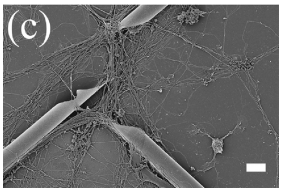
Neurite Outgrowth Goes Totally Tubular

A number of applications currently in use and in development combine neurons and electronic components, including brain–computer interfaces, deep brain stimulation, and motor prosthetic devices. To optimize the interaction between the cells and inorganic components, researchers have sought various approaches to guide the growth of the neurons' axons and dendrites in a desired direction, including chemical tracks and microgrooves. However, most efforts have taken place on flat substrates, ignoring the typically three-dimensional (3D) natural growth of neurites.

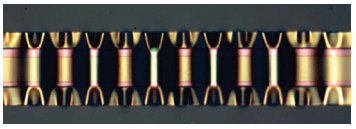
To incorporate this 3D aspect into combinations of neurons and electronic components, Yu *et al.* (DOI 10.1021/nn103618d) developed semiconductor nanomembrane tubes to guide neurite growth. They constructed the tubes using strained Si and Ge membranes. When a sacrificial oxide layer is removed, the nanomembranes roll up into tubes whose curvature and length can be precisely controlled. Testing the tubes with mouse neurons, the researchers found that the material was nontoxic whether or not it was coated with biocompatible polymers. Microscopy studies showed that the tubes appeared to attract the growth of neural extensions along the tubes and, more interestingly, inside the tubes. Given the tubes' large diameter of about 8 μm, the majority of neurites grew inside tubes in bundles. However, the researchers show that 4 μm tubes can accommodate what appear to be single axons. They speculate that these narrower tubes might be able to isolate single neural extensions from solution or act as insulators, much like myelin. The authors suggest that these semiconductor nanomembrane tubes hold great potential for new neural-electronic applications.



Catching the Wave with Stretchable Ferroelectric Ceramics

Lead zirconate titanate (PZT) is a popular choice for many applications, including components for sensors, actuators, and memory devices, due to its superior piezoelectric and ferroelectric properties. These properties might also be useful for applications in the human body, such as energy harvesting or health monitoring. However, like most ceramics, PZT is extraordinarily brittle, fracturing at strains significantly less than 1%. Consequently, its applications are limited to flat, low strain substrates, rather than the curved and elastic surfaces of the body.

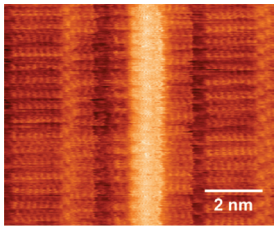
Hoping to expand the range of this material's potential applications, Feng *et al.* (DOI 10.1021/nn200477q) developed a way to incorporate PZT into soft, elastomeric substrates in "wavy" geometries that allow large and reversible strain deformations. The researchers transferred strips of PZT into a prestrained slab of the elastomer polydimethylsiloxane. Once the strain was relaxed, the PZT strips buckled without fracturing. Tests showed that the combined material could repeatedly undergo strains of several percent with the PZT returning to its original wavy shape. Further experiments indicated that the encased, wavy PZT ferroelectric and piezoelectric properties were similar to PZT in flat films on rigid silicon substrates. Theoretical and computational analyses on the mechanics of this novel material suggested that an applied electrical field can continuously tune the amplitude of the PZT waves. This effect enables vertical displacement ranges nearly a thousand times larger than PZT on rigid substrates. The authors note that incorporating PZT and other ceramics into wavy geometries could form the basis for future piezoelectric and ferroelectric devices.



For Chain Polymerization, Focus on Rate

One-dimensional conjugated polymer nanowires can be obtained through a method in which a scanning tunneling microscope tip excites a single molecule in a self-assembled monolayer of a diacetylene compound, leading to a chain polymerization reaction. In recent experiments using this method on a highly oriented pyrolytic graphic (HOPG) substrate, researchers successfully synthesized polydiacetylene nanowires. These electrically conductive nanowires have a variety of applications both for fundamental studies and for switching devices, transistors, and photovoltaics. However, although this method and its results are well-established, researchers still know little about some specifics of this process, including what factors determine the chain polymerization rate.

To answer this question, Mandal *et al.* (DOI 10.1021/nn103231j) investigated how molecular geometry affects rate by conducting chain polymerization experiments on HOPG as well as MoS_2 substrates. While both substrates have the same substituent diacetylene groups, the arrangement is identical in every domain in HOPG, but varies within different domains for MoS_2. Experiments showed that this difference in molecular geometry led to a substantially higher chain polymerization rate on the MoS_2 substrate, which was four times faster than on the HOPG substrate. Further investigation suggests that this difference in rate results from the differing distance between carbons in the two materials. Since MoS_2 has significantly higher molecular mobility, the distance between reactive carbons about to be bound in chain polymerization is shorter, thus increasing the rate. The authors note that this better understanding of chain polymerization could lead to ways to optimize fabrication of conjugated polymer nanowires. It also highlights the potentially important role of substrate selection in future molecular devices.



