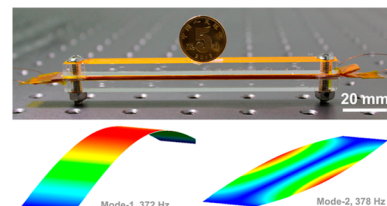


New Triboelectric Nanogenerator a Breath of Fresh Air

■ Wind energy is clean, renewable, and plentiful in nearly any location, making it a popular alternative to fossil fuels. While most wind energy is currently harvested using windmills, this scheme requires complex and massive power transmission and distribution systems to deliver the generated power from typically remote sites to users who are often located far away. Having a miniature, modularized, and efficient way to generate power from wind energy could address these issues. Some researchers have exploited triboelectric nanogenerators (TENGs) as wind energy harvesters. However, few studies have simulated the aerodynamics of these systems or sought to optimize their geometries to maximize output power.

In a new study, Wang *et al.* (DOI: 10.1021/acsnano.5b04396) developed a novel TENG for harvesting wind energy made of Kapton film with two Cu electrodes at both sides and two polytetrafluoroethylene (PTFE) films with Cu electrodes at the top and bottom acrylic substrates. When air flows into the device, it induces vibrations of the Kapton film, causing periodic contact and separation between the Cu electrode on the Kapton film and the PTFE films. By optimizing this device with a fluid channel size of $125 \times 10 \times 1.6 \text{ mm}^3$, it delivered a maximum output of about 9 kW/m^3 under a loading resistance of $2.3 \text{ M}\Omega$. Simulation experiments suggest that aero-elastic flutter is responsible for the Kapton film's vibration. A single TENG

produced enough energy to power a body temperature sensor with scavenged breath, and connecting multiple TENGs powered a globe light. The authors suggest that this system could lead to a new low-cost way to harvest clean energy.

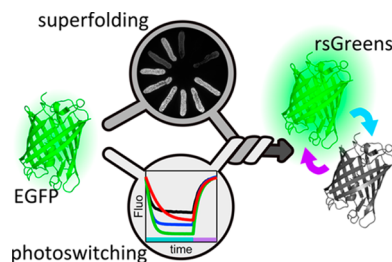


Bright Future in Super-Resolution Microscopy for Reversible Switching Greens

■ For decades, researchers have relied on fluorescent proteins (FPs) for minimally invasive imaging of intracellular structures in live systems. More recently, “smart” photoactive FPs have been developed, with features including irreversible photoactivation and photoconversion, or reversible photoswitching. These qualities have allowed the subsequent development of various imaging techniques such as (fluorescence) photoactivated localization microscopy ((f)PALM), reversible saturable optical fluorescence transitions (RESOLFT), and (photochromic) stochastic optical fluctuation imaging ((pc)SOFI). The success of these techniques has driven the search for even more FP-based smart labels with qualities better tailored to particular experiments.

In a new study, Duwé *et al.* (DOI: 10.1021/acsnano.5b04129) describe a new series of smart photoactive FP they call reversible switching greens (rsGreens). Variants of reversible switching enhanced green fluorescent protein (rsEGFP), the researchers designed rsGreens by introducing mutations using a combined rational and evolutionary approach. Tests on the new variants show up to 30-fold higher fluorescence in *Escherichia coli* colonies grown at 37°C and more than 4-fold higher fluorescence in HEK293T cells compared to rsEGFP. Further investigations suggest that this enhancement is due to higher expression levels that allow increased numbers of probe molecules to be functional at any given time. Members of the series displayed variable photoswitching kinetics that could

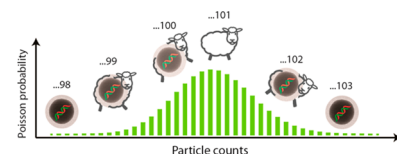
be successfully exploited in pcSOFI and RESOLFT. The authors suggest that the strategy used to create rsGreens could be applied to develop photoactive FPs with a wide range of photoswitching performance and fluorescence.



