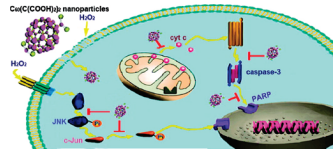
Buckyballs: Saving Cells from Certain Death

A potential application in nanobiotechnology that has received little attention is the development of nanotechnology-based drugs for antioxidant defense. Many tissues, notably those in the central nervous system, are vulnerable to damage from reactive oxygen species (ROS), normal products of cellular oxygen metabolism. While many natural products, including carotenoids, vitamin C, and uric acid, can effectively diminish ROS and its associated damage, studies have shown that some nanoparticles are also effective ROS scavengers, making them good candidates as potential antioxidants.

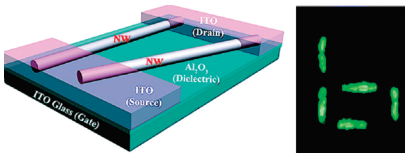
In a new study, Lao *et al.* (p 3358) tested a fullerene derivative, C_{60}-$(C(COOH)_2)_2$, on cerebral microvessel endothelial cells (CMECs). These cells, which serve as part of the blood brain barrier, are particularly vulnerable to oxidative stress due to their high mitochondrial content. The team incubated CMECs in solutions containing the $C_{60}(C(COOH)_2)_2$ nanoparticles, including some exposed to oxidizing H_2O_2. Fluorescent dye tests showed that more of the nanoparticles entered the cells that were under oxidative stress, suggesting that oxidant stimulation facilitated $C_{60}(C(COOH)_2)_2$ uptake. Further experiments showed that the nanoparticles prevented apoptosis in the CMECs in a dose-dependent manner, suggesting potent antioxidant protection. The researchers found that this protective action is based on maintaining the integrity of the cytoskeleton, by modulating signaling events related to the JNK pathway, part of the MAP-K pathway. This promising initial study suggests that fullerene derivatives may be used eventually to treat neurological disorders that result from oxidative damage.



Doped Nanowires a Clear Advantage in Transparent Thin Film Transistors

Numerous research efforts focus on transparent electronics in commercial applications including displays and charge-coupled devices. These technologies require the development of transparent thin film transistors (TTFT) with high device mobilities, moderate carrier concentrations, low threshold voltages, and steep subthreshold slopes. TTFTs fabricated with transparent conducting oxide thin films have been widely studied, but these films usually exhibit low mobilities and high threshold voltages, limiting their application in high-frequency devices. Other groups have incorporated nanowires into TTFTs, including In_2O_3 nanowires. Their wide energy band gap, single-crystalline nanostructure, and high device mobility make them a good choice for high-performance TTFTs.

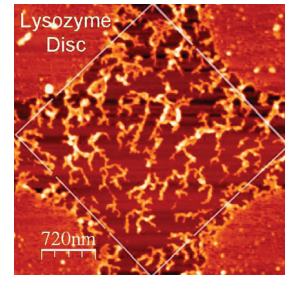
Seeking to build upon previous successes with In_2O_3 nanowires, Chen *et al.* (p 3383) used a laser ablation process to synthesize In_2O_3 nanowires doped with As, a well-known n-type dopant that enhances the conductive properties of In_2O_3 thin films. They then fabricated this material into TTFTs on glass substrates with indium tin oxide (ITO) as the source, drain, and gate electrodes. Tests showed that these devices exhibit high device mobilities, current on/off ratios, steep threshold slopes, and a saturation current of 60 μA for a single nanowire. The researchers were able to improve the device mobilities and saturation current further by using a self-assembled gate dielectric. These TTFTs were utilized successfully to control green organic light-emitting diodes (OLEDs) with varied intensities and fabricated into a seven-segment active-matrix OLEDs able to display numbers, suggesting that As-doped nanowires have the potential to serve as building blocks for future transparent electronics.



Nanowires Live on the Edge

The ability to place nanowires in a predictable manner is critical for their use in a variety of applications, ranging from high-performance solar cells to nanolasers to biosensors. Many of these devices require nanowires that are positioned on surfaces without crossing or collapsing over each other. Manipulating nanowires individually is too laborious to be practical; however, positioning nanowires in bulk over large areas while avoiding overlap remains a challenge.

Toward this end, Gao and Cai (p 3475) developed a new technique for interfacing and positioning nanowires. Rather than manufacturing the nanowires in bulk followed by positioning them on a surface, the team fabricated non-crossing nanowires directly on a surface using DNA aptamers, single-stranded nucleic acids that bind specifically to target molecules. Using lithography, the researchers fabricated a template of lysozyme on a cross-linked silane film. After incubating the film in a concentrated anti-lysozyme aptamer solution followed by a buffer solution, the aptamers bound preferentially to the lysozyme pattern edges. Atomic force microscopy measurements showed that these anchored aptamer fibers were 1−6 nm high and up to tens of micrometers long. Using the fibers as scaffolds, Gao and Cai used DNA metallization to bind Pd to the aptamers, creating Pd nanowires. In another experiment, they converted biotin-tagged aptamers to streptavidin nanowires, illustrating that the chemistry of individual aptamers can determine the template synthesis. The researchers suggest that such exploitation of the biospecific recognition of aptamers may eventually provide the spatial control and interfacing necessary for many desirable nanowire applications.



