Order High Vacuum Components Online

www.ancorp.com

A&N Corporation offers convenient online ordering of high and ultra high vacuum components including:

- Flanges and Fittings (ISO, CF, and ASA)
- Couplings
- View Ports
- Feedthroughs
- Valves
- Weldable/Roughing Components

Prefer a paper catalog? Just email your address to request@ancorp.com or call us at:

1-800-352-6431

nents sat:

High Vacuum Components Since 1965

For more information, see http://www.mrs.org/bulletin_ads

sufficient details about the field that they can become more effective researchers. Those who have not had the benefit of this will not know what they missed (I am sure their employers do not miss this point). (5) MSE departments enhance the level of interdisciplinarity on a university campus in that they provide a natural bridge between areas of engineering, medicine, and the natural sciences. Schools with the largest interdisciplinary multi-investigator proposals predominantly have diverse and healthy MSE departments.

The big challenge is in identifying how the curriculum in MSE departments should evolve to reflect the developments in the field. Major technological challenges such as energy and sustainability and problems at the interface of medicine and materials are interdisciplinary ones in which materials research plays a central role. In order to fulfill this role, the MSE department of the future needs to continue developing as the major player in the interdisciplinary research infrastructure of universities.

In light of the rapid changes in the field and associated changes in the curriculum, MRS should play a very active role in accreditation issues. The impact of MRS goes far beyond meetings: MRS has helped define a field and a profession, and as a professional society, MRS helps define the expectations of the next generation of researchers to tackle the difficult interdisciplinary problems.

> Peter F. Green 2006 MRS President



www.mrs.org/ spring2007

RESEARCH/RESEARCHERS

Color-Coded Method Visualizes Drug Release in Cancer Cells

Philip Low, the Ralph C. Corley Distinguished Professor of Chemistry at Purdue University, and his colleagues at Purdue and Endocyte Inc., have discovered details of how drugs are released within a cancer cell, improving the ability to deliver drugs to a specific target without affecting surrounding cells. "Most new drugs under development will be targeted directly to the pathologic, diseasecausing cells, and we have shed light on the details of one mechanism by which this is achieved," Low said.

As reported in the September 12 issue of the *Proceedings of the National Academy of Sciences* (p. 13872; 10.1073/pnas. 0601455103), Low and his team developed a color-coded method to visualize the cellular mechanisms by using a technique called fluorescence resonance energy transfer imaging (see Figure 1). "The drug turns from red to green when it is released inside the cell, clearly illuminating the process," said Jun Yang, a postdoctoral research associate in Low's group.

In targeted drug therapy, drugs are linked to molecules that are used in excess by pathologic cells-for example, a required nutrient-in order to transport drugs directly to the targeted cells while avoiding significant delivery of the toxic drug to normal cells. One commonly used agent, referred to as a ligand, is the vitamin folic acid. Cancer cells need folic acid to grow and divide and therefore have developed abundant receptors to capture it. These receptors are largely absent in normal cells. This means folic acid, and the drug linked to it, are attracted to the pathologic cells and are harmless to healthy cells, Low said.

"It is desirable to have the drug released from the ligand, folic acid, once the folate-linked complex enters the cell," Yang said. "This 'conditional drug release' is usually realized by attaching folate to the drug through a linker that falls apart inside the cell. There were several linkers in common use, but with mixed efficiency. In this study, we undertook to interrogate the full details of this breakdown process."



Figure 1. Depiction of drug release within a treated cancer cell. Once inside the cell, the drug turns from red to green as receptor endocytosis releases it from its folate-linker. By linking to the vitamin, toxic drugs are transported directly to the cancer cell and do not harm healthy cells. (Image courtesy of Proceedings of the National Academy of Sciences). Yang examined receptor endocytosis, the process by which cells absorb materials—such as a drug attached to folic acid—that have been captured by receptors on the cell surface. The compound is then broken down and processed, releasing the drug.

One of the key mechanisms of this breakdown is disulfide reduction, which involves the breaking of chemical bonds. It was thought that disulfide reduction relied on the movement of the material along microtubules (hollow tubelike structures) and fusion with special digestive-enzyme-containing compartments within the cell called lysosomes. However, the research showed that disulfide reduction occurred even when such components were removed from the process.

