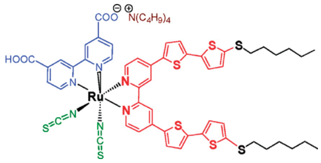
New Ruthenium Complex Sensitizes Thin-Film Solar Cells

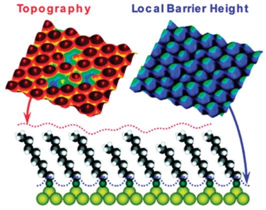
With their low manufacturing costs and high conversion efficiency, mesoscopic dye-sensitized solar cells have emerged as one of the most promising candidates for practical photovoltaic applications. Over the past two decades, researchers have continued to improve the performance of sensitizers for these cells, focusing on ruthenium dyes with thiophene-based ligands. However, few existing ruthenium sensitizers incorporating thiophene derivatives are capable of exhibiting a metal-to-ligand charge transfer transition absorption coefficient higher than $2.00 \times 10^4\ M^{-1}\ cm^{-1}$, limiting their performance in devices.



Seeking to improve performance, Chen *et al.* (p 3103) developed a novel high-molar-extinction coefficient heteroleptic ruthenium complex that incorporates an electron-rich hexylthio-terminal chain. The researchers synthesized this new complex, CYC-B11, using a one-pot reaction, then tested its performance by incorporating it into solar cells. Tests showed that the dye exhibits a light-harvesting capacity that exceeds all previously reported ruthenium dyes incorporating thiophene derivatives for dye-sensitized solar cells. The corresponding cells incorporating this new dye and a volatile liquid electrolyte exhibited a high conversion efficiency of 11.5% under AM 1.5G simulated sunlight. The devices were robust, showing consistent performance under 1000 h of light soaking at 60 °C. Solid-state dye-sensitized solar cells incorporating the new complex, using spiro-OMeTAD as the hole transport material, also displayed excellent efficiency of 4.7% under AM 1.5G simulated sunlight. The researchers note that these results highlight the promise of this novel dye for greatly enhanced solar cell performance and are currently optimizing its use in other devices.

Looking On, Looking In: Imaging Technique Captures Monolayer's Exposed and Buried Interface

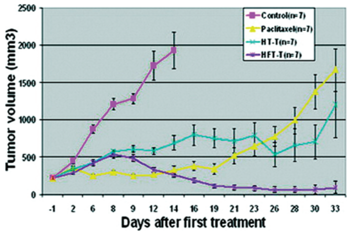
Alkanethiolate self-assembled monolayers (SAMs) on Au{111} are the most studied synthetic self-assembly systems, with applications in molecular electronics, nanofabrication, and biosensors. However, several key fundamental issues for the self-assembly of these materials remain poorly understood, including the mechanisms that lead to the reconstruction of the Au atoms that occurs during alkanethiolate adsorption and the existence of several superstructures for long-chain SAMs. Though researchers have made some headway in understanding these complexities by examining low-coverage, short-chain structures, these studies have typically used ensemble techniques that are inconsistent for high-coverage systems and long-chain SAMs.



To understand these more complex structures, Han *et al.* (p. 3115) used a low-temperature (4 K) ultrastable scanning tunneling microscope (STM) to image both single- and bicomponent SAMs with chain lengths from 6 to 12 carbons. By operating the STM simultaneously in both topographic and local barrier height modes, the researchers were able to image both the exposed methyl termini and buried thiolate head groups. They tested the sensitivity to the exposed and buried interfaces by measuring the molecular orientation and tilt of the alkanethiolate molecules. These values were comparable with previous results measured by IR spectroscopy and grazing-incidence X-ray diffraction, confirming the validity of this technique. The authors note that simultaneous imaging of the exposed and buried interfaces adds a new level to the sensitivity of STM, expanding the possibilities for using this locally sensitive technique to answer fundamental questions about the self-assembly process for a number of systems.

Bull's-Eye: Nanoparticles with Folic Acid Target Cancer Drug Therapy

Paclitaxel has long been used as a chemotherapeutic agent to treat solid carcinomas, including breast, head and neck, and lung tumors. Its poor aqueous solubility necessitates that it be administered with the surfactant Cremophor EL, which can lead to allergic and toxic side effects. To develop a new delivery system without these harmful effects, researchers have developed polymer-based vehicles, of which the albumin–paclitaxel "binary" nanoparticle has proven to be most effective. However, until chemotherapeueutic agents can target carcinomas specifically while leaving normal tissues unaffected, the effectiveness of these agents will be limited.



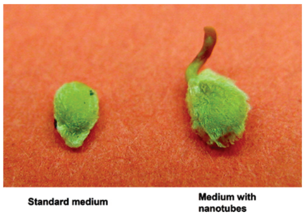
In a step toward solving this problem, Wang *et al.* (p 3165) developed a polymeric nanoparticle for the efficient and specific delivery of paclitaxel. By coupling a biodegradable heparin backbone to paclitaxel and folic acid (FA), a compound termed HFT-T, the authors were able to increase the solubility of paclitaxel as well as to increase therapeutic specificity by using FA as a tumor-targeting ligand. In studies using solid tumor implants in mice, the researchers found that HFT-T targeted tumors more effectively than heparin–paclitaxel nanoparticles lacking FA. The average tumor volume in mice treated with this novel agent was significantly reduced compared to mice treated only with paclitaxel. While the paclitaxel-treated tumors typically resurged several weeks after treatment, this was not observed in the HFT-T group. The researchers note that their novel approach could eventually prove promising for treating solid tumors in humans.

