FORESIGHT NANOTECH INSTITUTE
Advancing Beneficial Nanotechnology

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Foresight Nanotech Update

Inside This Issue

Luncheon Session

Technology Roadmap for Productive Nanosystems

Scott Mize, *President of Foresight*
Alex Kawczak, *Battelle*

October 27, 2005 12:15 pm
Our conference features a presentation on the Technology Roadmap for Productive Nanosystems, a joint initiative among Foresight Nanotech Institute, Battelle and The Waitt Family Foundation.

Register Now

If you haven't registered yet, now is the time. You can call our office at **(650) 289-0860**.

Advancing Beneficial Nanotechnology: Focusing on the Cutting Edge

13th Foresight Conference – October 22-27, 2005 San Francisco, CA

This year's conference is not to be missed. We have assembled world-class speakers and panels that will bridge the visionary aspects of nanotechnology through the challenges of policy issues and commercial applications to the cutting edge research that is being done in university and corporate laboratories.

Vision Weekend
October 22-23, 2005 (Saturday and Sunday)

Our Vision Weekend is known as the place where today's ideas become tomorrow's nanotech realities. Exclusive to Foresight participating members, the Vision Weekend is ground zero for idea exchange, creative communication and hearing speakers as they discuss their nanotech views in a candid, off-the-record environment.

(Continued on page 13)

Foresight Nanotech Conference Keynote

Keynote Address: Tuesday, October 25

Nanotechnology is Not Little in Washington

Floyd Kvamme
Co-chair, President's Council of Advisors on Science & Technology, and Partner, Kleiner Perkins Caulfied & Byers

Kvamme will cover Washington's perspectives on nanotechnology and discuss why top policy-makers think nanotechnology is strategically important to U.S. technical leadership, competitiveness and job creation.

Nanotechnology and Energy

Focus on Challenge #1: Meeting global energy needs with clean solutions

While nanotechnology has made great advances in the last two decades, it has yet to fulfill its ultimate potential. Foresight is dedicated to fostering nanotechnologies that can make a significant contribution to solving critical challenges which humanity faces. We have identified these as the Foresight Nanotechnology Challenges.

These challenges are:

1. **Meeting global energy needs with clean solutions**
2. **Providing abundant clean water globally**
3. **Increasing the health and longevity of human life**
4. **Maximizing the productivity of agriculture**
5. **Making powerful information technology available everywhere**
6. **Enabling the development of space**

In this issue of Foresight Nanotech Update, we have invited three experts to offer their ideas on how nanotechnology will impact energy in the future. We have also identified companies

(Continued on page 3)

Creating The New Foresight

By Scott Mize

What a difference a year makes. As many of you know, we have been hard at work overhauling and updating Foresight so that it can play a more central role in today's nanotechnology world. The environment in which we operate now is a far cry from the one in which Foresight was founded nearly 20 years ago. We are staying true to the original goals of Foresight, but putting them in a new context. As a think tank and public interest organization, to flourish at this stage in the field's development, it is essential that we bring value to an expanding community of stakeholders and interested parties. To establish a foundation for this, we have re-articulated our mission: To ensure the beneficial implementation of nanotechnology. To execute on this mission, we also have made some key changes in organizational focus.

We decided to complement our long-term technology focus with a near- and mid-term application focus. The first manifestation of this new focus is the Foresight Nanotechnology Challenges. These are our assessment of the most critical problems which humanity faces that can be addressed by nanotechnology. We believe that focusing on these challenges will produce the highest societal return on investment from nanotechnology.

We also made it a priority to initiate and participate in projects which contribute concretely to pushing forward the state of the art in the field. The Technology Roadmap for Productive Nanosystems is our first new project of this type. So far, we have assembled a world-class Steering Committee, Working Group, and set of of Roadmap Partners, and are set to kick off the series of Roadmap Workshops immediately after our annual conference on late October. We are very happy to have the partnership of Battelle for developing the Roadmap, and the support of Waitt Family Foundation.

We see the activities of Foresight falling into four areas (what we call the 4 P's): publishing, policy, prizes and programs.

Publishing

A think tank is essentially a publisher with a point of view. Our weekly *News Digest* has been a big hit. Our Web site is consistently ranked between #1 and #3 for "nanotech" and "nanotechnology" on the search engines, and traffic continues to grow. The new *Foresight Nanotech Update* will be delivered quarterly. We also provide press releases, opportunity alerts and action alerts on items of interest to the membership. All of these services will expand our position as a leading authoritative source of information on nanotechnology.

Policy

Now that Christine Peterson has moved to be Vice President of Policy and Research, we will see more activity in this area. Foresight is participating in the National Academy of Sciences review of the NNI, the International Council on Nanotechnology, California's Blue Ribbon Task Force on Nanotechnology, ASTM International's committee on nanotechnology, and the American National Standards Institute's committee on nanotechnology standards. Over time, we will be articulating and advocating policy positions which will address the most critical issues related to nanotechnology. These are likely to include partnerships with other leading policy organizations.

"We believe that focusing on these challenges will produce the highest societal return on investment from nanotechnology."

Prizes

We are currently raising funds to undertake a reformulation of our prize portfolio. Foresight currently awards five annual prizes, and offers one incentive prize, the Feynman Grand Prize. Incentive prizes are those contests where a cash award is given for being the first to achieve a specified milestone. We believe that incentive prizes can play a key role in moving the nanotechnology field forward. To this end, Peter Diamandis, the Chairman and CEO of X PRIZE Foundation, which recently awarded the $10 million Ansari X PRIZE for the first private sub-orbital space mission, has joined our Board. With his guidance at the helm of our Prize Steering Committee, we plan to develop one or more X Prize equivalents for nanotechnology.

Programs

We will also continue to undertake programs, that help us to achieve our mission. The two programs currently underway are our annual conference (the 13th edition of which will be held October 22-27 this year), and the Technology Roadmap for Productive Nanosystems described above. The conference is shaping up to be the best ever, and the Roadmap has had a good start. We plan to add other programs as funding becomes available.

The primary success criteria for Foresight is to execute consistently our new mission and strategy, including the activities described above. This will be our primary focus for the next several months, and beyond.

As a non-profit membership organization, we rely on you to play your part in supporting the organization. If you believe in what we are doing, below are several ways that you can help Foresight succeed:

Contribute

We are very grateful to have you as a member, and thank you for your past contributions. Please renew your membership in Foresight and consider increasing your level of support. Contributions received before the end of year will be particularly helpful.

Evangelize

We want your help in recruiting new members. We are asking each member to recruit at least one new member to join Foresight. We call this is our "each one reach one" initiative.

Introductions to potential major donors

Major donors (those who give over $5000 per year) play an essential role in supporting Foresight. If you know someone who is in a position to become a major donor and would be interested in what we are doing, please introduce us to them.

Introductions to potential corporate sponsors and partners. We have had success with securing more corporate sponsors than ever before and are expanding that effort. If you know a decision-maker in an organization that will participate in or be impacted by nanotechnology, or if you know an organization that may be a valuable partner in some way, please introduce us to them. We have some very robust sponsorship packages that deliver substantial value to these important partners.

Let us hear your thoughts and ideas. As members of Foresight, you are the primary group that we serve. We are eager to hear any ideas that you have that would help us to achieve our mission and be of better service to you and the public at large.

Foresight is in a unique position to make powerful contributions to advancing beneficial technology. As a think tank and public interest organization, we are the guys in the “white hats” who work for the common benefit of society and the planet. We can convene diverse interest groups and provide an open forum for discussion and action regarding critical issues in nanotechnology. We are also an honest broker in moving forward this important and transformational technology. I invite you all to play an active role with us in creating The New Foresight.