By inactivating different cellular components, Yang discovered which components are essential to the disulfide reduction process.

"It was surprising to learn that many other components of the cell, aside from those previously assumed to be responsible, were capable of releasing the drug from folic acid," Yang said. "This significantly increases the opportunity for the drug to be released. For instance, we used to believe it had to get to a specific location to be released, and now we know it can happen almost anywhere during endocytosis."

Theory Predicts that Cycloaddition Functionalizations May be Used to Manipulate CNT Conductance

Nicola Marzari, an associate professor at the Massachusetts Institute of Technology (MIT), and Young-Su Lee, an MIT graduate student in materials science and engineering, have used density functional theory to determine that cycloaddition functionalizations can be used to manipulate carbon nanotube (CNT) conductances. The researchers report their findings in the September 15 issue of *Physical Review Letters* (#116801; DOI: 10.1103/PhysRevLett. 97.116801).

With an internal bonding structure rivaling that of diamond, CNTs are extraordinarily strong and can be highly efficient electrical conductors. However, one problem in working with them is that there is no reliable way to arrange CNTs into a circuit, partly because growing them can result in a randomly oriented structure. Researchers have attached to the sidewalls of the CNTs chemical molecules that work as "handles" that allow the nanotubes to be assembled and manipulated. However, these molecular bonds also change the CNTs' structure and destroy their conductivity.

Now, Marzari and Lee have identified a class of molecules carbenes and nitrenes—that preserve the metallic properties of CNTs and their near-perfect ability to conduct electricity with little resistance (see Figure 1).



Figure 1. Certain molecules can attach themselves to metallic carbon nanotubes without interfering with the nanotubes' exceptional ability to conduct electricity. At left, the high conductance state has two molecular orbitals, shown in green. Some molecules let the nanotube switch between (left) highly conductive and (right) poorly conductive (with one red molecular orbital), creating the potential for new applications. (Image courtesy of N. Marzari.)

Precision Heating to1200°C in 24 seconds, for under \$10,000.

NOW THAT'S HOT!



Anneal your small samples faster and with better control using the programmable MILA-3000 tabletop furnace. Ulvac's Mini-Lamp Annealing System can rapidly heat and cool samples with it's infrared gold image furnace, providing precision high temperature control, clean heating and versatile atmosphere selection.

MILA-3000 Features:

- High controlled heating rates of 50°C/s
- Sample size 20x20x20 mm
- · Air, vacuum and inert/reactive gas atmosphere
- Temperature uniformity of +/- 2°C
- Low power consumption (1 kW)

For all your annealing and thermal processes, turn on the heat with the MILA-3000!



ULVAC Technologies, Inc Methuen, MA 01844 Phone: 978-686-7550 www.ulvac.com sales@ulvac.com

For more information, see http://www.mrs.org/bulletin_ads

The hexagon of carbon that makes up a nanotube has a predilection for clinging to other hexagons. One of the many challenges of working with CNTs is that they tend to stick to each other. Attaching a molecule to the sidewall of a nanotube serves a double purpose: It stops nanotubes from sticking, so that they can be processed and manipulated more easily, and it allows researchers to control and change the electronic properties of the nanotubes. Still, most such molecules also destroy the CNTs' conductance because they make the nanotube structurally more similar to diamond, which is an insulator, rather than to graphite, a semimetal.

The researchers indicate that their studies show that carbenes and nitrenes work by breaking a molecular bond on the nanotube's wall while creating their own new bond to the nanotube. This process—one bond formed, one bond lost—restores the perfect number of bonds each carbon atom had in the original nanotube; thus, "conductance is recovered," Marzari said.

The theory indicates that some molecular handles can even transform between a

"bond-broken" and a "bond-intact" state, allowing the CNTs to act like switches that can be turned on or off in the presence of certain substances or with a laser beam.

"This direct control of conductance may lead to novel strategies for the manipulation and assembly of nanotubes in metallic interconnects, or to sensing or imaging devices that respond in real time to optical or chemical stimuli," Marzari said.

The next step is for experiments to confirm that the approach works.

