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MICRO NANO

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From the Editors of R&D Magazine

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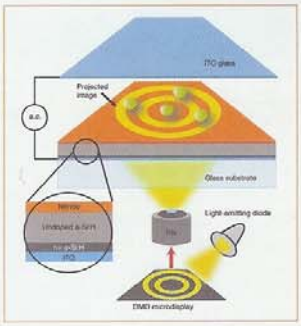
Microsystems and Nanotechnology

MICRO/NANO 25—Technologies of tomorrow

The following technologies have been chosen by the editors of Micro/Nano Newsletter *and* R&D Magazine *as representative of the best 25 micro- and nanotechnologies of 2006. These products, processes, and innovations are groundbreaking technologies that are likely to have the largest impact on their specific industries and society. In random order, the winners are…*

Optoelectronic tweezers—Univ. of California (http://nanophotonics.eecs.berkeley.edu/research/oet/oet.htm), Berkeley.

This device allows the manipulation of large numbers of single cells and particles using optical images projected on a glass slide coated with photoconductive materials. The device can produce instant microfluidic circuits without using sophisticated microfabrication techniques. The tweezers are created by suspending microscopic polystyrene (PS) particles in a liquid between a piece of glass and the photoconductive material. Where light strikes the photosensitive material, it behaves like a conducting electrode, while areas not exposed behave like insulators. Upon removal of the light, the photosensitive materials return to normal.



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Nanotechnology

New species of iron

A new form of iron [Fe(VI)] that has two electrons in its outermost shell has been reported by lead investigator John Berry at Max-Planck Institute for Bioinorganic Chemistry, Mülheim, Germany (now at the Univ. of Wisconsin, Madison). This Fe compound includes nitrogen (N), whereas the only other known Fe(VI) species, known as ferrate, carries oxygen (O). The new compound is called $(Me_3cy\text{-}ac)FeN(PF_6)_2$ or **5**. Another key difference between the two is that **5** has only one strong Fe-N multiple bond, which affects isomer shifts.

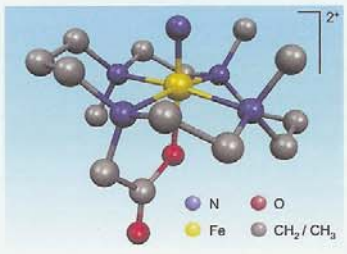


Fig. 1. Molecular structure of Fe(VI) containing N. *Source: Max-Planck Institute for Bioinorganic Chemistry, Germany.*

The compound is stable for months in a frozen solution at 77 K and for some time in a fluid solution at –40°C. A Mössbauer spectrum of the solution thawed to –40°C for 10 min shows only 29% diminished intensity of its signal due to **5**. On warming, **5** reacts and yields a high-spin Fe(III) species. The **5** (Fig. 1) has one short Fe–N bond length (1.57 Å) and an average of five Fe–N or Fe–O bonds (2.03-Å long).

The work is described in the June 1, 2006 online edition of *Science Express*.

For information, contact John Berry at berry@chem.wisc.edu.

BUSINESS NEWS

Tenn.-based **Oak Ridge National Lab** (www.ornl.gov) will build an S&T park that will be available for private sector companies and to create new companies from technologies developed at ORNL.

Calif.-based **NanoPolaris** (www.arrowres.com/splashnano.html) bought assets of **Unidym,** a developer of carbon nanotube-based electronics. Expected new products are nanotube thin-film transistors that allow bendable palm pilots, roll-up electronic brochures, and low-cost RFID tags.

QuarTek (www.quartekcorp.com), Greensboro, N.C., will create diapers that hold liquids during use and then become water-soluble, quickly biodegrading when discarded. Worldwide diaper industry is worth ~$34 billion at retail.

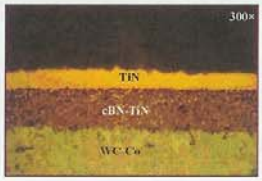
EUROSTARS, a new initiative established by EUREKA (www.eureka.be), a European intergovernmental network, will support small- and medium-size enterprises in R&D. Total budget is expected to be ~$505 million over 7 years.

Mass.-based **QD Vision Inc.** (www.qdvision) manufactured a quantum-dot display the size of a cell-phone screen. Its architecture has a layer of QD material sandwiched between two semiconductor regions with light coming from the quantum dots.

technologies, including enzyme-linked immunosorbent assays (ELISA) or mass spectrometry. The biobarcodes are nucleic acid sequences of 30 to 33 bases. Part of each biobarcode recognizes a specific target DNA sequence while the remainder is common and used for detection and readout functions. Each biobarcode is linked to a gold (Au) nanoparticle (30-nm dia). Magnetic nanoparticles are also constructed, which contain a short piece of DNA that binds to a separate unique region of the target DNA. The developers have recently shown how the devices can be multiplexed to detect and distinguish among different DNA sequences simultaneously.

Cubic boron nitride coatings—NanoMech LLC (www.nanomech.biz), Fayetteville, Ark.

The application of cubic boron nitride (cBN) nanoparticles has been shown to dramatically improve the cost and effectiveness of the surface coatings of carbide cutting tools. Using a novel electrostatic coating (ESC) process, the cBN nanoparticles are sprayed onto cutting tools at room temperature and pressure in powder or suspension form under the influence of an electric field. The electric field aids the formation of a uniform thickness coating. The process can produce single and multi-phase materials with the properties that suit abrasive, lubricating, anti-corrosion, super-hydrophobic, optical, electrical, or thermal functions.



Glowing nanowires—National Institute of Standards and Technology (www.nist.gov/public_affairs/techbeat/tb2006_0525.htm), Gaithersburg, Md.