Scott Mize, *President*
mize@foresight.org

Nanotechnology and Energy *(Continued from page 1)*

that are currently working on nanotechnology solutions and products that may provide solutions to this challenge.

The next issue of Foresight Nanotech Update will focus on Challenge #2 Providing abundant clean water globally. If you have any suggestions or ideas on this issue, please send me an email.

Thank you,

Judy Conner, *Editor / Director of Communications*
editor@foresight.org

Energy Experts Q & A: Clark Gellings

"We see a great deal of promise in nanotechnology applications for cleaning air and water waste streams. "

Clark Gellings
Vice President, Innovation
Electric Power Research Institute

1. When do you think we will begin to see energy applications of nanotech being used? How will these applications apply to the Intelligrid?

EPRI recently announced the first application of nanotechnology in the electricity industry. It involves the use of magnetic molecules to clean up of water systems in Nuclear plants. These so called "Magmolecules" are designed to adhere to certain molecules which are radioactive so they can be easily filtered out of the water stream. EPRI sees many other similar applications in circulating water systems in power production – both with nuclear and fossil energy systems. The first IntelliGrid applications are likely to be in the deployment of advanced sensors.

2. How soon will we see the impact of nanotechnology in traditional energy consumption?

Based on a preliminary review, EPRI believes that there are at least seven other areas where nanotechnologies may hold benefits for the electricity industry. These include the following:

- Improved performance photovoltaic cells for producing electricity from the sun
- Thermoelectric devices which convert heat directly into electricity
- Sensors for monitoring the condition of the power system and its components inexpensively
- Improved structural materials for use in applications such as advanced conductors and lighter weight wind turbine blades
- Improved catalysts and electrolytes for use in fuel cells
- Improved catalysts for use in the removal of nitrous oxides
- Improved portability of electricity through the development of better batteries and ultracapacitors

3. Traditional energy has made our planet dirtier and less inhabitable. How would nanotechnology change the consequences?

We see a great deal of promise in nanotechnology applications for cleaning air and water waste streams.

4. What are the anticipated downsides of nanotechnology applications toward energy?

At present we do not see any.

5. What do you anticipate as the upsides of nanotechnology energy applications?

- Increased performance of renewable and other distributed energy resources
- Improved asset utilization of the power delivery system
- Improved environmental performance of the power system

6. Do you see nanotechnology making energy available globally to the point where conflict over energy may lessen?

- If the cost and performance of photovoltaic devices can be substantially improved through the use of nanotechnologies, then perhaps.

7. If you were in the office pool, which nanotech solution would you put your money on to make the biggest impact in the future?

- The use of carbon nanotubes in ultracapacitors.

About Clark Gellings

Clark Gellings *is Vice President of Innovation at the Electric Power Research Institute. He joined EPRI in 1982 as a Program Manager, Customer Systems, and subsequently served in a series of senior executive positions leading to his current appointment.*

Gellings is a registered Professional Engineer, a Fellow in the Institute of Electrical and Electronics Engineers (IEEE), a Fellow in the Illuminating Engineering Society (IES), and President of the U.S. National Committee of CIGRE. He holds a bachelor's degree in Electrical Engineering from Newark College of Engineering, a master's degree in Management Science from Stevens Institute of Technology, and a master's degree in Mechanical Engineering from New Jersey Institute of Technology.

Electric Power Research Institute
http://www.epri.com

Future Foresight Nanotech Updates

Each edition of Foresight Nanotech Update will feature Q&A's from thought leaders about the Foresight Nanotechnology Challenges. The next issue will be devoted to **Challenge #2: Providing abundant clean water globally.** If you would like to be considered for the Q&A on clean water or suggest someone who might be appropriate, please contact Judy Conner at

editor@foresight.org

Energy Experts Q & A: Joel Makower

"The upside will come if nanotechnology can create new energy products and services at disruptive prices, efficiency, environmental friendliness, and reliability - the Holy Grails of the clean-energy world."

Joel Makower
Co-founder and Principal
Clean Edge, Inc.

1. When do you think we will begin to see energy applications of nanotech being used?

The real question is when we'll see any nanotech applications hit mainstream markets. When they do, I think energy will be one of the first applications to gain traction, egged on by the multiple pressures on the global energy market that is raising prices -- and keeping them high -- for the foreseeable future. However, to succeed nano energy applications will have to compete successfully in two ways: to be a key part of a winning clean-energy technology (such as solar or wind or hydrogen fuel cells) and to do so as the low-price, high-performance choice.

But there are many other technologies competing to be the low-cost, high-performance energy provider. In the solar arena alone, there are more than a score of venture-financed companies racing to develop a half-dozen different non-nano technologies. It will be footrace to the finish.

2. How soon we will see the impact of nanotechnology in traditional energy consumption?

I'm not sure what "traditional energy consumption" refers to. If you mean "traditional energy production" -- that is, energy generated from coal, natural gas, and nuclear -- I don't expect to see nanotechnology playing much of a role.

3. Traditional energy has made our planet dirtier and less inhabitable. How would nanotechnology change the consequences?

The environmental appeal of all clean-energy technologies is that they emit few, if any, gases that contribute to global warming and reduce other air emissions that contribute to smog and respiratory problems, and generally wreak far less havoc on the earth by requiring less digging, mining, and drilling. To the extent that nanotechnologies contribute to these goals by requiring fewer materials, less energy, and fewer impacts on the air, land, and soil, they will be widely embraced -- assuming they can do this cost-effectively.

4. What are the anticipated downsides of nanotechnology applications toward energy?

The downsides are the same as for any nanotechnology: long development timelines and assurances that there won't be any negative unintended consequences to people or the planet.

Most people understand that any new technology has risks, though I think many of the risks associated with nano have been overblown -- Bill Joy's self-replicating, bacterium-sized nanorobots gobbling everything in sight comes to mind. But in the post-9/11 world, people are naturally more cautious, so any new nanotechnology will have to demonstrate that it not only is safe and cost-effective, but also incapable of being deployed for evil purposes. In most of the clean-energy applications of nanotechnology that I've seen, such concerns should be pretty easy to laid to rest.

5. What do you anticipate as the upsides of nanotechnology energy applications?

The upside will come if nanotechnology can create new energy products and services at disruptive prices, efficiency, environmental friendliness, and reliability -- the Holy Grails of the clean-energy world. So, for example, a solar cell using nanotechnology in such a way that it dramatically increases the efficiency at which sunlight is converted into electricity, and does so using cheap, readily available materials with low energy manufacturing needs, will stand to conquer markets and play a key role in reducing global warming, improving global security, and bringing affordable electricity to the two billion denizens of the planet that lack it. I'd say that's a pretty nice upside.

6. Do you see nanotechnology making energy available globally to the point where conflict over energy may lessen?

That's a wonderful dream, and nano certainly can play a role. It's important to point out that reaching that state of Nirvana will likely require a host of clean-energy technologies: solar, wind, geothermal, and biobased energy resources, plus some form of hydrogen fuel cells that doesn't require oil, coal, or natural gas to generate electricity. That sounds like a pretty tall order, but all of those ingredients are all in the works; the barriers at this point are as much political and financial as they are technical. To the extent nanotechnology can facilitate any or all of these clean-energy resources, it will be embraced with open arms.

7. If you were in the office pool, which nanotech solution would you put your money on to make the biggest impact in the future?

