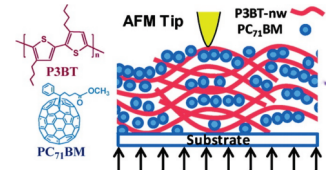
For Squeezing More Energy from Sunlight, Structure Equals Function

Polymer-based bulk heterojunction solar cells have recently shown great promise to provide low-cost solar power conversion due to inexpensive high throughput manufacturing techniques that might be used for their production. Composites of poly(3-hexylthiopehene) (P3HT) and phenyl-C_{61}-butyric acid methyl ester (PCBM) have dominated research in this field, providing some of the highest measured power conversion efficiencies. Researchers have strived to improve efficiency in devices based on these materials by optimizing the two-phase nanostructure of the donor and acceptor materials.

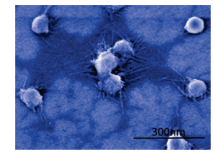
Toward this end, Xin *et al*. (p 1861) created new composite materials based on self-assembled poly(3-butylthiophene) nanowires (P3BT-nw) as the donor component and fullerenes as the acceptors. The researchers varied the morphology of these films using different processing conditions involving various drying times for the solvent and the presence or absence of thermal annealing. Transmission electron microscopy (TEM) and atomic force microscopy (AFM) revealed that longer drying times led to denser collections of nanowires in the films. Those allowed to dry completely showed aggregation of fullerenes in the interstices of the nanowires. Structure correlated strongly with function in these films, with denser films displaying a high short-circuit current density but relatively low open circuit voltage. Films with fewer nanowires resulted in higher open-circuit voltage but lower current density. In a device structure that balances these factors, an average efficiency of 3.35% was achieved. The authors suggest that further improvement can be achieved in a structure that maintains the interpenetrating network of nanowires and fullerene phases but avoids a device bridging effect.



Spitting Image: Characterizing Exosomes from Saliva

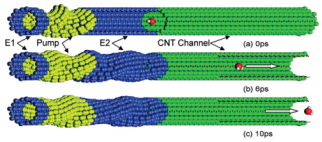
Researchers have recently become interested in characterizing naturally occurring sub-100 nm cellular nanostructures such as vaults, viruses, and lipid vesicles due to their potential applications in drug delivery and immunotherapy. Other nanosized particles of interest are exosomes, 50−100 nm particles secreted by a range of mammalian cells into body fluids such as saliva, blood, and urine. The physiological function of salivary exosomes is unclear, though they have recently gained significance as novel biomarkers for oral cancer. Previous studies with transmission electron microscopy (TEM), proteomic analysis, and transcriptional analysis have been unable to fully characterize these nanoparticles, and a thorough investigation of individual exosomes could shed light on their function as biomarkers and clarify their physiological role.

Seeking to further the knowledge of individual salivary exosomes, Sharma *et al*. (p 1921) used ultrasensitive low-force atomic force microscopy (AFM) and correlated the structural evidence gleaned from this technique with field-emission scanning electron microscopy (FESEM) images. These methods revealed spherical vesicles up to 100 nm in diameter with a trilobed membrane. The images show the exosomes possess a heterogeneous surface, suggesting the presence of proteins enclosed within the membrane. The membranes were elastic, and the exosomes remained intact with forces up to 5 nN before rupture. Experiments using force spectroscopy with antiCD63 IgG-functionalized AFM tips revealed sensitive detection of antigenCD63, a potentially useful cancer biomarker. The researchers suggest that these findings add critical knowledge of salivary exosomes' morphological, biomechanical, and surface biomolecular properties for applications in cancer diagnosis and developing new cell delivery systems.



Nanoscale Water Pumps Do the Twist

Carbon nanotubes (CNTs) have unique electrical, mechanical, and thermal properties that enable their use for a variety of applications, including microelectromechanical and nanoelectromechanical systems. Furthermore, the large surface area and smooth walls of CNTs suggest they might also be useful for transporting atoms and molecules. Previous studies have investigated water transport in CNTs to explore their potential as microcapillaries. However, little research has focused on using CNTs as energy pumps to propel water actively.



To investigate this possibility, Duan and Wang (p 2338) employed molecular dynamics simulations using long CNTs that were pretwisted on one end and secured on each side of the twist. By releasing one of the restraints, the researchers were able to explore the transportation of water through the untwisted portion of the CNTs resulting from the transfer of potential energy stored in the twist. The researchers found that shorter pumps stored higher strain energy than longer pumps, resulting in higher driving forces on the water and more efficient transport for single water molecules. In scenarios where more water molecules were placed in the tube, transportation was successful, though delayed. Further delays were introduced when the untwisted portion of the tube was left unrestrained, dissipating some of the potential energy. The researchers also found that high environmental temperatures slowed water movement due to more collisions between the water molecules and the CNT walls. The authors suggest that these findings contribute to the knowledge necessary to advance CNT pumps for applications including microarrays and drug delivery.

