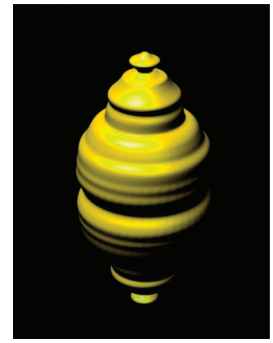
Opening Up the Potential of Vault Particles

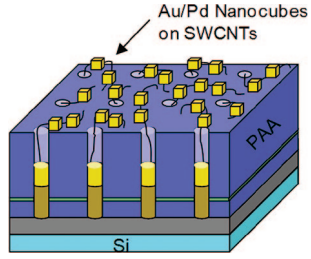
Finding a suitable method to deliver therapeutic agents to specific host tissues could revolutionize treatment for a variety of diseases, including cancer. One promising approach for getting therapeutics to their destination is encapsulating them into nanoparticles, which have been shown to accumulate preferentially in tumor tissues. While some research teams have focused on constructing synthetic nanoparticles for this use, Kickhoefer *et al.* (p 27) suggest that natural, nanometer-sized cellular components known as vault particles might also serve this purpose. These barrel-shaped ribonuclear protein particles, found in phylogeny as diverse as mammals, avians, kinetoplasts, and amoebas, have easily modifiable structures and sizes large enough to encompass a wide variety of drugs, nucleic acids, or proteins.



To test this idea, the researchers created recombinant vault particles, adding one of three different tags to the C-terminus of the protein that comprises the particles' outer shell: an 11-amino-acid epitope tag, a 33-amino-acid IgG-binding peptide, and the 55-amino-acid epidermal growth factor (EGF). Microscopy images suggest that the tags are expressed externally on the modified vault particles' caps. Further tests showed that these recombinant vault particles could be targeted to epithelial cancer cells, which overexpress the epidermal growth factor receptor (EGFR), either directly with the EGF-modified vaults, or through a monoclonal anti-EGFR antibody bound to vaults containing the IgG-binding peptide. The authors suggest that the ability to direct vaults to specific cells represents a significant advance to using modified vault particles as vehicles for therapeutics.

Nanocube–Nanotube Combo Sniffs Out Glucose

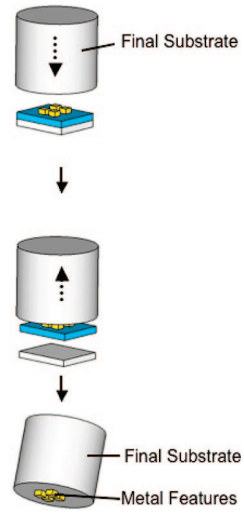
Nanomaterials offer many advantages as components for electrochemical biosensors, with the power to increase sensitivity and lower power needs for real-time detection of clinically important analytes, including biomolecules for the early diagnosis and successful treatment of diseases. Some groups have sought to incorporate single-walled carbon nanotubes (SWCNTs) into such devices, decorating the nanotubes with Pd and Pt nanoparticles to increase electrocatalytic activity further. Though these biosensors show some of the best performances reported thus far, they lack a scalable fabrication method, have limited biocompatibility, and often require complex biofunctionalization schemes that increase fabrication time and cost.



Seeking to overcome these problems, Claussen *et al.* (p 37) developed a SWCNT-based electrochemical biosensor that incorporates Au-coated Pd nanocubes to enhance electrocatalytic activity, provide selective biofunctionalization docking points, and improve biocompatibility. The researchers grew SWCNTs in a porous anodic alumina template, electrodepositing the Au/Pd nanocubes onto the SWCNTs once they grew to the desired length. The team functionalized the Au surfaces with glucose oxidase, an enzyme that breaks down the sugar into its metabolites and hydrogen peroxide, and used this biosensor to detect glucose. The researchers found that the sensor generated a redox current proportional to glucose concentration, with a wide linear range and low detection limit. These promising results, coupled with the high biocompatibility of the device, could make this biofunctionalization scheme useful for a range of biomarker detection strategies.

Sticky Film Transfers Metallic Nanopatterns

Conventional lithographic techniques, including electron-beam lithography, are typically limited to large, planar surfaces. The ability to construct nanoscale patterns on small or curved substrates is advantageous for many applications, including fiber-based sensing, nanoscale optical lithography, three-dimensional fabrication, and integration of compact optical elements on fiber and semiconductor lasers. To harness the unusual optical, thermal, electrical, and magnetic properties of nanostructures into functional devices, their size, shape, and position on these substrates need to be precisely controlled.



In a new study, Smythe *et al.* (p 59) introduce a novel technique that uses a thin thiol-ene film to strip nanoscale metallic features from one substrate, then attach them to a second, unconventional substrate that would be difficult or impossible to pattern with current lithographic techniques. The researchers started by using traditional electron-beam lithography to pattern Au and Ag features on a Si substrate. They then pressed a thin polymer film bearing thiol-groups onto the features, stripping them off the substrate. The film was pressed onto a final substrate, which could be removed sacrificially with an oxygen plasma, leaving the features intact. Using this method, Smythe *et al.* transferred a variety of arbitrary metallic patterns onto the small facet of an optical fiber and a small microsphere, both surfaces incompatible with conventional lithography. The study suggests that this method could be adapted to transfer patterns made of different materials onto a variety of unconventional substrate geometries and compositions.