That's the billion-dollar question. I'm excited about nanotechnology's role in creating new flexible organic materials -- whether for flat-panel displays or solar-collecting polymers -- and I believe there will be significant and impactful markets there. But I'm not much of a gambler, so I wouldn't counsel laying down anything of monetary value based on my predictive powers.

(Continued on page 6)

Joel Makower *(Continued from page 5)*

About Joel Makower

Joel Makower*, co-founder and principal, is a well-respected business writer and analyst, and a leading voice on business, technology, and the environment. Prior to founding Clean Edge, he was editor of The Green Business Letter, a monthly newsletter on corporate environmental strategy, and the creative force behind GreenBiz.com, an acclaimed web portal on business and the environment. Previously, Joel founded Tilden Press Inc., an award-winning company that researches, writes, and produces books, newsletters, and other editorial products and services.*

He is a former nationally syndicated columnist, a bestselling author or co-author of more than a dozen books, including The E-Factor: The Bottom-Line Approach to Environmentally Responsible Business, and is a frequent lecturer to companies, associations, and business schools on clean technology and sustainable business strategy.

Clean Edge, Inc.
http://wwwcleanedge.com

Energy Experts Q & A: Michael Heller

Michael Heller
Professor, Departments of Bioengineering and Electrical and Computer Engineering, University California, San Diego

1. When do you think we will begin to see energy applications of nanotech being used?

At first, nanotechnology will probably impact energy applications in more subtle ways. By way of another example, the "microelectronics" area has already moved into the nano realm. There are already nanoscale features and components within newer computers and memory devices, but generally individuals don't think of it as nanotech.

Regarding the energy area, my feeling is that it will also be a more evolutionary process. It may first be exhibited in improved nanomaterials for energy transmission, and then possibly more efficient fuel cells and photovoltaic devices.

2. How soon we will see the impact of nanotechnology in traditional energy consumption?

There are enormous efforts and strides being made in research on both traditional energy systems (non-renewable) as well as newer ones related to renewable (solar, wind, etc.). One may see for example, in the photovoltaic area where nanolayers of quantum dots will be used to greatly increase the efficiency of these devices. Research is also now being done on metallic nanoparticles and nanopore structures that will be used for advanced fuel cell systems for more efficient energy production.

We may expect new nanomaterials to play a role in increased efficiency in using existing energy sources such as more robust and inexpensive wind turbines. Another area where nanotech will assist is in the transmission of electrical energy. Carbon nanotube based wires are getting a lot of research attention, but it is always difficult to predict when such technologies will ultimately be commercialized. .

Regarding the impact of nanotech on large scale energy production, the true lynch pin is always how efficiently and cost effective the energy can be produced. The key requirement of any large scale energy systems is its energy yield ratio (EYR). Basically, how much energy do we have to put into the system ($) relative to how much we get out ($$$)?

For example with the best oil scenario:
To get oil out of the ground in the Middle East, the energy yield ration (EYR) is about 100 to 1.
To move that oil to a gulf coast refinery using tankers, the EYR now drops to about 10 to 1
By the time the oil is useable as gasoline in your car the (EYR) may be < 5 to 1.

The effective use or impact of nanotechnology on energy production and transmission will most certainly be related to scale. For example, it may be that newer photovoltaic (solar energy) devices can be used for your home or on in a small geographic area, but the success of a very large scale photovoltaic system requires development of efficient storage and transmission systems.

How efficient and cost effective these nanotech solutions are is important. There are no easy answers to the energy issues, but nonetheless nanotech will most certainly be important in developing new energy systems. But, the energy yield ratio will still apply whether the area is classical non-renewable oil, nuclear energy, or the desired cleaner processes believed possible with the renewable energy sources.

3. Traditional energy has made our planet dirtier and less inhabitable. How would nanotechnology change the consequences?

The huge impact on our environment is due to both energy and population. As more people modernize, they will all want mobility and the kind of lifestyle that demands more energy.

No matter what we do, humans will have an impact on the environment. Energy is a part of what we will have to deal with and I'm not sure there is really a totally clean source of energy. Anytime you produce or convert energy there is a down side. We can get processes that are relatively more efficient, more balanced, and not as polluting but there will still be an impact. Nanotechnology may have some unforeseen consequences, but I believe it will have overwhelming benefits. We have made a commitment to technology and we have to start to better understanding risk/benefit ratios and understand that there are always risks as well as benefits.

4. What are the anticipated downsides of nanotechnology applications toward energy?

Some of the practical downsides of nanotech are that the renewable energy processes (solar) being developed at this time will cover a

"Regarding the impact of nanotech on large scale energy production, the true lynch pin is always how efficiently and cost effective the energy can be produced."

lot of ground (low energy density). With oil, there is a hole in the ground, a tanker and a pipeline (energy density is very high). Solar energy is dilute and takes a lot of space to get the large-scale energy collection that you need. How many solar panels need to be laid out to get the equivalent to a gallon of oil? It is always a question of energy density and how efficiently we can collect it.

5. What do you anticipate as the upsides of nanotechnology energy applications?

The upsides of applying nanotechnology in energy will be improvement in efficiencies across the entire collection/production and distribution system.

6. Do you see nanotechnology making energy available globally to the point where conflict over energy may lessen?

Energy and resource distribution are global issues, and I think nanotech will help to improve these areas. I also feel that we as a nation and as a species, need to be more energy independent and mindful of how energy is used in our society.

7. If you were in the office pool, which nanotech solution would you put your money on to make the biggest impact in the future?

Right now in my research, we are working on nanofabrication and nanomanufacturing assembly technology. We work on basic science and technology and are trying to develop a foundation for viable nanofabrication. At the same time, we are keeping our options open to potential targets and applications. I guess if I were going to put my money on something, it might be quantum dot layers for photovoltaics. But I really think we should keep our options open to all applications of nanotechnology and watch the research that is coming out of the university and corporate laboratories.

Dr. Michael Heller *is a Professor, Departments of Bioengineering and Electrical and Computer Engineering, University California, San Diego. He also serves as an exclusive consultant to Nanogen.*

He has numerous patents and publications related to work on DNA microarrays, medical diagnostics and nanotechnology. Dr. Heller has served on several review panels for the National Nanotechnology Initiative.

http://www-bioeng.ucsd.edu/faculty/alpha/faculty.cfm?psnid=546746

Nanotechnology & Energy

Solar and Fuel Cells

*There are two specific applications, solar and fuel cells, where nanotechnology processes or products will eventually assist in solving Foresight Nanotechnology Challenge #1 Meeting global energy needs with clean solutions. Foresight Nanotech Institute has identified a small selection of companies doing work in this area. **

Solar Cells

Konarka *http://www.konarka.com/*

Headquartered: Lowell, Massachusetts, USA
CEO: Howard Berke
Technology focus: Nanomaterials use dye to harvest energy from both the sun and indoor light, and pass the energy through titanium dioxide and electrodes to produce DC electricity. The photoactive materials are coated or printed onto rolls of plastic at one-third the cost of traditional photovoltaics."
Product: Power Plastic
Recent news: "Lowell, Mass., and Wilmington, Del. – September 28, 2005 – Konarka Technologies, Inc., an innovator in developing and commercializing Power Plastic' that converts light to energy, and Textronics, Inc., a pioneer in the field of electronic textiles, today announced a joint development program to create prototype garments and fashion accessories with portable, wearable power-generation capabilities. The technology will utilize Konarka's light-activated Power Plastic' and Textronics' electronic textile systems to provide renewable, wearable energy sources for personal electronic devices."

