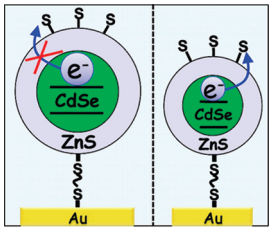
Isolated, to the Core?

Interest continues to grow in semiconductor nanoparticles due to their unique, size-tunable optical properties, a characteristic attributed to electron confinement. Research over the past decade and a half has shown that the electronic properties of these nanoparticles can be tailored by coating the semiconductor core with a shell composed of another material. Such differences in core/shell nanoparticles' attributes, compared to the core alone, are thought to result from the confined potential of the electron–hole pair, which isolates the core from traps on both the surface and the environment. However, it has been unclear how isolated the core truly is in core/shell nanoparticles.

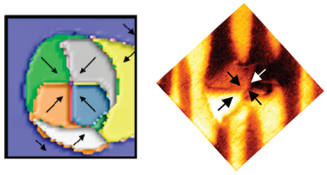
Xie *et al.* (p 863) investigated this question by applying a number of photoemission spectroscopy techniques to CdSe/ZnS core/shell nanoparticles and CdSe cores only, self-assembled on Au substrates with dithiol organic linkers. Their results suggest that the HOMO for the core/shell nanoparticles and the cores only both interact strongly with the Au substrate and are both pinned at the same energies relative to the Fermi level. When the researchers coated the nanoparticles with a dithiol layer, causing the formation of trap states, they found an effect on the LUMO signal that was size-dependent for the core/shell nanoparticles but not for the cores only. Results indicate that the LUMO states were not affected by surface trap states for core/shell nanoparticles with large cores, but those with small cores interacted strongly with these states. These findings suggest that the core of core/shell nanoparticles may not be as isolated from their environments as previous research had assumed.



The Power of Imperfection

All materials that exhibit long-range order, such as liquid crystals, superconductors, and ferroics, invariably also have topological defects. The type and mobility of these defects, as well as their interactions with structural elements such as point defects and dislocations, have a significant influence on the materials' functionality. For example, the domain walls in ferroic systems have been shown in numerous studies to influence virtually all aspects of ferroelectric behavior. However, despite the bevy of research on these two-dimensional defects, the influence of one-dimensional (1D) defects, such as vortex and antivortex states, is not well-known.

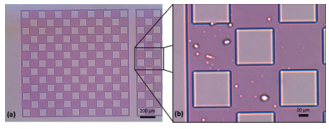
Seeking to illuminate the impact of these 1D defects, Vasudevan *et al.* (p 879) studied them in epitaxial $BiFeO_3$ films. The researchers worked with (100)-oriented thin films grown on $SrRuO_3$-buffered substrates with equal-width strip domains about 200 nm apart. Using pulses from the biased tip of a scanning probe microscope at the ferroelastic domain walls, the researchers created topological defects with complex domain arrangements in the films. Piezoresponse force microscopy (PFM) and phase-field modeling suggested the formation of center-type defects, with polarization vectors pointing into or away from the defect's center. These defects were only stable when formed with a high-voltage pulse. Similarly, PFM and phase-field modeling also suggested possible formations of closure, or vortex-like, domain arrangements, with polarization vectors pointing in a clockwise direction. The defects were reversible when the opposite bias was applied. The authors note that these results provide insight into how topological defects affect ferroelastic domains and suggest that formation of these defects is far more ubiquitous than previously believed.



Putting Aside Differences with Nanomembrane Bonding

The ability to bond different semiconductors together directly in a heterojunction could have many useful applications, including novel solar cells, photodetectors, or light emitters. However, these possibilities are currently limited to heteroepitaxy between materials with similar lattice constants, and thus composition, which have the least difficulty in creating high-quality interfaces and electronic junctions. Though researchers have had some success at forming heterojunctions through wafer bonding, these materials tend to develop massive numbers of dislocations with thermal-expansion mismatch during bonding or thermal cycling during use, significantly degrading their properties.

Seeking to avoid these problems, Kiefer *et al.* (p 1179) tried a new approach by bonding a very thin (200 nm) Si nanomembrane to a bulk Ge wafer. Though previous studies have shown that these two dissimilar materials generally do not form successful heterojunctions, optical microscopy and cross-sectional transmission electron microscopy showed excellent bonding and high interface quality, with an interfacial region of about 1 nm. No inhomogeneities were visible in the bond interface or in the crystalline material near the interfacial region. Electrical tests showed that the resulting heterojunction was highly conductive. On the basis of the high twist angle between the two materials (about 22°), the researchers suggest that the interfacial atoms rearrange into an amorphous layer to bond the two surfaces covalently. These structural and electrical findings suggest that interfacial conductivity between the two layers fits a tunneling model. The authors suggest that their approach of combining semiconductors by bonding a thin membrane to a substrate could lead to a new generation of high-performance semiconductor devices.