Model of Collagen Nanostructure Explains Its Strength

Collagen's characteristic nanostructure may be the reason for its high strength and ability to sustain large deformation in its physiological role in tissues such as bone, tendon, and muscle. Previous experimentation has shown that collagen isolated from different tissue sources universally displays a design that consists of a staggered assembly of tropocollagen molecules with lengths of approximately 300 nm. The reason why strands of amino acids associate to form tropocollagen molecules consistently at this length has been an unexplained phenomenon.

M.J. Buehler, principal investigator at the Atomistic Mechanics Modeling Laboratory at the Massachusetts Institute of Technology, has used a combination of theoretical and molecular modeling that led to a breakthrough in understanding how molecular and tissue properties are linked. Buehler has reported his findings in the August 15 issue of the *Proceedings of the National Academy of Sciences* (p. 12285; DOI: 10.1073/pnas.0603216103).

Buehler discovered that the characteristic design of collagen displays a clever strategy that enables nature to take advantage of the nanoscale properties of individual molecules at larger scales, leading to a tough material. This is achieved by arranging tropocollagen molecules into a staggered assembly known as collagen fibrils, tiny fibers with diameters of 50-200 nm and lengths of several micrometers. When a tensile force is applied at the end of a collagen fibril, the force is transmitted as shear forces between molecules and a tensile force within molecules. Whereas the elastic tensile strength of the tropocollagen mol-



ecules stems from their triple-helical arrangements, the shear force between molecules is transmitted by a combination of weak interactions, including hydrogen bonds and dispersive interactions, as well as some covalent cross-links (see Figure 1).

Individual tropocollagen molecules are 5–10 times stronger than steel and able to

300

Collegen fibri

a

sustain tensile strains of up to 50% before fracture occurs. Steel, in comparison, typically sustains tensile strains of only a few percent before it breaks. Buehler said, "The fracture strength of individual [tropocollagen] molecules is largely controlled by covalent polypeptide chemistry. The shear strength between two [tropocollagen] molecules is controlled by weak dispersive and hydrogen-bond interactions and by some intermolecular covalent cross-links." "The natural design of collagen represents a delicate balance between tensile forces within each tropocollagen molecule and shear forces between the molecules," said Buehler. He discovered that there exists a characteristic molecular length scale at which collagen fibrils have optimal mechanical properties—being strong while providing large energy dissipation. Buehler's modeling results predict that the optimal length of tropocollagen molecules is approximately 200 nm,



Figure 1. (a) (top) Staggered arrangement of tropocollagen molecules into collagen fibrils. (bottom) Expanded view illustrates how forces are transmitted inside the collagen fibril as a result of macroscopic external tensile loading. When a tensile force is applied at the end of a collagen fibril, the force is transmitted as a shear force between molecules and a tensile force within molecules. (b) Sequence of images displaying the atomistic mechanisms as two tropocollagen molecules in a collagen fibril undergo nanoscopic shear deformation. This intermolecular shear deformation is induced by macroscopic tensile loading. The sequence depicts the surface of each tropocollagen molecule and its interaction with other molecules. Tropocollagen molecules interact through a nanoscale layer of water molecules and weak interactions, including hydrogen bonds and electrostatic forces. These atomic interactions break as molecules slide on top of each other. (Figure courtesy of M.J. Buehler,http://web.mit.edu/mbuehler/ www/, rendered using visual molecular dynamics [VMD] software.)

Cost-Effective Portable Spin Coater Two-Stage Spinning





Adjustable Speed Stage 1 500 to 2500 rpm 2 to 18 seconds Stage 2 1,000 to 8,000 rpm

Dispense liquid during Stage 1 Spin-up and flatten during Stage 2

1,000 to 8,000 rpm 3 to 60 seconds

Vacuum Chucks

Wide Range of Vacuum Chucks Available To Hold Different Substrates in KW-4A Spin Coater

KW-4A SERIES PRODUCT LINE



For more information, see http://www.mrs.org/bulletin_ads

which is very close to the experimentally observed characteristic length of 280 nm. Buehler developed a new theoretical framework that provides a quantitative treatment of the nanomechanics of collagen fibrils.