Heliovolt *http://www.heliovolt.com/*

Headquartered: Austin, Texas
CEO: Dr. Billy J Stanbery
Technology focus: "HelioVolt has developed the fastest and most effective way to manufacture CIS (Copper Indium Selenide), the most reliable and best-performing thin film material for generating electricity from sunlight. HelioVolt's FASST™ technology is available to manufacturers who want to apply CIS coatings in custom shapes, sizes, and tints to create power generating steel, metal and polymer roofing, and architectural glass."
Product: "photovoltaic modules incorporated as building materials (roofing, glazing, curtain walls)"
Recent news: 21 June 2005 - "HelioVolt Corporation, a next-generation solar energy technology company, has closed $8m in Series A venture funding from New Enterprise Associates of Menlo Park, CA."

Nanosolar *http://www.nanosolar.com/*

Headquartered: Palo Alto, CA
CEO: Martin Roscheisen
Technology focus: Semiconductor quantum dots and nanoparticles form the basis of its proprietary printable semiconductor paint; also "nanotemplates with precise three-dimensional order that can be used to engineer solar cells based on advanced ultra-thin solar-cell architectures."
Product: SolarPly™ modules and panel, ranging in size from 4x12 inches to 10x14 ft. These are claimed to be "the world's most cost-efficient" and "as efficient and durable as conventional crystalline silicon cells."
Recent news: Red Herring, June 29, 2005 - Nanosolar named one of the Top 10 Cleantech Companies.

Miasolé *http://miasole.com/*

Headquartered: San Jose, CA
CEO: David Pearce
Technology focus: "manufactures the first solar technology inexpensive and plentiful enough to make solar power practical for large-scale use." CIGS is a compound of copper, indium, gallium and selenium, a semiconductor that can be applied as a thin film on many carrier substrates to create photovolataic cells comparable to polycrystalline silicon solar cells in efficiency. Miasolé uses high-volume, thin-film manufacturing technology it has proven in the hard disk industry."
Product: A thin-film photovoltaic cell consisting of an ultra-thin layer of photoactive material (CIGS) on a stainless steel foil 50 microns thick, easily used in modules or incorporated into building materials like membrane roofing.
Recent news: June 10, 2005, San Jose Mercury News (CA) Miasole has raised $16 million in a round led by Menlo Park's Kleiner Perkins Caufield & Byers.

Orionsolar *http://www.orionsolar.net/*

Headquartered: Ariel, Israel
CEO: Dr. Jonathan Goldstein, President
Technology focus: Photovoltaic panels based upon dye and titanium dioxide, and encased in glass or plastic
Product: Being developed are roof top panels for supplementary power for buses; inexpensive solar home systems for residential power in the developing world.
Recent news: "April 14, 2005 - Israeli start-up company Orionsolar, a developer of solar energy photovoltaics, has received terms for a second round financing. $750,000 will be invested by the New York based investment group 21ventures. Orionsolar has joined the race to build very low cost solar energy panels costing less than $1 per peak watt, equivalent to less than 8 cents per kWh. Orionsolar is avoiding silicon, which is very expensive to manufacture, and has chosen dye cell nanotechnology."
http://www.megavolt.co.il/articles/Orionsolar.html

Fuel Cells

QuantumSphere *http://www.qsinano.com/*

Headquartered: Costa Mesa, CA
CEO: Kevin Maloney
Technology focus: Highest quality metallic nanopowders produced by "an adaptation of the gas phase condensation method combined with proprietary trade secrets and intellectual property."

Product: QSI-Nano™ Nickel/Cobalt (Ni/Co) replacement for platinum catalyst.
Recent news: "COSTA MESA, CA (PRWEB) August 31, 2005 QuantumSphere, Inc., the leading manufacturer of metallic nanopowders for applications in aerospace, defense, energy and other markets demanding advanced material applications, announced ("QSI- nano™ Ni/Co alloy") as a clear replacement solution for the platinum electrode market."
http://www.prweb.com/releases/2005/8/prweb278655.htm

PolyFuel *http://www.polyfuel.com/*
Headquartered: Mountain View, CA
CEO: James D. Balcom
Technology focus: Fuel cell membranes based upon hydrocarbon polymers directly engineered to have the appropriate nano-architectures to give the desired chemical characteristics
Product: "PolyFuel's membranes ... are considered to be best-in-class for both portable direct methanol fuel cells (DMFC) — designed for portable electronic devices ... — and for hydrogen fuel cells — designed to power automotive vehicles."
Recent news: "Tokyo and Mountain View, CA - April 12, 2005 - PolyFuel Inc., the leader in engineered membranes for fuel cells, today announced a new version of its hydrocarbon membrane for portable applications that provides fuel cell manufacturers with the best in class performance attributes of its predecessor, while at the same time providing significantly greater manufacturing flexibility."

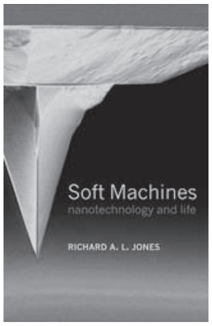
Kainos Energy *http://www.kainosenergy.com/*
Headquartered: San Jose CA
CEO: Not stated; a wholly-owned subsidiary of NanoGram Corporation
Technology focus: "Using laser-based nanoparticle manufacturing (NPM™) and laser reactive deposition (LRD™) technologies developed by NanoGram Corporation, Kainos Energy is applying a radical processing approach using these mature nanomaterials synthesis and deposition processes to overcome the challenges to Solid Oxide Fuel Cell (SOFC) commercialization."
Product: "As SOFCs have high fuel efficiencies (> 55%, compared to < 30% for fossil fueled plants) and may be adapted to utilize future alternative fuels such as syngas and biomass, Kainos Energy's cell designs are ideally suited for distributed generation (DG) applications." The company is also developing fuel cells as Auxiliary Power Units for vehicles and portable fuel cells for handheld devices.
Recent news: September 7 2004 - Kainos Energy Corporation awarded a Phase I Small Business Innovation Research (SBIR) grant from the National Science Foundation.

** Note: This is not a comprehensive list nor suggestions for investment purposes.*

Soft Machines: Nanotechnology and Life

by Richard A. L. Jones

Book Review by James Lewis Ph.D



Soft Machines: Nanotechnology and Life
by Richard A. L. Jones
Hardcover: 229 pages
Oxford University Press
(October 30, 2004)
ISBN: 0198528558

Author's book web site:
http://www.softmachines.org/

Writing in 1996 in the introduction to the web version of Engines of Creation, Eric Drexler states "The molecular machinery found in nature provides an existence proof for enormous capabilities," referring to the vision of nanotechnology that he presented in Engines. Richard Jones, a professor of physics at Sheffield University whose research focuses on the properties of polymers and biopolymers at surfaces and interfaces, begins Soft Machines with the same premise. "A radical nanotechnology must be possible in principle, because we are here. Biology itself provides a fully-worked-out example of a functioning nanotechnology, with its molecular machines and precise molecule by molecule, chemical syntheses." From this premise he asks: Are the hard machine designs of Drexler, scaled-down from familiar macroscopic machinery, or the soft machines evolved by life, the most effective model for radically advanced nanotechnology? Jones's argument is that "Nature has evolved to get nanotechnology right." That just because human engineering works better at the macroscopic scale than does nature (think jumbo jet versus bird) does not mean it will work better at the nanoscopic scale, because the rules for engineering at the nanoscale are very different. Classing most current nanotechnology as incremental and evolutionary, Jones notes that most nanotechnologists are skeptical of Drexler's vision of radical (advanced) nanotechnology, with atomically precise molecular manufacturing. Jones believes that radical nanotechnology will be developed, but not as proposed by Drexler.