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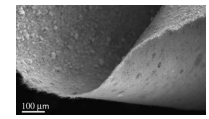
Around the Bend with Germanium Nanowires

Germanium is a brittle material, displaying measurable ductility only at high temperatures. Typical room temperature fracture strengths are between 40 and 95 MPa, orders of magnitude lower than the ideal strength expected for a perfect Ge crystal of 14−20 GPa. Researchers have shown that nanowires made of other materials that are brittle in bulk have fracture strengths near those of ideal perfect crystals, presumably due to limited size and reduced concentrations of defects and stresses.

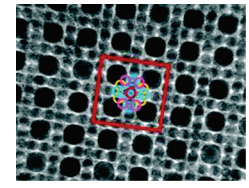
To investigate whether Ge follows the same pattern, Smith *et al.* (p 2356) tested the mechanical strength of Ge nanowires with diameters ranging from 23 to 97 nm. The researchers synthesized these using a novel approach they developed and termed supercritical fluid−liquid−solid growth, which enables the production of large quantities of nanowires. These Ge nanowires were drop-cast onto transmission electron microscopy (TEM) grids coated with a membrane arrayed with 2 μm diameter holes. They then used electrochemically sharpened tungsten probes to break individual nanowires close to the membrane and to manipulate them across the holes to test bending strength. The researchers found a trend of increasing bending strength with decreasing nanowire diameter, with the thinnest nanowires approaching the ideal strength predicted for perfect Ge crystals. Those nanowires bent and released prior to fracture displayed some elasticity, snapping back but retaining some bend. The researchers took advantage of these properties to craft a highly flexible fabric made of Ge nanowires. They suggest their findings demonstrate the remarkable flexibility and strength of Ge nanowires and illustrate their potential as building blocks for numerous applications.



As the Nanocrystal Superlattice Tilts

Interest continues to grow in multicomponent nanocrystal assemblies due to their fundamental role in self-assembly and novel physical properties arising from particle interactions. These structures offer promising potential for applications in electrical, optical, and magnetic devices. Previous research has shown that various combinations of nanocrystals can customize the properties of these structures. Since synergistic effects have been shown to arise from particle interactions, understanding the three-dimensional structures of nanocrystal superlattices is critical for tailoring their collective properties.

To find a better way to study the structures of nanocrystal superlattices, Chen *et al.* (p 2374) employed a dual-axis tomography holder to use with transmission electron microscopy (TEM). They used this technique on novel binary nanocrystal superlattices (BNSLs) consisting of different sizes of Fe_3O_4 nanocrystals, to obtain 9 different tilt series and identify 14 distinct crystallographic projections from these AB_{13}-type BNSLs. Analyzing TEM images and small-angle electron diffraction patterns from each tilt series, the researchers were able to confirm that these BNSLs can be assigned uniquely to the ico-AB_{13} type, which has an icosahedral structure consisting of 13 small spheres inside a simple cubic lattice of large spheres. The technique enabled the researchers to rule out an alternative polymorph that has been suggested, the cubooctahedral AB_{13} type. The authors note that this technique offers opportunities for further exploration of structural diversity and structure−property relationships in nanoscale superlattices.



Silicon Membranes in the Rough

Quantum confinement is a phenomenon where electrons in a crystalline solid are constrained to a region smaller than the typical carrier de Broglie wavelength; this causes the transport and optical properties of charge carriers to be different from those in bulk material. This effect introduces changes in the density of states (DOS), inducing shifts and degeneracy splitting in features of the band structure. Variations in thickness in the confinement directions, such as those due to surface roughness, can alter the ideal DOS expected from confinement, causing states to be broadened and electron transport to be affected.

In a new study, Chen *et al.* (p 2466) studied these effects in very thin Si sheets with a combination of spectroscopy and theory. Silicon has shown potential as a useful thermoelectric material when fabricated as nanowires, and previous studies have already shown a dramatic increase in the thermoelectric properties of Si nanowires *via* the reduction of thermal conductivity. Using high-energy-resolution soft X-ray absorption spectroscopy, the researchers investigated changes in the Si conduction band for sheets ranging from 1.3 nm to hundreds of nm. They found that quantum confinement effects lift the 6-fold degeneracy of the bulk-Si conduction band minimum, forming two nonequivalent sub-band ladders. Results show that even slight surface roughness "smears" the nominally step-like features in the DOS due to these sub-bands. Theoretically extrapolating their one-dimensional findings to two-dimensional nanowires, they show that even very small surface roughness washes out the sub-bands. The researchers suggest that these surface roughness effects must be seriously considered when contemplating the use of quantum size effects in Si for enhancing the thermoelectric power factor.