Buehler used large-scale computer simulations that begin at the atomistic scale, treating individual chemical interactions based on quantum mechanical calculations to obtain results consistent with his theory. Previous models of collagen typically involved empirical parameters and lacked a rigorous connection between quantum chemistry, molecular structure, material properties and collagen's physiological function. Buehler's model provides a first-principles-based materials representation. Furthermore, the model provides a basis for understanding the effects of diseases "caused by defects in the molecular structure of collagen altering the intermolecular and molecular properties due to genetic mutations, which modifies the mechanical behavior of collagen fibrils."

Collagen, an extracellular matrix protein, plays an important role in defining the infrastructure of physiological tissues under load or strain, and is critical to tissues within the skeletal, muscular, and cardiovascular networks. Improved understanding of nature's design criteria will help guide materials and biomedical engineers to develop enhanced biomimetic polymers. Buehler's work could contribute to research that may one day develop cures for collagen-related diseases such as the Ehler–Danlos syndrome, joint hyperextensibility, or scurvy.

"We are currently extending our models to describe the deformation mechanics of other structural proteins and more complex materials such as bone," said Buehler. "For example, the smallest building blocks of bone are mineralized collagen fibrils, which can be modeled using similar concepts."

Combination of Top-Down and Bottom-Up Approaches Allows Fabrication of High-Aspect-Ratio 2D KTiOPO₄ Photonic Crystals

In many applications where optoelectronic modulation of light is needed, it would be very useful to have micro- or nanostructures fabricated from materials with large electro-optic coefficients such as the ones found in many inorganic nonlinear crystals. Unfortunately, when topdown procedures are applied to such materials to produce, for instance, twodimensional (2D) photonic crystals, they are not as effective as when they are applied to semiconductors. A. Peña of the Universitat Rovira i Virgili, S. Di Finizio from the ICFO-Institut de Ciencies Fotoniques, J. Martorell and A. Rodriguez of the Universitat Politecnica de Catalunya, Spain, and their colleagues have obtained 2D photonic crystals by growing microrods of KTiOPO₄ inside the air holes of an ordered macroporous silicon membrane closely bound to a KTiOPO₄ substrate (see Figure 1).

As reported in the September issue of *Advanced Materials* (DOI: 10.1002/adma. 200502566), the researchers prepared the silicon membranes by computer-controlled light-assisted electrochemical etching of a patterned *n*-type <100> silicon wafer, with which they control the growth, size, depth, and quality of the pores. A *c*-oriented KTiOPO₄ substrate was bound to the sili-



For more information, see http://www.mrs.org/bulletin_ads

RESEARCH/RESEARCHERS



10 µm



20 µm



10 µm



3 µm



20 µm



10 µm

Figure 1. Scanning electron microscopy images of (a) a macroporous silicon two-dimensional (2D) square lattice membrane; (b) top surface of a 2D KTIOPO₄ (KTP) photonic crystal after polishing and partial etching of the silicon mask; and (c) side view of the 2D KTP photonic crystal, where the silicon template has been selectively etched from the KTP. (d) Detailed view of a 2D KTP crystal with a period of 4.5 µm, which was also used for the optical measurements. (e) Side view of a plane of columns of a 2D KTP photonic crystal lattice. (f) Energy-dispersive x-ray analysis of the KTP columns grown within the air holes of the silicon matrix: red areas indicate the presence of silicon, green areas incicate potassium, and bluer areas indicate titanium. Images (b), (c), and (e) were taken without the deposition of a gold layer, so that the samples could be used for Materials, DOI: 10.1002/adma.200502566; © 2006 Wiley-VCH.)

con membrane and the template/substrate set was dipped into a supersaturated growth solution of KTiOPO₄, removed, and slowly cooled to avoid thermal stresses that might produce cracks in the grown columns. After removing the composite material from the growth solution, polishing its surface to optical quality, and partially removing the silicon template by selective chemical etching, the researchers obtained a 2D photonic crystal consisting of squared KTiOPO₄ rods with 4.5 µm lattice parameters and 80 µm rod lengths.

These photonic structures showed a high degree of crystallinity, with the axis of the KTiOPO₄ rods perfectly oriented with the KTiOPO₄ substrate. The researchers demonstrated the photonic-crystal

See More... Do More...

