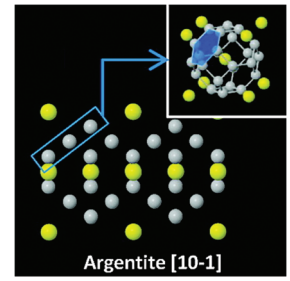
Flipping the Switch: Toward Understanding Switching Behavior

Developing low-power, low-cost, and high-density memory devices is necessary for designing novel portable digital systems. Substantial research efforts have focused on ionic and electronic mixed conductor-based solid electrolyte nonvolatile memories to replace switches made using conventional silicon-based technologies. Switching behavior in these new materials has been widely attributed to repetitive formation and breakage of the conductive filament inside a solid electrolyte. However, neither experimental nor theoretical works have yet elucidated the formation mechanism of such metallic filaments or provided details on how filaments grow microscopically and how the lattice responds.

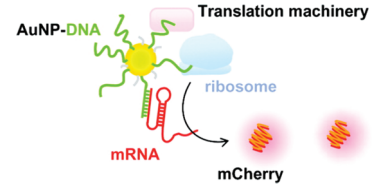
To clarify this process, Xu *et al.* (p 2515) directly observed at atomic resolution the formation and breakage of a conducting pathway in a $Ag/Ag_2S/W$ sandwich structure by completely reproducing its performance inside a high-resolution transmission electron microscope (TEM) equipped with a scanning tunneling microscope (STM). Their results show that the ionic and electronic conducting channel is created by the conducting Ag_2S argentite phase and the pure Ag crystal together. They also found that, after applying a negative bias, the argentite Ag_2S and Ag conducting channel becomes trespassed by the nonconductive acanthite phase, which breaks the channel. This leads to a dramatic increase in the resistance of the channel, switching the device off. The authors suggest that these findings will be beneficial for the practical development of advanced metal-cation-type nonvolatile memory devices. They also note that the approach they used to investigate this process provides a general method to answer other fundamental questions related to switch operations.



Tiny Gold Nanoparticles, Big Translation Enhancement

Nanoparticles (NPs) hold great potential for numerous biological and therapeutic applications. However, they exhibit substantial nonspecific adsorption of biomolecules, which can obscure biological function and lead to denaturation and other undesirable effects. One promising biological use for NPs that has not been well-explored is the possibility of enhancing *in vitro* translation of a protein. In this case, nonspecific adsorption could prove to be a boon. Since AuNP−DNA conjugates are approximately the same size as proteins, they could act as artificial scaffolds to bring key translation machinery proteins into proximity through the formation of numerous weak bonds. Contrary to being detrimental, these weak bonds could aid the turnover of species necessary for dynamic and repeating reactions.

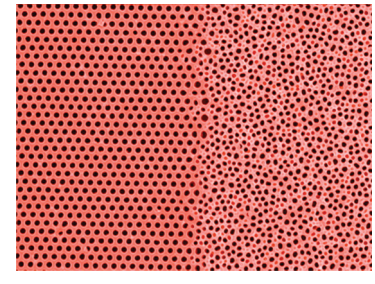
Park and Hamad-Schifferli (p 2555) tested this possibility by covalently conjugating AuNPs to DNA, then evaluating the effect of these conjugates on mRNA that coded for fluorescent proteins. Results showed that the AuNP−DNA conjugates enhanced production of these proteins in retic lysate mixes by 65−100%. Using gel electrophoresis, the researchers confirmed the presence of nonspecific adsorption of the conjugates to the translation machinery. They found that, if this adsorption was disabled, enhanced translation did not occur. Further tests showed that the highest amount of translation enhancement occurred when the DNA in the conjugates formed an incomplete duplex with mRNA. The authors suggest that these results show proof of principle that the nonspecific adsorption of AuNPs can be exploited to boost protein synthesis.



Nanopatterned Porous Alumina, in a Step and Flash

Researchers have explored anodic aluminum oxide (AAO) as a template material to develop various functional structures with commercial applications in electronic, optoelectronic, magnetic, and energy storage devices. While AAO contains a closely packed high aspect ratio of nanochannels, the pore array is usually far from that of the idealized model, resulting in defect-free domains that are limited to several square micrometers in area. Researchers have taken several approaches to increase the defect-free domain areas, including patterning the Al surface prior to the anodization process. However, most of these methods have been used on bulk Al foils but have not been successful in fabricating highly ordered AAO on substrates.

To solve this problem, Kustandi *et al.* (p 2561) developed a step and flash imprint lithography (SFIL) procedure that enables the rapid formation of highly ordered AAO on 4 in. Si substrates. The researchers deposited Al films about 500 nm thick onto substrates, then spun an organic planarization layer on top. They followed this with nanoliter droplets of UV-curable, low-viscosity materials, forming an etch barrier in the imprint area. A patterned quartz template was brought into contact with the covered substrate, followed by exposure to cross-linked monomers in the fluid, leaving behind an ordered array of polymeric holes. This pattern was transferred through the Al layer *via* wet etching, with anodization finally leaving behind an ordered array of pores. The researchers suggest that this method could open up a new way of producing large domains of highly ordered AAO on substrates for various device applications.