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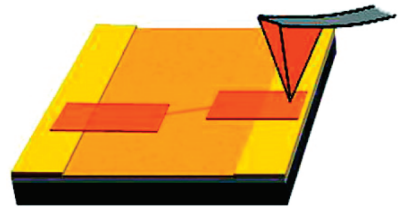
Dip-Pen Mightier Than Electron-Beam Lithography?

There have been numerous demonstrations of single-walled carbon nanotube (SWNT) devices, including single-electron and field-effect transistors, chemical sensors, and transparent electronics. For SWNT devices to achieve their potential in these applications, further research is needed on facile fabrication methods that maintain the electrical properties of SWNTs in the device configuration. Typically, electron-beam lithography is used to fabricate SWNT devices; however, exposing SWNTs to electron irradiation can damage them and prevent measurement of their intrinsic properties, necessitating other methods without this drawback.

In a proof-of-concept study, Wang *et al.* (p 3543) used dip-pen nanolithography (DPN) to pattern the electrical contacts in SWNT devices. DPN is a scanning-probe technique that

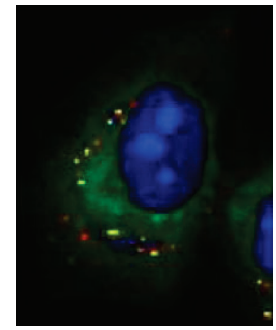


combines the nanoscale resolution of electron-beam lithography with direct-write capability. Using the imaging capabilities of DPN, the researchers were able to locate individual SWNTs deposited on a substrate onto which a thin film of Au had been evaporated. Then, they used DPN to mask electrical contacts to these SWNTs by depositing an alkanethiol "ink" followed by a wet Au etchant to form individual devices, eventually developing three different types: semimetallic, semiconducting, and metallic. Tests showed that the conductivity of the contacts compared favorably to those created with electron-beam lithography, and electrical characterization of the devices demonstrated that this fabrication method does not alter the electronic properties of the SWNTs. The authors suggest that DPN is a viable alternative to electron-beam lithography for creating single nanotube devices.

Intracellular Drug Delivery: Getting an Inside Look

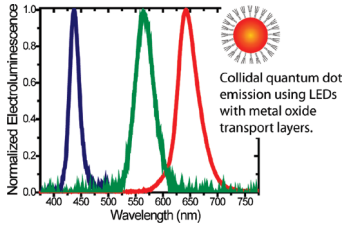
Nanosized vehicles for drug delivery offer numerous advantages over many conventional drug carriers, including the potential to target specific tissues more easily, and more efficient conversion of molecules with undesirable pharmacokinetics into therapeutic agents. Many materials have been considered for *in vivo* use, including micelles, liposomes, and diverse polymeric nanostructures. Though numerous experiments have been performed to understand the retention and cytotoxicity of these materials within the body, researchers still know little about the fate, consequences, and impact of these nanoparticles on intracellular homeostasis. Fluorescent imaging is often used to track these carriers, but this technique has disadvantages, including the potential of the fluorophore to leak out of the system or interfere with the biochemical behavior of the labeled molecule. Without a robust method for imaging the vehicle and delivery of its payload, the efficacy of a drug delivery system remains unknown.

Seeking a new way to track nanoparticle vehicles inside cells, Chernenko *et al.* (p 3552) developed a novel method combining optical microscopy with Raman spectroscopy, which has high spatial resolution and is sensitive to small intracellular fluctuations. The researchers tested this method on two well-studied nanocarrier systems of biodegradable and biocompatible polymers: poly(ε-caprolactone) (PCL) and poly(lactic-*co*-glycolic acid) (PLGA). After incubating HeLa cells with media containing either system for several hours, the researchers were able to identify the spectral characteristic of each polymer's functional groups. They were able to follow the metabolic pathways of the nanoparticles using Raman imaging, including the uptake and distribution of nanoparticles using their chemical signatures within the cell. The researchers suggest that these results highlight the potential of Raman imaging for noninvasive monitoring of nanoparticle-based drug carrier systems.



Metal Oxides Light Up Colloidal Quantum Dot LEDs

Light-emitting devices (LEDs) that use colloidal quantum dots (QDs) as their luminescent centers are a topic of increasing interest due to their potential applications, including thin film displays with improved color saturation. Such applications require a device structure capable of electrically exciting different color QDs at comparable input powers to produce multicolor displays. So far, prototype QD-LED devices have relied on semiconducting polymers, molecular organics, and ceramics as charge transport layers, with each material having both benefits and drawbacks.



As a novel material for the charge transport layer, Wood *et al.* (p 3581) focused on semiconducting metal oxides. The team had previously shown that metal oxides were viable in air-stable QD-LEDs, finding that the efficiency of these structures was significantly reduced by charging of the QDs. Seeking to improve device efficiency, the researchers tested p- and n-type inorganic charge transport thin films systematically to counteract this charging process. Wood *et al.* tested four different metal oxides as the charge transport layer in devices (NiO, WO_3, ZnO, and SnO_2), in addition to varying the composition of the QDs (ZnCdS, CdSe/ZnS, and ZnSeCd). They explored various ways to improve device efficiency, including decreasing the amount of QD luminescence quenching due to free carriers in the adjacent metal oxide layers and inserting an insulating layer to prevent charging of the QD film. They found that the presence of both a 10 nm thick ZnO layer and a 15 nm thick ZnS layer results in the most efficient of the devices they tested. The authors note that better understanding of the electronic and structural properties of the materials in these devices is required for developing air-stable, efficient devices that are capable of multicolor applications.