Gallium nitride (GaN) semiconductor nanowires are grown on Si substrates, emitting ultraviolet (UV) light, as part of a project to create nanolasers. The wires are grown under high-vacuum by depositing atoms layer-by-layer (LBL) on a Si crystal. The wires (30- to 500-nm dia; up to 12-um long), when excited with a laser or electric current, emit an intense glow in the UV or visible parts of the spectrum, depending upon the alloy composition. The wires produce sufficiently intense light to enable room-temperature measurements of their characteristics. Applications include components in lab-on-a-chip (LOC) devices for identifying chemical and biological agents, scanning probe tips, and tools for laser surgery and electronics manufacturing.

NanoSolve Additives—Zyvex Corp. (www.zyvex.com), Richardson, Texas.

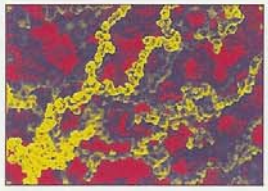
Carbon nanotubes (CNTs) incorporated into other materials provide dramatic improvements to the resulting composite's mechanical and physical properties. Previously, phase separation, aggregation, poor dispersion, and poor adhesion limited CNTs use into other materials. Here, this surface treatment improves dispersion in various polymers and solvents, including water and enhances the interaction between CNTs and their host matrix. The surface treatment consists of two components—one adheres to the CNTs and the other is customized to the application, allowing fast adaptation to the customer's requirements and improved time-to-market capabilities. Products are available as dispersions in chlorinated solvents, common organic solvents, water, bisphenol A and/or bisphenol F resins, and polyether pre-polymers.

Multi-compartmental bioreactors—Centro Interdipartimentale di Ricerca "E. Piaggio" (www.piaggio.ccii.unipi.it), Pisa, Italy.

This *in vitro* biomimetic metabolic system for interpreting and curing metabolic disorders, also can be used for testing and designing drugs without using animal models. The system consists of a network of chambers connected in series or parallel that is separated by biocompatible membranes or endothelial cells. Each chamber houses a specific tissue type. The soft-lithography fabricated chamber culture elements are designed using allometric scaling to mimic the main features of the metabolic system. A control system enables maintenance of pH, temperature, hydrostatic pressure, and flow.

Nanostrands—Metal Matrix Composites Co. (www.nanostrands.com), Midway, Utah.

These 3-D interconnected, self-assembled lattices of sub-micron and nanostructured strands of nickel (Ni) create opportunities in energy conversion and storage, filtering of hot gases, and numerous others. This material technology is a unique form of a high-aspect ratio (1,000 to 1 or higher) sub-micron diameter Ni powder. The diameter can be controlled from 50- to >1,000 nm. The nanostrands exhibit a high degree of branching and 3-D interconnectivity. Compared to carbon nanofibers, the Ni nanostrands can be engineered to meet the diameter and length requirements of nanostructure design.



Stretchable single-crystal Si—Univ. of Illinois (www.mse.uiuc.edu), Urbana-Champaign.

Used for creating electronic devices for flexible applications, these materials can be used in biomedical or biological devices, 3-D structural monitors, and conformable skins. The devices are fabricated as ultra-thin ribbons on a Si wafer using conventional IC procedures. The ribbons are undercut creating ones that are ~100-nm thick. A rubber substrate is then stretched and placed on top of the ribbons and removed, releasing the ribbons from the wafer and adhering them to the rubber. As the stress is released in the rubber, the ribbons buckle into a series of well-defined waves. Resulting devices can be repeatedly stretched and compressed without altering their electrical properties.

Nanostructured hydrogen sensor—Argonne National Laboratory (www.makelengineeering.com), Ill.

Based on nanostructured, self-assembled palladium (Pd) thin-films, these H_2 sensors have a response time <75 msec (5× faster than the best competitor) and a recovery time of 200 msec (50× better than the best competitor). The sensors have a wide temperature range, are relatively insensitive to moisture, have no warm-up requirements, and are unaffected by cobalt (CO), carbon dioxide (CO_2), and methanol. Thick-film Pd-based H_2 sensors are non-reproducible compared to these thin-film devices. A siloxane monolayer applied to the device modifies the structure of the Pd at the nanoscale level.

DNA buckyballs—Cornell Univ. (http://LuoLabs.bee.cornell.edu), Ithaca, N.Y.

These specially prepared, branched DNA-polystyrene (PS) hybrid buckyballs spontaneously self-assemble into mostly hollow balls that are ~400-nm dia (carbon buckyballs are ~7-nm dia). The rods forming the structure are each ~15-nm long. The DNA buckyballs are the first structures to be assembled from dendrimer-like DNA. About 70% of the volume of the DNA buckyball is hollow, allowing water to enter, suggesting that drugs can be encapsulated in the buckyballs and used as a drug delivery mechanism where natural enzymes break down the DNA, releasing the drug.

Rapid molecule sorting—IBM Almaden Research Center (www.research.ibm.com), San Jose, Calif.

By modifying the tip of an AFM and varying the strength and duration of an electric field applied to it, different molecular species can be separated from each other within a few milliseconds—>1,000× faster than conventional methods. Movement of as few as 10 molecules can be controlled. The process has the ability to deliver molecules to a surface with great precision, which can be useful for creating future lithography features for nanoelectronic devices.

3-D nanostructures—Univ. of Wisconsin (www.nsec.wisc.edu), Madison.

Block copolymers have been found to spontaneously assemble into intricate 3-D shapes when deposited onto 2-D surface patterns created with photolithography. This process allows photolithography to be extended into three dimensions with the resulting structures exhibiting different properties from the same block copolymer materials fabricated in bulk. The resulting 3-D nanostructures are stable, well-defined, and nearly defect-free over large areas. They align with the underlying lithographic pattern, a key requirement for any device or application based on them. Structures can also be creat-

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