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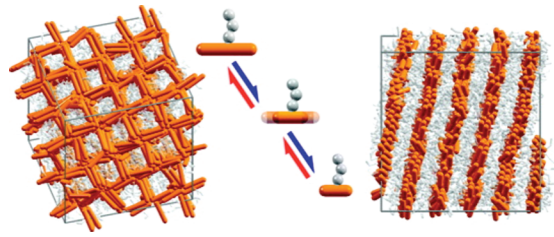
Reconfigurable Nanorod Assemblies Take—and Change—Shape

Researchers have long known that some organic supramolecules and liquid crystals exhibit conformational changes under external stimuli such as temperature, pressure, stress, solution pH, and electric or magnetic fields. These microscopic changes can lead to macroscopic structural transformations, which can result in significant changes in materials properties such as elastic modulus, thermal conductivity, bioactivity, and electromagnetic resonance. Though many examples of such reconfigurable materials exist in nature, few examples of traditional synthetic materials, especially those based on nanoparticles, are known. Reconfigurable nanoparticles would be advantageous for numerous applications, including smart materials, electromagnetic sensors, and drug delivery.

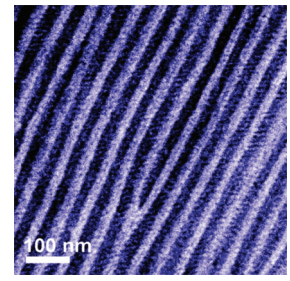
In a step toward developing reconfigurable nanomaterials, Nguyen and Glotzer (p 2585) performed molecular dynamics simulations that investigated a transformation between two thermodynamically stable structures self-assembled by laterally tethered nanorods whose rod lengths are switched between the two values. In the simulation, building blocks with longer rods assembled into a square grid structure, while those with short rods formed bilayer sheets with internal smectic A ordering at the same thermodynamic conditions. Shortening or lengthening the rods over a short time scale relative to the system equilibration time led to transformations between the square grid structure and bilayer sheets, with intermediate rod lengths showing honeycomb, honeycomb grid, or pentagonal grid structures. The authors suggest that such reversible nanoscale rod shortening and lengthening may be achievable experimentally through anisotropic cross-linking in an organic rod made of a polymer gel, for example. They add that, despite the simple shape change illustrated in this study, their approach is applicable to more interesting shapes that change in symmetry and topology.



Supramolecules Go Above and Beyond as Semiconductors

With their high purity and well-defined electronic properties, small-molecule organic semiconductors have decided advantages over their polymer analogues. However, due to dewetting and their strong tendency to crystallize, solution processing of these materials into uniform films remains a challenge. Additionally, when dealing with mixtures of electron donors and acceptors, researchers have yet to overcome the major hurdle of organizing the functional small molecules into nanoscopic grains to increase donor/acceptor interfaces. These grains need to be macroscopically oriented normal to the surface and the orientation, and molecular packing of the organic semiconductors within each grain needs to be tailored. Though various approaches have been explored to overcome these barriers, including the use of conjugated polymers and block copolymers, these materials present their own challenges, preventing further advancement.

Seeking a new approach, Rancatore *et al.* (p 2721) created supramolecules by attaching a quaterthiophene organic semiconductor to the side chains of a block copolymer poly(4-vinylpyridine) *via* noncovalent hydrogen bonds. Through a series of experiments, the researchers showed that these supramolecules act as p-type semiconductors in organic field-effect transistors. This material was readily solution-processed and successfully ordered into hierarchical assemblies with macroscopic alignment of the organic semiconductor in thin films. Results showed that the supramolecules exhibited the same field-effect mobilities as that of the quaterthiophene alone. The authors suggest that this approach should be applicable to other organic semiconductors, providing a versatile method to access films with spatial and orientational control of the semiconductor and potentially leading to the fabrication of high-performance organic photovoltaics or organic light-emitting diodes.



Multiplexed Quantum Dots Shine New Light on Prostate Cancer

Cancerous tumors display complex heterogeneity on molecular, cellular, and architectural levels, providing incredible challenges for researchers interested in studying the mechanisms of cancer development and in developing targeted therapies. Cancer cells within the same tumor are heterogeneous in their genetic mutations and their phenotypic expression profiles. Tumors themselves are a complicated mix of benign cells, malignant cells, fibroblasts, vascular cells, and others. Normal and cancerous cells are often arranged into distinct structures, such as glands in the prostate, with multiple lesions of varying degrees of malignancy found within the same tumor. Consequently, finding a way to identify different cells within tumors could lead to numerous research and clinical applications.

In a new study, Liu *et al.* (p 2755) evaluate multiplexed quantum dots for this purpose. Conjugating quantum dots to antibodies for four different protein biomarkers (E-cadherin, high-molecular-weight cytokeratin, p63, and α-methulacyl CoA racemase), the researchers were able to map tumor heterogeneity in sections of human prostate cancer tissue specimens using wavelength-resolved spectral imaging. Without removing cells from tissue sections, the researchers show that the major types of prostate cells can be separated with high precision. Through visualizing these various cell types in multiple tumors, the researchers demonstrated a stepwise process toward malignancy that starts with a single malignant cell forming in the basal or luminal layer, followed by a gland containing both a malignant region and a benign region, and ending with completely malignant structures with a single luminal cell layer. The authors suggest that this approach could eventually provide pivotal information for cancer research.