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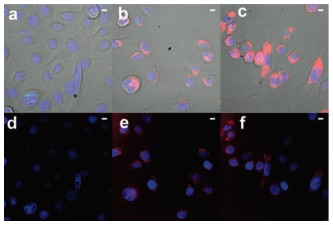
Optical Viral Ghosts Friendly for Cell Imaging

Researchers have recently developed a wide variety of nanosized structures for biomedical imaging and therapy. Those capable of use in near-infrared (NIR) fluorescent imaging hold several advantages, including relatively deep optical penetration, better signal-to-background ratio in tissues, and the potential for imaging at the subcellular or molecular level. Studies have demonstrated some success with nanoparticles including quantum dots and metallic materials, but using biological materials as base materials for imaging nanoparticles is increasingly gaining traction. Several studies have demonstrated plant viruses' ability to conjugate dyes or to target molecules. However, none so far have incorporated a NIR chromophore into a plant virus for use in mammalian intracellular imaging.

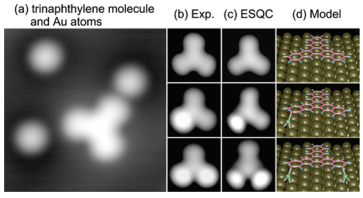


To test this possibility, Jung *et al.* (p 1243) encapsulated indocyanine green (ICG) into the capsid of brome mosaic virus (BMV), an RNA virus that commonly infects grasses and other plants. After growing BMV on barley leaves, the researchers disassociated the viruses' capsid proteins, removed the native RNA, then replaced it with ICG. Once the capsid proteins were reassembled, the researchers named the resulting ICG-doped, genome-less viruses "optical viral ghosts" (OVG). They showed that these OVGs were physically and optically stable at physiological temperatures and over time. Additional experiments demonstrated that the OVGs were taken up by human bronchial epithelial cells and were easily visible at the nuclear periphery, establishing their worth as intracellular imaging tools. The authors suggest that these plant-virus-based nanoparticles could eventually be made even more useful by attaching targeting moieties or endowing them with therapeutic capabilities.

Taking Molecular Computing to the Next Logical Step

Moore's law dictates that the number of transistors that developers can fit on a chip doubles about every 18 months. To keep this trend, researchers are working on reducing the size of the most fundamental components needed for computing: logic gates. Previous studies have shown some successes in creating logic gates that operate on the molecular level. However, the search continues for ways to shrink logic gates even further.

In a new study, Soe *et al.* (p 1436) created a logic gate based on a single molecule, choosing the trinaphthylene molecule as their model. This star-shaped molecule has three naphthyl branches that act as two inputs and an output. The investigators physisorbed this molecule onto a Au substrate, then manipulated the input branches by adding or subtracting single Au atoms, with an Au atom acting as a logical "1" and no Au atom acting as a "0". They measured the output by placing the tip of a scanning tunneling microscope on the molecule's third branch to evaluate changes in the electronic spectra. Their findings showed that the trinaphthylene molecule effectively served as a NOR gate, with Au inputs shifting the ground state's energy by 0.1−0.2 eV as a function of the number of added Au atoms and a change in the frontier molecular orbital distributions. The authors suggest that other molecules might also be useful for creating molecular logic gates, with differing Boolean truth tables based on molecular orbital structure.



Double-Walled Carbon Nanotubes Get Sorted by Taking a Spin

Double-walled carbon nanotubes (DWNTs) are drawing increasing attention due to their unique properties intermediate between those of single-walled nanotubes and multiwalled nanotubes. For example, DWNTs exhibit band gaps big enough for use in field-effect transistors like single-walled nanotubes, but they also have the longevity and high stability of multiwalled nanotubes. However, researchers have not been able to investigate these beneficial properties fully due to DWNT's polydispersity. Each DWNT can be one of four different permutations based on whether the outer and inner walls are metallic or semiconducting.

Seeking a way to sort DWNTs based on their electronic type, Green and Hersam (p 1459) looked to density gradient ultracentrifugation (DGU) Using different ratios of sodium cholate and sodium dodecyl sulfate as cosurfactants, the researchers used a multistep DGU process to isolate DWNTs from single- and multiwalled nanotube impurities, then separated DWNTs into collections of those with semiconducting or metallic outer walls. Optical absorbance and Ramanspectroscopy verified purities of 96 and 98% for the semiconducting and metallic DWNTs, respectively. To test the performance of these materials, the researchers incorporated networks of both types of DWNTs into thin-film transistors (TFT). Tests showed that the semiconducting devices had on/off ratios 2 orders of magnitude higher than metallic ones. However, neither type of device performed as well as TFT based on single-walled nanotubes, potentially because of gate screening and electronic perturbations from the DWNT's inner wall. The authors note that further improvements to their DGU protocol may lead to separations of DWNTs into all four permutations.