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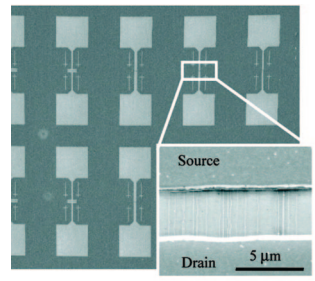
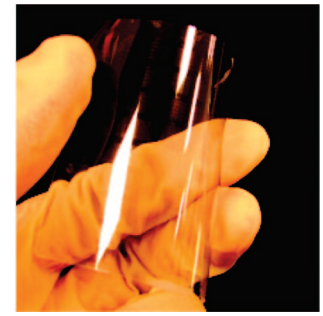
Seeing the Future of Transparent Electronics

Transparent, or "invisible", electronics are an emerging technology that may be the basis for the next generation of optoelectronic devices. If these devices are also flexible, they have a variety of exciting commercial applications ranging from electronic paper, wearable displays, smart tags, and artificial skin. To realize this technology, researchers have investigated the development of transparent, thin-film transistors (TTFT) with high device mobility and low-temperature fabrication. Previously, researchers have considered composing such transistors using materials such as wide band gap semiconductors and semiconductor nanowires arranged in random networks. However, these materials generally have low carrier mobilities.

Seeking to improve existing performance, Ishikawa *et al.* (p 73) fabricated TTFTs made with highly aligned single-walled carbon nanotubes. The researchers grew the nanotubes on quartz substrates and transferred them to glass with prepatterned indium tin oxide (ITO) gate electrodes, followed by patterning of transparent source and drain electrodes. The low-temperature fabrication allowed the researchers to use a similar technique with polyethylene terephthalate (PET) as a flexible substrate. Performance tests showed that the TTFTs on glass substrates had good transparency and high effective mobilities of about 1300 $cm^2 V^{-1} s^{-1}$, the highest among transparent transistors using various active materials reported thus far. The TTFTs

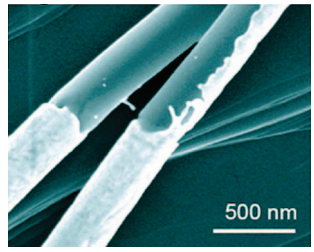




on PET substrates operated successfully when bent up to 120°. As proof of principle, the researchers further utilized the transistors to construct a fully transparent and flexible logic inverter on a plastic substrate, as well as to control commercial GaN light-emitting diodes with light intensity modulation of 10^3. The results suggest that aligned nanotubes could form the building blocks for future high-performance transparent and flexible electronics.

Spare the Rod, Spoil the Signal?

Plasmonic nanostructures are a topic of intense interest due to their potential use as waveguides and enhancing structures for metal-enhanced fluorescence and surface-enhanced Raman scattering (SERS). Researchers have used a variety of methods to fabricate nanostructures to probe their relationship with plasmonic properties. However, relatively few methods exist to create free-standing, dispersible nanostructures with control over feature size on the sub-100-mn scale.



In a new study, Chen *et al.* (p 87) detail their fabrication of novel heteronanostructures with a rod-sheath shape. The researchers grew multisegmented nanowires out of Au and polypyrrole in an anodic aluminum oxide membrane and allowed them to remain in this template while being dried in a vacuum. The polymer segments contracted by ~10% and adhered to the walls of the template, forming a crescent-shaped channel. Filling the channels with Au produced the rod−sheath structure. The researchers then investigated the SERS behavior of the rod−sheath structures and found that the intensity of the Raman signal at the junction formed between rod and sheath segments is more than four times higher than that at the edge of the rod or sheath, suggesting a strong electromagnetic field at the junction of the rod and sheath segments. Calculations also showed that both rods and sheaths have high electric fields at their ends, corresponding to the influence of the sharp nanostructures on the local fields. Plasmon interference could be tuned by varying the sheath and rod lengths. These novel rod−sheath heteronanostructures represent a new type of material for plasmonic focusing.

Getting to the Bottom of Phonon Bottlenecks

Confinement of charge carriers gives quantum dots (QDs) their size-tunable electronic properties. These properties make QDs promising materials for diverse applications ranging from optoelectronic devices to quantum computing to biological image probes. The electron−phonon interaction is integral to most of these applications and is also intriguing from a fundamental perspective. Although many theoretical and experimental studies have focused on the phonon-mediated relaxation of electrons and holes in QDs, this phenomenon is not yet fully understood. Specifically, quantization of the electronic energy levels induced in the QDs by spatial confinement seems to result in mismatches between the electronic gaps and phonon frequencies, leading to the expectation of a "phonon bottleneck", a dramatic slowdown of electron−phonon relaxation. However, recent experiments have shown no such phonon bottlenecks.

To understand this phenomenon, Kilina *et al.* (p 93) conducted a time-domain *ab initio* study of the charge-phonon relaxation dynamics in PbSe and CdSe quantum dots, two widely used semiconductors with substantially different electronic structure. Their simulations suggest that, at an atomistic level, subpicosecond relaxation and absence of phonon bottlenecks in both materials result from efficient nonadiabatic decay channels. The researchers surmise that the relaxation happens quickly because the underlying atomic structure, surface reconstruction, thermal fluctuations, and other factors break the symmetry of the QDs, lift electronic state degeneracies, and generate a dense distribution of energy levels. They note that these findings apply generally to nanomaterials, broadening our fundamental view of electron−phonon interactions.