Soft Machines is an informative and readable exploration of the nanoworld: length scales, energies, forces, the tools used in the exploration, the importance of Brownian motion and van der Waals (surface) forces, quantum effects and band structures, nanotubes and quantum dots, etc. There are educational and entertaining descriptions of technologies from cryo-transmission electron microscopy to CMOS. The discussion of the role of Brownian motion and entropy in self-assembly, and the role of self-assembly in producing nanoscale and larger structures, is particularly well done, as one would expect from the author of a technical book on the subject of the physics of matter that is neither simple liquid nor crystalline solid (Soft Condensed Matter, Oxford University Press, 2002).

From the nanostructures formed by self-assembly of relatively simple synthetic polymers, Jones moves to discussing the more complicated molecules used by biology—proteins and nucleic acids—and gives a good account of how the unique sequence of amino acids in a given protein specify the unique three-dimensional structure of that protein. In this way the linear arrangement of the four "letters" in the genome determines the three dimensional structures of the thousands of protein and RNA molecular machines specified by the genome.

But self-assembly is not the end of the story of how a complex organism is formed from those thousands of different kinds of molecular machines. A relatively simple class of soap-like molecules called lipids play an essential role in getting to a higher level of organization: they self assemble into membranes that sequester protein and RNA molecular machines into cells and, in the case of larger, more complex cells, into organelles within cells. An important component of cells and organelles is a class of proteins called membrane proteins that can not fold into the proper three dimensional shapes by themselves, but need to fold in the presence of membranes to form the various pores, pumps, and complexes, composed of several kinds of proteins, that can convert chemical energy to mechanical motion, and then into a different type of chemical energy. So folding and assembly in a particular compartment introduces additional information beyond what is inherent in the linear sequence of the protein that helps to form more complex molecular machine systems. Another example that Jones describes is the case of precursor proteins that divide the folding into two stages by removing a part of the protein after the initial stage of folding so that something different can happen in the second stage.

> *"Soft Machines is an informative and readable exploration of the nanoworld: length scales, energies, forces, the tools used in the exploration, the importance of Brownian motion and van der Waals (surface) forces, quantum effects and band structures, nanotubes and quantum dots, etc."*

Having established some general principles governing biological molecular machine systems, Jones comes to the core of his argument in considering biological molecular motors. Applying conventional engineering principles to nanoscale motors made from rigid materials presents serious challenges in designing around Brownian motion and strong surface forces. In contrast evolution has produced biological motors made from soft materials that actually rely on Brownian motion and surface forces to work. As example, Jones describes how Brownian motion causes polymers to expand and contract in response to changes in the chemical environment, and how it is the basis for molecular recognition, in which one molecule specifically binds to another. In turn, the way in which proteins can change shape in response to binding another molecule provides mechanisms for protein motors, pumps, and valves. Jones provides an overview of how biological nanomachines working on these principles store energy from the metabolism of food by pumping hydrogen ions across membranes, and then reclaim that energy to make the ATP molecules that provide the cell with its energy currency, and how biological nanomachines serve as linear and rotary motors. Jones provides a solid account of the principles involved, although he does not provide enough detail to do justice to the current atomically detailed knowledge of how these nanomachines function. Efforts to harness various molecular motors based on

"A final brief chapter on "Our Nanotechnological Future" identifies four approaches to developing radical nanotechnology. "

Brownian motion and molecular conformation change, including his own research, are briefly described.

In asking how far can traditional machinery with gears and cogs be reduced, Jones arrives at the designs of diamondoid gears and other machine components done by Drexler and others. Jones believes that Brownian motion and surface forces will make such designs inoperable, even if they could be synthesized. Although all chemical bonds of a given type are perfectly uniform, flexing caused by Brownian motion will make it impossible to achieve the precision tolerances necessary for machinery to operate. Gear surfaces that approach closely will seize due to surface forces. These conclusions are firmly stated and shown to be applicable to some possible situations, but no calculations are presented for specific designs that have been proposed by others. The conclusions thus appear to result from an educated intuition about how physical forces work on the nanoscale rather than from computer simulations of specific proposed designs. Molecular dynamics simulations recently completed at Nanorex of seven designs by Eric Drexler, Ralph Merkle, Mark Sims, and Ninad Sathaye [http://www.nanoengineer-1.com/mambo/index.php?option=com_content&task=view&id=60&Itemid=57] show that Brownian motion, although clearly visible in the way the atoms jiggle, does not compromise the designs. Surface forces are also accounted for in the force fields used in these simulations.

Jones proceeds to consider fluid flow, sensors, and transducers, and describes how biological nanomachines use how macromolecules change shape to accomplish these functions. An additional chapter describes how molecular shape change governs the movements of ions and molecules, making possible nerves and brains. Although brains and the simpler processes considered earlier exploit only the "basic tricks of soft nanotechnology—self-assembly, molecular recognition, and Brownian-motion-activated conformational change", photosynthesis introduces "a new element--the organized transport of electrons" and thus takes "the first steps to developing molecular electronics." Jones finishes his exploration of the nanoworld with a survey of current efforts to make nanostructures that organize the transport of electrons, from solar cells to conducting polymers to molecular electronics.

A final brief chapter on "Our Nanotechnological Future" identifies four approaches to developing radical nanotechnology. The first is continuing the current top-down approach to making computer chips and MEMS towards nano-electronics and NENS. The second approach is often called bionanotechnology, in which components isolated from organisms, such as molecular motors, are incorporated into artificial nanostructures, or in which simple bacteria would be genetically engineered to contain the components of interest. The third approach Jones christens biomimetic nanotechnology, "copying the principles of operation of biological nanotechnology, but executing them in synthetic materials." The fourth approach exploits "rigid diamondoid structures put together by positionally-sensitive mechanochemistry, as proposed by Drexler and his followers". Jones concludes that, although the fourth approach does not contradict any physical laws, it is least likely to succeed. Compared to the second or third approaches "it is working against the grain, rather than with the grain, of the special physics of the nanoworld". Compared to the first approach, it lacks a large base of experience and a large financial driving force.

Aside from the fact that Jones does not take account of molecular dynamics simulations that seem to show that some diamondoid molecular mechanisms would in fact work, the arguments that Jones produces seem largely sound as far as they go, but not thorough enough to be conclusive. No detailed road map from current capabilities to advanced nanotechnology yet exists for any of the four paths he points to. Further, the distinctions among the four paths do not need to be as rigid as he presents them. For example, the path to advanced nanotechnology through current protein engineering originally suggested by Drexler in 1981 incorporates much of the biomimetic nanotechnology approach. Both roadblocks and breakthroughs may yet lie in wait along any path to our nanotechnological future.

Future Foresight Nanotech Updates

The next book to be reviewed by *Foresight Nanotech Update* will be ***Nanohype*** written by David Berube, Professor of Communication Studies and associate director of NanoScience and Technology Studies at the University of South Carolina.

This book will be released this November by Prometheus, the publisher.

Common Sense about "Nanoparticle Toxicity"

By Christine L. Peterson

"The emerging age of nanotechnologies will raise many difficult issues, with nanotoxicity one of the earliest but not the most challenging. Successfully working together on this will give us experience and build trust which can then transfer to the harder work to come."

The first significant battle in near-term nanotech is heating up as various players stake out positions and takes sides on the issue of nanoparticle toxicity.