One Little, Two Little, Three Little Particles

■ Due to the increasing use of nanoparticles in consumer goods, industrial applications, and medical diagnostics, there is an increasing need to measure nanoparticle concentrations down to the level of single particles to gauge their impact. However, the concentrations of nanoparticles in colloidal dispersions are usually measured and given in mass concentration. Although methods exist to count single nanoparticles, they are excessively time-consuming or use complex technology that is limited to few laboratories.

In a new study, Paunescu *et al.* (DOI: 10.1021/acsnano.5b04429) describe a method that enables counting individual nanoparticles one by one based on polymerase chain reaction (PCR), a method long used to detect few copies of nucleic



acids through amplification. The researchers synthesized nanoparticles by depositing DNA on the surface of preformed silica particles through a layer-by-layer approach and adding a silica shell on top. After removing the shell with a fluoride comprising buffer, they used quantitative PCR to detect and to count the nanoparticles in solution, which allows indirect measurement of silica particle concentrations down to the range of parts per billion. To increase sensitivity down to the level of individual

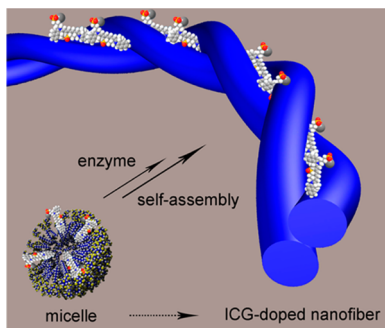
nanoparticles, the researchers used a binary method that relied on serial dilutions into wells and an algorithm based on the presence or absence of nanoparticles in a well. This method, which they term digital particle PCR, was able to count individual nanoparticles in the range of 60–250 nm in drinking water. The authors suggest that this method could be used for better understanding, tracing, and detecting nanoparticles in various media of interest.

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Building Cancer Fighters within Tumors

■ Treating cancer with hyperthermia has become an increasingly common treatment modality. Although heat can be delivered to tumors through a variety of methods, considerable interest has surrounded the use of photothermal therapy (PTT), a method in which photothermal conversion agents (PTCAs) absorb and convert optical energy into tumor-damaging heat. Photothermal therapy has a variety of advantages over other methods, including specific spatiotemporal selectivity and minimal invasiveness. However, most reported PTCAs have not yet qualified for clinical implementation due to poor pharmacokinetics, concerns over long-term biosafety, or other reasons. Clinical agents already approved by the Food and Drug Administration, such as the dye indocyanine green (ICG), might be good candidates for new PTCAs. However, ICG in



particular has a short half-life in circulation and cannot actively target tumors, leading to low tumor accumulation.

To improve ICG's suitability for PTT, Huang *et al.* (DOI: 10.1021/acsnano.5b03874) developed a strategy in which ICG-doped nanofibers formed within tumors were triggered by endogenous phosphatase,

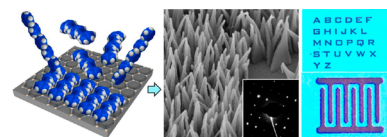
often overproduced by cancers. The researchers combined ICG with peptide precursor NapFFKYp to form micelles. These micelles then formed twisted nanofibers that incorporated ICG in the presence of alkaline phosphatase. Tests in cells, in tissue mimic, and *in vivo* showed that this process took place successfully. Further investigation showed that these assemblies significantly increased the tumor uptake of ICG, with tumors completely eradicated after administering laser irradiation 24–48 h post-injection. The authors suggest that this strategy could offer a useful cancer theranostic for PTT.

Organic Semiconducting Crystals Grow Up

■ Conjugated materials, including semiconducting or conducting polymers and small molecules, have attracted recent attention due to their tunable electronic properties and mechanical flexibility, qualities that hold promise for a variety of applications. To achieve the highest charge carrier transport in large area, high-density device arrays with high throughput, it is crucial to align single crystals of these materials. While various methods have achieved this goal parallel to substrates, aligning crystals vertically for applications that benefit from high surface area and directional transport in the vertical direction, such as solar cells and sensors, has remained challenging.