10.1021/nn9013643 CCC: $40.75

The Good Seed: Carbon Nanotubes Spread into Nano-Agriculture

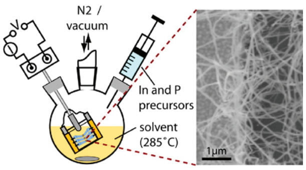
Over the past decade, interest has surged in using various nanomaterials for biological applications, including delivery of pharmaceutical agents or nucleic acids. Much of the research in this area has focused on animals, leaving a limited knowledge of the effects of nanomaterials on plant physiology and plant development. There is growing interest in applying nanoparticles to plants for agricultural and horticultural use; however, though researchers have had some success in using nanoparticles to penetrate plant cell walls, penetration of seeds could be more complicated due to the significant thickness of seed coat covering the whole seed.

Seeking to delve into seeds using nanomaterials, Khodakovskaya *et al.* (p 3221) germinated tomato seeds on media supplemented with different concentrations of carbon nanotubes (CNTs) ranging from 10 to 40 μg/mL. Analysis with electron microscopy showed that CNTs were effectively incorporated into the seeds at all concentrations. Tests showed that CNTs increased the rate of germination, with seeds in the CNT media sprouting several days before non-CNT-grown controls. CNTs also greatly increased the proportion of seeds that germinated compared to controls. Seedlings grown with CNTs had significantly longer and more developed stems, displaying 2.5-fold more vegetative mass than those grown without CNTs. Further tests suggest that these materials exerted their effects by increasing seed water intake. The researchers note that this observed positive effect could have important implications for agriculture, horticulture, or possibly energy production as it applies to biofuels.



Electrifying the Potential for InP Nanowire Growth

Indium phosphide nanowires have been the focus of significant technological interest due to their potential for use in a variety of applications, including single-junction solar cells and high-speed electronics. These nanowires are typically grown from catalyst particles using several different methods, including the solution−liquid−solid (SLS) process. However, the efficient placement and integration of nanowires into devices remains a significant challenge.



A recent report demonstrated that CdSe nanowires can be grown in a controllable fashion between two electrodes using a variation of the SLS method by varying the electrochemical potential of the catalyst seed particles. This technique enables simultaneous synthesis and integration of nanowires into device geometries, eliminating the need for postsynthesis placement of the wires. In a new study, Dorn *et al.* (p 3260) extended this method to grow InP nanowires. The researchers constructed growth mediums consisting of fused silica substrates with three pairs of interdigitated electrodes composed of a 5 nm Ti adhesion layer, a 75 nm Pt layer, and a 20 nm Bi layer. After applying a bias voltage and injecting a precursor solution, Dorn's team observed that the nanowires grow almost exclusively in the gaps between the electrodes, indicating that growth emanates from the electrode edge and is guided across the gap by the electric field. The researchers found that as the nanowires stretched across the gap and connected with growing nanowires on adjacent electrodes, conductivity increased, allowing them to monitor nanowire bridging using conductivity as a function of time. The authors suggest that this technique could enable nanowire device fabrication for solar cells, batteries, and other applications.

Polyethyleneimine is Coat of Many Functions for Mesoporous Silica Nanoparticles

Mesoporous silica nanoparticles (MSNPs) have emerged as an efficient drug delivery platform due to their large surface area and ordered porous channels that can be used to encapsulate molecules. These particles have already been shown to be a suitable transport system for several anticancer drugs and have potential to act as carriers for nucleic acids, making them attractive vectors for DNA and siRNA. However, to maximize the delivery of these negatively charged nucleic acids to cells, the surfaces of MSNPs must be converted to a positive charge.

To reach this goal, Xia *et al.* (p 3273) coated MSNPs with polyethyleneimine (PEI), a type of synthetic cationic polymer that has already been studied alone as a delivery vehicle for drugs. Since low-molecular-weight PEI is known to be nontoxic but less effective at transfecting nucleotides, and high-molecular-weight PEI can be toxic but more effective at transfection, the team experimented with a range of PEI polymer sizes from 0.6 to 25 kD to balance these effects. The researchers showed that particles coated with 10 kD PEI were particularly efficient at transducing cells with siRNA that knocked down green fluorescent protein (GFP) expression with less toxicity than higher-weight PEI. Similarly, this size polymer was effective at transfecting other cells with plasmids that induce GFP expression. Though the 25 kD PEI-coated particles showed considerable *in vitro* toxicity, tests in mice showed that it was well-tolerated *in vivo*. These results suggest that, by careful selection of PEI size, it is possible to construct cationic MSNP particles that enhance nucleotide and drug delivery with minimal or no toxicity.