Based on that label, the issue seems pretty clear at first. If nanoparticles are toxic, then they're bad and should be prohibited. Right?

Well, maybe not. It turns out that one of the most promising uses of nanoparticles is in the fight against cancer, in which we may want those particles to function like chemotherapy does—in other words, to be toxic to cancer cells. So in this case, what we want is not zero toxicity but controlled toxicity. Meanwhile, a few studies have been done testing various nanoparticles for negative impacts on organisms, with mixed results. There is at least some evidence for concern.

Already we can see that this question is not simple. Let's step way back, look at the big picture, and see if we can make some sense out of it.

First, we have to figure out what is included by this term "nanoparticle." There is no agreed-upon definition, but as of July 2005 the standards body ASTM International was working on the following: "Nanoparticle: A particle (a tiny piece of any substance) with dimensions between 1 and 100 nm containing between tens and thousands of atoms."

This is an alarmingly broad definition, including not just buckyballs, nanotubes, and the relatively-new sizes of common materials such as titanium dioxide now in sunscreens, but also vitamins, proteins, and an immense collection of both natural and man-made chemical substances.

By October, the ASTM definition had evolved into: "Nanoparticle: A nanoscale particle of any composition that has a maximum dimension of 100 nanometers." This is even broader—now there is no minimum number of atoms required.

How is it possible to say anything coherent about the potential toxicity of such an incredibly large group of material entities, other than that it must vary tremendously, from extremely benign to highly dangerous? And that to say anything more would require more specificity on which nanoparticles we're talking about?

Yet the nanoparticle toxicity debate is marching on regardless. Here are a few key players, roughly in order of harshest to most lax:

ETC Group: This NGO headquartered in Canada first raised the issue and has called for a moratorium.

Natural Resources Defense Council: NRDC is heading up a group of environmental organizations in calling for very strict regulation of nanoparticles.

Environmental Defense: This leading environmental NGO is advocating a large increase in the fraction of U.S. federal nano research dollars which are spent on safety testing.

Insurance companies: Swiss Re, a major re-insurance company, issued a report expressing concern about nanoparticle liability. Munich Re has revealed similar worries.

International Council on Nanotechnology: Along with its sister organization, Center for Biological and Environmenal Nanotechnology, ICON is working to develop standards of care.

U.S. Environmental Protection Agency: EPA has proposed to regulate nanomaterials through a voluntary pilot program.

DuPont: The CEO of this multinational chemical company has joined with Environmental Defense in calling for a large increase in U.S. federal nanosafety testing.

Nanotech industry association: The leading such organization in the U.S. avoids the topic on their website.

Nanoparticle industry: Companies are looking for guidance on how to handle nanoparticles safely and avoid liability, while still producing new products at competitive prices. Until such guidance emerges, they are keeping quiet on the issue and hoping to avoid strict regulation, such as the labeling and tracking being called for by the NRDC-led group.

Who are the good guys and who the bad guys in this list? With few exceptions, all those involved seem to have a position which is both coherent and understandable. The differences appear to arise from varying values placed on potential benefits versus potential risks, with those near the top favoring the Precautionary Principle's emphasis on avoiding risk, and those nearer the end focused on technological progress and its advantages, e.g., in tackling problems such as the Foresight Nanotech Challenges (clean energy, water, health, food, infotech, and space).

Meanwhile, although very strong regulation of nanoparticles is being proposed by some NGOs, most new chemicals submitted to the EPA for approval of commercial-scale production are accompanied by no health data at all. If data exists, it must be submitted, but it is not required that any be generated—so it generally isn't.

Given the complexity—not to say chaos—described above, what is a common sense approach to this difficult issue?

Here's what we're doing at Foresight:

1. Communicate with all stakeholders who are sincerely trying to address the issue. Assume good will unless clearly demonstrated otherwise.

2. Give serious attention to proposals that seem worth exploring, such as the joint DuPont/Environmental Defense proposal to require increased federal funding of safety testing.
3. Support the EPA's voluntary pilot program, with the understanding that it will eventually lead to stronger requirements and regulation — as it should.
4. Support the establishment of industry guidelines on standards of care ("best practices") for both worker safety and product testing.
5. Advocate a unified, consistent approach to chemical/nanomaterial approval.

In supporting these positions, Foresight has found the most useful mechanism to date is ICON, mentioned above. I serve on their Advisory Board and have been impressed with the quality of participants, most recently the leadership of Andrew Maynard — formerly at NIOSH and now affiliated with the Project on Emerging Nanotechnologies at the Woodrow Wilson Center for International Scholars — in stepping up to organize their task force on nanomaterials best practices. Foresight encourages other NGOs and corporations addressing the nanotoxicity issue to work with ICON.

The emerging age of nanotechnologies will raise many difficult issues, with nanotoxicity one of the earliest but not the most challenging. Successfully working together on this will give us experience and build trust which can then transfer to the harder work to come. All stakeholders are invited to contact Foresight to express their views, propose alliances, and contribute to the discussion and development of strategies. Your input is both welcome and needed.

Christine Peterson *is co-founder and VP Public Policy of Foresight Nanotech Institute. Contact her at foresight@foresight.org.*

Foresight Nanotech Institute - Public Policy

Foresight Institute focuses its public policy activities on maximizing the benefits and minimizing the downsides of nanotechnology. Our highest priority is identifying and promoting policies that can assist with the Foresight Nanotech Challenges.

Addressing these challenges involves many policy areas: from setting an appropriate level of safety research funding, to exploring how to increase access to nanotechnologies; from helping promote specific technical breakthroughs, to reviewing how publicly funded nanotech patents can be better administered for greatest societal benefit.

As the largest civil society organization focused specifically on nanotechnology issues, Foresight Institute uses a variety of processes to develop and deliver policy education and recommendations. These include commissioning policy studies, speaking on policy topics for diverse audiences, testifying for government committees, briefing the press on policy matters, conducting surveys, and discussing policy issues in open online public discussions.

Individuals and organizations are invited to participate in Foresight policy activities. We encourage your suggestions for policy study topics, critiques of our positions on the issues, and comments on our weblog, Nanodot.

http://www. Nanodot.org

We are particularly interested in cooperating with other organizations in policy studies on how nanotechnologies will affect their areas of concern, from medicine, to the environment, the developing world, and other areas that will experience a strong impact from nanotech. Individuals are invited to join as Foresight members, and corporations can participate through corporate membership, conference sponsorship, or underwriting policy studies of mutual interest.

Foundations and other organizations with an interest in our work should speak with Christine Peterson, Foresight's VP, Public Policy.

Foresight@foresight.org

13th Foresight Conference *(Continued from page 1)*

This event features over sixteen speakers including: Peter Diamandis, X Prize Foundation; Aubrey de Grey of University, Cambridge; Eric Drexler, Nanorex; Richard A.L. Jones, University of Sheffield; Congressman Mike Honda, Vice Chair, Democratic National Committee, Ron Bailey, Science Correspondent, Reason Magazine; and Alan Goldstein, Biomedical Materials Engineering, Alfred University.

Applications & Policy
October 24-25, 2005 (Monday and Tuesday)

The Applications & Policy sessions focus on the Foresight Nanotechnology Challenges, and will examine the commercial breakthroughs and public policy actions that are driving nanotechnology solutions to these challenges facing humanity.