In a new study, Wang *et al.* (DOI: 10.1021/acsnano.5b03465) developed a facile, solution-based method for growing single crystalline conjugated molecules vertically using graphene as the guiding substrate. Using polyaniline tetraaniline (TANI) as a model, the researchers filled a loosely covered container with a nonsolvent for this molecule, then dropped a TANI solution onto a SiO₂/Si substrate coated with a single layer of graphene raised just above the nonsolvent. As the nonsolvent's vapor infiltrated the chamber, it induced TANI single crystals to grow vertically along their π - π stacking direction. The density of this crystalline growth was controllable by varying the concentration of the TANI solution,

and the orientation on the substrate was also customizable by varying the choice of infiltrating solvents. Because these crystals only grew on the graphene surface, patterned growth was possible by patterning graphene on the substrate. The authors suggest that growing crystals vertically could have potential in applications such as solar cells, supercapacitors, and sensors.



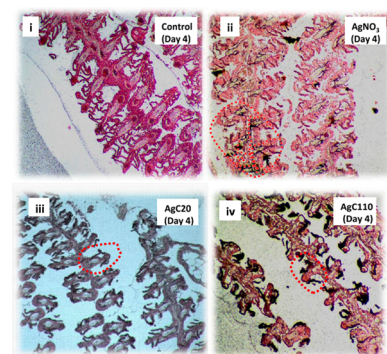
For Nanoparticle Toxicity, Size Matters

■ Nanoparticle production for consumer products continues to grow, with over 2000 nanoproducts currently in the marketplace. More than 400 of these nanoproducts contain silver nanoparticles (AgNPs), attractive for their antimicrobial properties. The likelihood of these materials reaching water systems and aquatic organisms that reside there is high. Numerous studies have shown that ionic silver can be toxic to fish and fish embryos, but less is known about the effects of AgNPs, particularly how specific characteristics such as size might impact toxicological outcomes.

In a new study, Osborne *et al.* (DOI: 10.1021/acsnano.5b04583) put this variable to the test by examining the effects of 20 vs 110 nm AgNPs on the gills and intestines of adult zebrafish, two sites

already known as target organs for Ag toxicity. The researchers exposed the animals to these materials for 4 h, 4 days, or 4 days plus a 7 day depuration period, using ionic AgNO₃ as a positive control. Results showed significantly more 20 nm particles than 110 nm particles in the gills after 4 h and 4 days. Although numbers of the two particle sizes were similar in the intestines at these time points, both particle types were retained here, even after depuration. The 20 nm particles were retained in the basolateral membranes of these organs and appeared to disrupt and to inhibit the Na⁺/K⁺ ion channel located there, with the 20 nm particles causing stronger effects than the larger nanoparticles or AgNO₃ on this structure. The authors suggest that the specific characteristics of

nanoparticles, such as size, should play an important role in studies examining their toxicity.



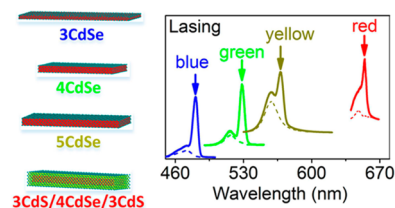
Rhapsody in Blue Amplified Spontaneous Emission and Lasing

Highly luminescent colloidal semiconductor nanocrystals' tunable emission and gain wavelengths, low cost, and solution processability have drawn attention to their potential as optical gain media. Although colloidal quantum dots have demonstrated optical gain and lasing, they have required high pump thresholds to generate amplified spontaneous emission (ASE) due to fast nonradiative Auger recombination. Such high thresholds have stymied the use of these materials for multicolor lasing, particularly in the blue range. Recent research using colloidal nanoplatelets has lowered the ASE threshold, making green lasing possible. However, finding the right medium with a sufficiently low ASE threshold and high threshold for

gain saturation to make blue ASE and lasing possible has remained a challenge.