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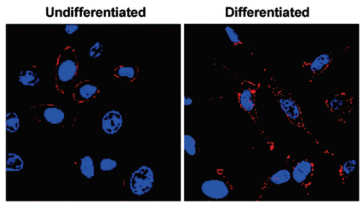
Differentiation Makes a Difference for Nanomaterial Toxicity

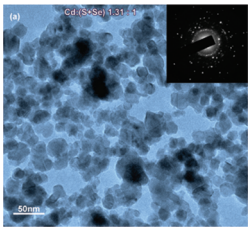
Researchers continue to look out for the potential hazards of nanomaterials as these components come closer to applications that could affect humans and their environment. Consequently, understanding the best and most efficient ways to test the toxicity of new nanomaterials has become a high priority. Assays for toxicity often use transformed cells, which are homogeneous and inexpensive to grow. However, while transformed cells are end-differentiated, primary cultures that more closely mimic *in vivo* effects are typically composed of mixtures of differentiated and undifferentiated cells. Whether nanomaterials have different toxicities in these two populations has not yet been determined.

To investigate this question, Zhang *et al.* (DOI 10.1021/nn200328m) used a high-throughput assay they recently designed to investigate the effects of mesoporous silica nanoparticles (MSNP) on undifferentiated and differentiated primary human bronchial epithelial cells. They coated the MSNPs with cationic polyethyleneimine (PEI) of varying molecular weights ranging from 0.6 to 25 kD. Their automated assay, which used fluorescent dyes to assess various components of cell damage and viability, showed that MSNPs coated with higher molecular weight PEI were clearly more toxic to differentiated cells than undifferentiated ones. Other experiments showed that the reason for this increased toxicity was greater association of the particles with differentiated cells, which lowered the cells' membrane potentials. Treating these cells with a heparinase, which removed negatively charged sulfates produced by the differentiated cells, greatly reduced these toxic effects. The researchers note that these results make an argument for using primary cultures, which may give more accurate toxicity results than transformed cells.



A New Wave for Sensitized Solar Cells

Though various types of quantum dots have been used as sensitizers in mesoscopic solar cells, TiO_2 has been used most often as the photoanode. However, some studies have suggested that SnO_2 has some significant



advantages. SnO_2 has a higher electron mobilityand a lower conduction band minimum than TiO_2, which could ease charge transport from low band gap sensitizers and enhance light harvesting by taking advantage of long wavelength photons.

To see how SnO_2 stacks up against TiO_2 in sensitized solar cells, Hossain *et al.* (DOI 10.1021/nn200315b) created SnO_2 photoanodes by layering CdS and CdSe onto SnO_2 electrodes using the successive ionic layer adsorption and reaction method (SILAR). They also added a layer of TiO_2 onto the SnO_2 surface to reduce the density of electron trap states, as well as a thin passivation layer of ZnS to inhibit injected electrons from recombining with holes in the electrolyte. Incident photon-to-current efficiencies (IPCE) spectra of sensitized SnO_2 and TiO_2 solar cells had a strong response over the range of visible light, extending up to about 850 nm for the SnO_2 solar cells. Between 400 and 600 nm, SnO_2 solar cells had IPCEs of about 80%, compared to about 65% for TiO_2-based devices. Photocurrent densities were an unprecedented 32% higher for the SnO_2 devices. Though the overall power conversion efficiency was lower for the SnO_2 solar cells, at 3.68%, compared with 4–5% for TiO_2, the authors suggest that SnO_2 could prove to be a significant competitor with TiO_2 in sensitized solar cells.

Transformation Optics Transforms Simulations

Researchers have become more and more interested in surface plasmons over the past decade due to their ability to direct light at the nanoscale. Finding new ways to optimize the interaction between light and matter within nanostructures has been a central goal, with a special focus on light harvesting and nanofocusing. Thus far, these efforts have mainly relied on numerical simulations. However, a field known as transformation optics, which focuses on how light and other electromagnetic waves can be bent and distorted, could hold promise for understanding how light interacts with complex nanostructures.

In a new study, Aubry *et al.* (DOI 10.1021/nn200438e) take transformation optics on a test ride by describing the optical response generated by a nanowire dimer and a nanowire placed close to a metal surface. By using transformation optics theory, the researchers were able to transform the nanowire dimer into a system consisting of a collection of dipoles between two semi-infinite metal slabs. The team analytically derived the absorption cross section and electrical field distribution under the electrostatic approximation. They then used conformal mapping to derive the behavior of local surface plasmons and their interaction with the external field. Comparing their results to numerical simulations, the researchers found matching results for structures up to 20 nm. Using a similar tactic, they were able to derive the absorption cross section of a nanowire near a metallic surface within and beyond the quasi-static limit. The authors note that these results showcase the power of transformation optics for predicting the propagation of surface plasmons in complex nanostructures.