Hear over thirty speakers including: George Atkinson, U.S. Department of State; Scott Hubbard, NASA Ames Research Center; Randy Hayes, Rainforest Action Network; Peter Singer, University of Toronto Joint Centre for Bioethics; David Bishop, Lucent; Jim Von Ehr, Zyvex; and Adam Werbach, Conservationist and former President, Sierra Club. These sessions also feature panels on nanotechnology applications for clean energy, clean water, human health, agriculture, information technology, and space development.

Research
October 26-27, 2005 (Wednesday and Thursday)

Research days are a forum for researchers from all disciplines to present and discuss important recent work and results. The research sessions include technical talks from: Steve Mayo, Caltech and Howard Hughes Medical Institute; Z.L.Wang, Georgia Tech; Roy Bar-Ziv, Weizmann Institute of Science (Israel); William Goddard, Caltech; Alex Zettl, UC Berkeley; and Hiroshi Yokayama, AIST (Japan).

Why Care About Nanotechnology?

By Nadrian C. Seeman

This regular opinion feature asks experts including researchers, business professionals and policy makers the question: "Why should individuals care about nanotechnology?"

"Our different programs are of value in several ways. The program to facilitate the structural basis of drug target crystallization could enable scientists to develop new cures for various illnesses."

Why care about nanotechnology?

Nanotechnology is really just another word for the chemistry of building new materials. The history of our species could be written as progress in our ability to control the structure of matter on finer and finer scales. Until fairly recently, these scales were macroscopic, but we as a species are now learning how to control the structure of matter to make devices with smaller and smaller features, particularly for electronics and molecular biology applications.

Nanotechnology largely deals with organizing matter on the same scale that the cell does, a few nanometers. Needless to say, it is important for the public to understand the key features of all aspects of science, and more and more of science is currently falling under the rubric of nanotechnology.

What are your research goals?

In a nutshell, we seek to control the structure of matter in three dimensions on the finest possible scale. We work with branched DNA molecules to do this. The combination of branched DNA and cohesive interactions, such as sticky ends allows one to design and to build specifically structured networks in 2D and 3D.

We have demonstrated this in 2D, and we are working to improve our arrays (crystals) in 3D.

Why do we want to do this? The first goal is to use our branched DNA system to scaffold the organization of biological macromolecules into crystalline arrays, thus overcoming the crystallization problem of biological crystallography. This will enable the 3D structural characterization of potential drug targets, leading to rational drug design.

If one can imagine organizing biological components this way, one can also imagine organizing nanoelectronic components in the same way. It is commonly accepted that the currently used top-down methods of building computer components will hit the wall in the next decade or so. DNA nanotechnology will enable us to assemble these components bottom-up. This will lead to smaller, faster architectures. In addition, bottom-up assembly offers the possibiity of 3D, not just 2D organization.

Our other goals involve the use of DNA nanomechanical devices. We have built robust sequence-dependent devices, and a little nanorobot that walks on a sidewalk. We have used the sequence-dependent devices to build a machine that emulates the action of a ribosome: It translates DNA signals into polymer assembly instructions, just as the ribosome translates the genetic code into protein assembly instructions.

Having built this prototype, we hope to generalize the device to build polymers with the same specificity that the cell uses to build proteins. We envision the nanorobot as a component in a nano-assembly line. It could bring supplies to particular stations along the line. In addition, a group of them could be organized to weave polymers together into stronger fibers.

How is your research relevant to the general public?

Our different programs are of value in several ways. The program to facilitate the structural basis of drug target crystallization could enable scientists to develop new cures for various illnesses. The HIV protease inhibitors were developed from crystal structures of the protease, but there was a lot of luck involved in getting those crystals. We would like to eliminate the dependence on luck.

The program to organize nanoelectronics in 3D from the bottom-up is a potentially disruptive technology that will increase the speed and decrease the sizes of computuational devices. In addition, we expect that there will be biomedical applications. Note that we are NOT proposing to use any electrical properties of DNA itself, just to use DNA as a scaffold.

We feel that the DNA-based nanomechanical devices will enable us to build previously unimagined new materials. We will gain unprecedented control over their composition, and in addition we will be able to control their spatial organization, leading to new, and perhaps environmentally-responsive properties.

In context with your research, how do you see it impacting the future?

All of the themes outlined above are areas of active research in our laboratory. New York University has licensed our patents to Nanoscience Technologies, Inc., which plans to bring our findings to the marketplace, thereby bridging the gap between the academic work that we do and the real-world applications that will result from them. It is likely that the new drugs, greater computational power and new materials that will result from our research program are likely to have a huge impact on our future.

Nadrian C. Seeman *is a Professor of Chemistry, New York University and President, International Society for Nanoscale Science, Computation and Engineering.*

http://seemanlab4.chem.nyu.edu/homepage.html

Research Review

By James Lewis, Ph.D

Molecular transistor on silicon surface

Paul G. Piva, Gino A. DiLabio, Jason L. Pitters, Janik Zikovsky, Moh'd Rezeq, Stanislav Dogel, Werner A. Hofer and Robert A. Wolkow, "Field regulation of single-molecule conductivity by a charged surface atom", Nature 435, 658-661, June 02, 2005.

Researchers at the University of Alberta led by Robert Wolkow achieved a major milestone in their quest to develop silicon-hybrid molecular devices, in which an organic molecule precisely positioned on a silicon surface provides a function that silicon by itself cannot efficiently perform, such as emitting light or detecting subtle molecular interactions. Such hybrid devices could serve as optical devices or chemical or biochemical sensors.

The step that they achieved is to demonstrate that the electrostatic field emanating from a single, specific silicon atom on the surface of a silicon crystal regulates the conductivity of an organic molecule bound to the crystal surface. Working with the H-terminated Si(100) surface of a crystal highly n-type doped with As atoms, a scanning tunneling microscope (STM) was used to remove the H atom from one Si atom, leaving a dangling bond on the silicon atom. Styrene molecules (a hydrocarbon in which two carbon atoms joined by a double bond are attached to a benzene ring) formed a line next to the dangling bond by reaction of the double bond with the Si atoms down the line from the dangling bond. The line of styrene molecules adsorbed to the Si surface was imaged with the STM, with the result that, at the appropriate bias voltage for the STM tip, the styrene molecules next to the dangling bond appeared brighter and more elevated than the molecules down the line, distant from the dangling bond. The effect depends upon the fact that in highly n-doped Si the dangling bond is negatively charged. Capping the dangling bond with a large, organic radical also eliminated the effect. These observations demonstrate that the conductivity of the adsorbed styrene molecules is regulated by the adjacent dangling Si bond.

The authors modeled the effects they observed using quantum mechanics. The results agreed with the STM observations that the styrene molecules nearest the dangling bond become conducting at lower bias voltages. The authors expect to extend these studies by using molecular design and the placement of additional dangling bonds to "pre-program" the bias voltage at which conduction begins.

Robert Wolkow: *http://www.phys.ualberta.ca/~wolkow/*

Practical production of carbon nanotube sheets

Mei Zhang, Shaoli Fang, Anvar A. Zakhidov, Sergey B. Lee, Ali E. Aliev, Christopher D. Williams, Ken R. Atkinson, Ray H. Baughman, "Strong, Transparent, Multifunctional, Carbon Nanotube Sheets", Science 309, 1215-1219, August 19, 2005.