Toward accomplishing this goal, She *et al.* (DOI: 10.1021/acsnano.5b02509) found that multicolor lasing, even in the blue, was possible using CdSe nanoplatelets of different thicknesses. Tests showed that these materials are capable of ASE in red, yellow, green, and blue, with a threshold for blue ASE of $50 \mu\text{J}/\text{cm}^2$, the lowest value yet reported for nanocrystals. By placing these colloidal nanoplatelets in simple optical cavities, the researchers also demonstrated red, yellow, green, and blue lasing. Further experiments showed that the lateral dimensions of these nanoplatelets had only a weak effect on the Auger recombination effects and, thus, had no significant

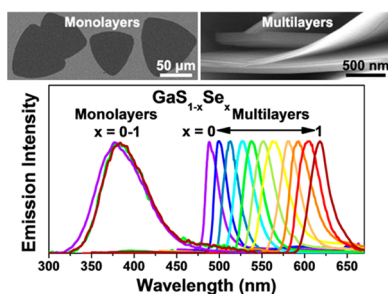
effect on the ASE threshold or gain saturation. The authors suggest that these results further support the promise of colloidal nanoplatelets as solution-processed optical gain materials.



Minding the Band Gap with Gallium Sulfide/Selenide

Graphene's high electron mobility and ballistic conduction have made this material promising for a variety of electronic applications. However, the lack of a band gap in pristine graphene has hampered its use in optoelectronic devices. Consequently, researchers have recently begun exploring other graphene-like two-dimensional materials with sizable band gaps as alternatives to graphene, such as transition metal dichalcogenides. Group-III monochalcogenides, such as GaS and GaSe, have shown particular promise for optoelectronics. Although studies have shown prominent band gaps for these materials, much about the electronic structures of these materials remains unknown.

Adding to the knowledge base for these materials, Jung *et al.* (DOI: 10.1021/acsnano.5b04876) investigated the electronic band



structure of GaS–GaSe alloys as both multilayer nanosheets and monolayers synthesized using chemical vapor transport. Their findings show that these materials have band gaps of 2.0–2.5 eV as multilayer nanosheets, linearly tuning the emission of these materials in the red-to-green range. However, as epitaxially grown monolayers, the band gaps jump to 3.3–3.4 eV,

blue-shifting the emission to the UV region. First-principles calculations show that as the number of layers increases to three, both the direct and indirect band gaps decrease significantly, with the indirect band gap approaching that of the multilayers. Further experiments show that oxygen adsorption plays a crucial role in the strong emission of GaS, causing the direct and indirect band gaps of GaS to converge. The authors suggest that the wide band gap tuning over the visible-to-UV range could eventually lead to full-color flexible and transparent light emitters and displays.

Making Sense of Materials Design with Digital Alchemy

Atomic valency constrains the building blocks of natural materials to only about 80 stable elements. However, for the engineered anisotropic colloidal nanoparticle "elements" with attractive patches known as patchy particles, valence is not discrete. Consequently, it is possible to design building blocks to assemble new complex materials with desired characteristics. However, the relationship between building block attributes and the resulting bulk structure is not always straightforward, complicating the design of optimal building blocks for any given structure.

In a new study, van Anders *et al.* (DOI: 10.1021/acsnano.5b04181) developed a statistical framework that forms the basis

for a novel computational approach to building block design. This new method, which the researchers dub "digital alchemy," linking it to prescientific attempts to modify chemical elements, relies on a set of novel thermodynamic response functions, moduli, and susceptibilities to optimize the building blocks for a given target structure and determine which building block attributes are most important to control for self-assembly. As proof of principle, the researchers use digital alchemy to establish direct links between the attributes of colloidal building blocks and their bulk structures for three types of colloidal nanoparticles: truncated tetrahedra that self-assemble into diamond structures, rhombic dodecahedra that self-assemble into

face-centered cubic structures, and isotropically interacting spheres that self-assemble into icosahedral quasicrystal structures. Although this study focuses on colloidal systems, the authors suggest that their method could also be applied to other systems with building blocks that have adjustable interactions, such as polymers or DNA origami.