Integrated Solutions for Integrated Applications



Carl Zeiss LSM 5 PASCAL Confocal Laser Scanning Microscope

Insight into Biology and Materials Science through:

- 3D Imaging
- Surface topography
- Volumetric measurement
- Multi-label Imaging
- Fluorescence & Reflected light imaging

Applications in Research and Quality Assurance:

- Microfluidics
- Microarrays
- Microreplication
- Sensors
- Lab-on-Chip

Carl Zeiss MicroImaging Inc. Thornwood, NY 10594 800.233.2343 micro@zeiss.com zeiss.com/materials





We make it visible.

For more information, see http://www.mrs.org/bulletin_ads

properties of the 2D structures by measuring the specular reflection of light as a function of the wavelength of the incident field, observing a dip at 1100 nm, corresponding to the third-order Bragg reflection band. The researchers also demonstrated the potential of the 2D array of KTiOPO₄ rods to host an efficient nonlinear interaction by measurements of the diffracted light at the second-harmonic frequency of the incident wave.

This procedure enables control over the direction of growth relative to the orientation of the 2D structure. For any given application, it will then be possible to use the most appropriate combination of nonlinear or electro-optic coefficients of the material, something which is not always possible in bulk KTiOPO₄, given the limited material birefringence. Such newly developed photonic crystals, which should be easily integrated in siliconbased devices, may find applications in generating light more efficiently at higher frequencies, in the electro-optic modulation of light, and in obtaining backward parametric amplification and oscillation.

Submicrometer Technique Etches Curvilinear Silicon and Glass Patterns with HF-Saturated Hydrogel Stamps

Applications in micro-optics, microfluidics, and microelectronics call for micrometer-sized devices with curvilinear or multilevel surface topographies. Casting elastomers against rigid masters is a parallel process that can rapidly create such architectures, but the resulting polymeric devices possess low resistance to mechanical wear, are permeable to gases, and often swell when exposed to organic solvents. Durable inorganic substrates, with better mechanical and chemical properties, may be patterned by expensive techniques such as reactive ion etching, laser ablation, or micromachining, but the throughput rate of these serial processes is low. In the July 16 issue of Advanced Materials (p. 2004; DOI: 10.1002/adma.200600716), followed by a recent publication in *Chemistry* of Materials (p. 4722; DOI: 10.1021/ cm061468p), researchers at Northwestern University, led by B.A. Grzybowski, have presented a novel, inexpensive, directprinting technique that is suitable for rapid prototyping of multilevel reliefs in a variety of rigid substrates. The technique boasts a lateral resolution (in silicon) of several hundred nanometers, and it can pattern several square centimeters at a time.

Using soft lithographic techniques, Grzybowski and co-workers created a flexible hydrogel stamp by first patterning a reusable micropatterned master



Figure 1. Schematic illustration of the experimental procedure for reactiondiffusion microetching.





Figure 2. Three-dimensional (3D) architecture fabricated by sequential application of arrays of parallel lines along perpendicular directions. Pattern in GaAs: (a) scanning electron microscope image, (b) large-area optical micrograph, and (c) atomic force microscope image of a 3D structure showing trenches 0.7 μ m and 0.4 μ m deep. (Reprinted with permission from Chemistry of Materials **18** (20) (October 3, 2006) p. 4722; DOI: 10.1021/cm061468p; © 2006 American Chemical Society.) with the desired topography, then casting high-gel-strength agarose against it. They "inked" the agarose stamp by soaking it for 4 h in a 0.6 M aqueous solution of hydrofluoric acid, with 0.1 vol% Triton X-100 surfactant.

The researchers laid the saturated stamp, feature side up, in light mineral oil, which confined the etchant to the raised features and reduced evaporation. Next, they placed the solid substrate to be patterned (e.g., a glass slide or a silicon wafer) directly upon the stamp, and ensured intimate contact by resting a small weight on top. Depending on the material system and the desired feature depth, the subsequent isotropic etching takes from several minutes to several days. The scientists then cleaned the etched surface using a piranha solution. The scheme is summarized in Figure 1.

The bulk agarose gel acts as a two-way "pump" that supplies fresh etchant and efficiently removes reaction products through diffusive transport. The etch rate is reaction-limited and is approximately constant. More concentrated acid solutions etch faster (which is helpful when making high-aspect-ratio features) but have detrimental effects on the stamp.