Researchers from the University of Texas at Dallas and from CSIRO in Australia have made 5-cm-wide, meter-long sheets of carbon nanotubes as thin as 50 nm using a solid-state process that "appears to be scalable for continuous high-rate production." Multiwalled nanotube (MWNT) forests composed of MWNTs 10 nm in diameter and 70-300 microns high were synthesized by catalytic chemical vapor deposition. MWNTs were drawn from the sidewall of the forest "using an adhesive strip, like that on a 3M Post-it Note". Drawing by hand at ~1 m/min converted a 245-micron-high forest into a freestanding 3-m-long MWNT sheet. Mechanical drawing methods boosted sheet production to about 7 m/min. As drawn, the sheets are electronically conducting aerogels, ~18 microns thick, that can support liquid droplets 50,000 times the weight of the area of sheet supporting the drop. By causing the aerogel to adhere to planar surfaces of glass, plastic, or metal, the density of the sheet increases about 360-fold, with a concomitant shrinkage in thickness to 50 nm. The high transparency and electrical conductivity of the sheets would be consistent with "such applications as displays, video recorders, solar cells, and solid-state lighting".

> *"A useful feature is that carbon nanotube sheets adhering to transparent plastic sheets can be bent and strained without degrading electrical conductivity. "*

A useful feature is that carbon nanotube sheets adhering to transparent plastic sheets can be bent and strained without degrading electrical conductivity. A stack of 18 sheets had a tensile strength greater than that of Mylar and Kapton films or ultra-high-strength steel or aluminum alloys. The authors also demonstrate that their sheets are suitable as organic light-emitting diodes.

Ray Baughman:
http://nanotech.utdallas.edu/nn/home.asp?pid=3&USER_ID=3

Molecular motors transport macroscopic cargo

José Berná, David A. Leigh, Monika Lubomska, Sandra M. Mendoza, Emilio M. Pérez´, Petra Rudolf, Gilberto Teobaldi and Francesco Zerbetto, "Macroscopic transport by synthetic molecular machines", Nature Materials 4, 704–710, September 2005.

Scientists at the universities of Edinburgh, Groningen and Bologna led by David Leigh covered a surface with wholly synthetic molecular motors and used energy harvested from light to move tiny droplets on a mm scale, up a 12-degree slope against the force of gravity. Although the molecular motors used are purely synthetic, they operate by the same principle of physics used by biological molecular motors: rectifying Brownian motion, that is, the biased use of random thermal movement of molecules. The molecular motors are rotaxanes, molecular structures consisting of two components that are not covalently bonded to each other: a rod threaded through a ring, with bulky groups on each end of the rod that prevent the ring from sliding off the rod.

Normally, Brownian motion causes the ring to oscillate between two chemically different segments of the rod, termed stations, that are about a nm apart. Illumination with UV light causes one station to change from a conformation with high affinity for the ring to a conformation with low affinity. The second station is a short fluoroalkane segment. Thus, illuminating the molecule covers the fluorine atoms because the ring is now biased against binding to the first station and thus covers the second station. Chemical groups on the ring allow the rotaxane to be incorporated into a self assembled monolayer covering a gold layer on a glass surface, with the rod of the rotaxane lying parallel to the surface. The contact angles made by various liquids with the surface are very sensitive to the presence of exposed fluorine atoms so that exposure to UV light changes the wettability of the surface,

A 1.25 microliter drop of diiodomethane was deposited on the surface and irradiated with UV on one side of the drop to produce a gradient of wettability along the length of the drop. After 80 s of irradiation, the front of the drop began to advance. 900 s of irradiation produced an elongation of the drop by 0.8 mm, and more than 1000 s resulted in transporting the entire droplet at about 1 micron/s. Using mica instead of glass to get a flatter surface results in droplet movement at about twice the speed, 1.5 mm instead of 0.8 mm. It was even possible to do work against gravity by moving the droplet up a 12-degree gradient.

The authors estimate that in this case each shuttle molecule does about 15 zJ (zeptojoules) of work against gravity, realizing by biased Brownian motion at least 50% efficiency in using the free energy made available by the nanometer movement of the ring between stations on the rod. Thus, although light causes each individual molecule to act as a switch between two states, the collective action of the monolayer of rotaxanes is to act as a motor moving the drop. The authors demonstrated the movement of small quantities of liquid, not by scaled down macroscopic pumps, but rather by harnessing forces unique to the nanoscale. They speculate that their work might find microfluidic application in moving liquids in a lab-on-a-chip or in reaction vessels.

Technology Roadmap for Productive Nanosystems

Productive nanosystems are molecular-scale systems that make other useful materials and devices that are nanostructured

Nanotechnology is shaping up to be the next industrial revolution. Not since the 19th century has a wave of technology cut across so many aspects of how we work and live. Its promise seems limitless. The challenge for today is how to shape the development of nanotechnology so its best potential can be realized.

One way to accelerate the productive development of technology is by creating a Roadmap to:

- Coordinate the thinking and activity of key stakeholders, including governments, corporations, research institutions, policy professionals, investors, educators and the media
- Provide a framework to determine and articulate the steps that must be taken to progress from the present state of development to a desired future goal
- Illuminate what we should focus on today and provide a basis for defining current research and commercialization agendas

Productive Nanosystems

Foresight Nanotech Institute and Battelle have launched a Technology Roadmap for Productive Nanosystems, underwritten in part by the Waitt Family Foundation.

The Roadmap will chart a path beginning with current abilities to advanced systems – starting from what can be developed in labs today – and create a step-by-step map of each type of development that must take place to move from one stage to another, with milestones for achieving each step.

A Steering Committee will oversee the Roadmap process and review the outcomes. Sponsoring project partners provide technical expertise and underwriting. A hands-on partnership, the Roadmap Initiative offers a unique opportunity for helping to shape and accelerate the future of nanotechnology.

Benefits for Nanotechnology and Humanity

The final product of the Roadmap Initiative will be a print document and web site that provides details on the development pathways. Its scope will include:

- Current capabilities in design, modeling, fabrication and testing.

(Continued on page 20)

Technology Roadmap *(Continued from page 19)*

- Strategies for developing next-generation nanosystems.
- A basis for formulating research and commercialization agendas.
- Establishing milestones and concrete metrics to be used for judging progress.
- Policy issues and recommendations.

The Roadmap for Productive Nanosystems is currently seeking sponsoring partners to provide funding and technical expertise to this project. Partners will collaborate actively in the project by committing resources to the project and reviewing the work of the group on a quarterly basis. Upon completion, all partners will receive a complete Roadmap Document in advance of general release, as well as recognition in news and promotional activities.

For information on becoming a Roadmap Partner, contact:
foresight@foresight.org.

Become a member of Foresight Nanotech Institute

Foresight is the leading think tank and public interest institute on nanotechnology. Founded in 1986, Foresight was the first organization to educate society about the benefits and risks of nanotechnology. At that time, nanotechnology was a little-known concept.

Today, with the basic framework of public understanding in place, we are refocusing our efforts on guiding nanotechnology research, public policy and education to address the critical challenges facing humanity.

Foresight's new mission is to ensure the beneficial implementation of nanotechnology.

Foresight is accomplishing this by providing balanced, accurate and timely information to help society understand and utilize nanotechnology through public policy activities, publications, guidelines, networking events, tutorials, conferences, roadmaps and prizes.

Foresight is a member-supported organization. Our membership, including approximately 15,000 individuals in over 125 countries and a growing number of corporations, is diverse demographically and geographically. They are interested in ensuring that the future of nanotechnology unfolds for the benefit of all. These concerned individuals include scientists, engineers, business people, investors, publishers, artists, ethicists, policy makers, interested laypersons, and students from grammar school to graduate level.

We have updated our membership levels and added benefits to meet the needs and interests of individuals and companies. To find out more about membership, or obtain a donation form either call
(650) 289-0860 or go to this website
http://www.foresight.org/members/index.html

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