This easy-to-use, reliable method is reminiscent of woodcut printing, but on a submicrometer scale. The scientists have demonstrated the versatility of the technique by fabricating several difficult devices using their technique, including an array of convex/concave microlenses and a multilevel passive microfluidic mixer in glass.

"By exploiting other interfacial chemistries," Grzybowski said, "we have used the reaction-diffusion microetching process to pattern other materials, including zinc oxide and gallium arsenide." An example is shown in Figure 2.

RICH LOUIE

Nanocrystalline, Flexible Photoelectrochromic Films Display Quick Response Time

Changes in the optical properties of chromogenic materials occur by electric, thermal, or photo activation—for example, electrochromic "smart" windows that display switchable glazing. The change in color of photoelectrochromic (PEC) materials results from light absorption and application of an electric field. For example, a previously reported PEC device is based on an inorganic electrochromic film combined with a dye-sensitized semiconductor electrode. Recently, G. De Filpo and co-researchers at the Department of Chemistry, University of Calabria, Italy, developed a PEC film that uses a polymer-

ic conductive support, thereby making the film flexible. In addition, the optical response is much faster than previous PEC devices due to an innovative assembly design.

As reported in a recent issue of *Chemistry* of Materials, De Filpo and co-researchers fabricated a nanocrystalline film by spincoating onto poly(ethylene terephthalate) a colloid containing TiO₂ nanoparticles 25 nm in diameter. After hydrothermal treatment, the film was immersed in a phosphate buffer to attach PO4- groups to the TiO₂ nanospheres. The PET-TiO₂-PO₄ films were then immersed in a solution containing methylene blue (MB), which adsorbed onto the film surface. It is well known that MB is photoactive in the triplet electronic state; photoreduction changes its color from blue to colorless. Oxidation of MB by means of application of direct current in the presence of an oxidative agent results in a color change from light blue to intense blue. Illumination with red light returns MB to its colorless, singlet ground state. A commercial microporous polar membrane (Nafion 112 from DuPont), which was previously immersed overnight in an electrolyte solution containing ethyl

viologen diperchlorate (an oxidative agent), 0.2 M triethylamine (an electron donor), and 0.5 M LiClO₄ (a charge carrier), as well as a UV-photopolymerizable acrylate monomer and photoinitiator, was then placed between the PET-TiO2-PO4-MB film and a PET film, and the entire device was irradiated with UV light for 5 min in order to polymerize the acrylate monomer, thereby linking the PEC film to the Nafion and PET supports. The device was sealed on all edges with cyanoacrylate glue.

When a voltage is applied to the nanocrystalline electrode, the bound MB molecules are oxidized and a fraction of the ethyl viologen molecules present in the electrolyte solution are reduced on the opposite electrode. This process is very fast and does not depend on the diffusion rate of the molecules toward the electrode. In addition, being able to transport electrical charges, the TiO_2 nanoparticles have a very large surface area (about $50 \text{ m}^2/\text{g}$) so that it is possible to oxidize a large number of MB molecules per unit surface area. Using scanning electron microscopy, the cross section and surface morphology of the TiO_2 layer were found to be very porous. The high mobility of the electrical charges

results from the mutual contact of the TiO₂ nanoparticles. Optical characterization of the device was performed with UV-vis spectroscopy, while the electro-optical response of the film was characterized by using two lasers simultaneously (He-Ne 632.8 nm, 1 mW and 5 mW). A lowerpowered reading laser was used to measure the optical transmission of the film, while a higher-powered writing laser was used to promote the bleaching process. Before being exposed to red light, the device displayed an absorption maximum at 660 nmcharacteristic of MB-resulting in an intense blue color and an optical transmission of 1%. The device becomes transparent (an optical transmission of 57%) and the absorption maximum vanishes 20 s after irradiation with red light. However, a 1-s electrical impulse of 0.4 V dc results in re-coloring the device in about 600 ms.

De Filpo said that future work is planned to improve the bleaching time of the film, which is still too long for practical use. However, the flexible nature of the device expands its use beyond traditional applications.

STEVEN TROHALAKI



For more information, see http://www.mrs.org/bulletin_ads