Nanotechnology Now
NanoNews-Now

Welcome to the first edition of NanoNews-Now, the monthly interactive newsletter from Nanotechnology Now. Each of our newsletters will focus on a specific industry, technology, or branch of science that we believe is subject to imminent disruption by advances being made in nanotechnology. For a more complete explanation of exactly how "disruptive technologies" impact on business, take a look at our ongoing survey at Nanotech-Now.com and the first of our follow-up interviews. In our "Update"section we continue our exploration with a second follow-up interview on the current subject.

If you are new to the world of nanotechnology, you may want to consult our glossary when you encounter a term you don't recognize. We've also made reading easier by linking the first use of any technical term to its glossary entry.

BATTERIES EXCLUDED

Considering all the industries, products, technologies, and social situations that will be disrupted by advances in nanotechnology, why did we choose to focus on batteries? According to Stephen Casalnuovo, a technical staff member at Sandia National Laboratories in New Mexico, "Power remains one of the outstanding problems in building microsystems." He explains it this way… "you can build MEMS, microdevices, microsensors and integrated circuits the size of a fingernail, but when it comes down to how you are going to power them, the battery becomes the largest component of the system and (the one that) wears down first."

To allow mobile devices to have a source of electricity and maintain their portability as they shrink smaller and smaller, it will be necessary for the POWER SUPPLY to shrink as well. Clearly, nanotechnology will be the driving force behind solving the "big battery" issue; after all, that's the size scale we're working at, where it is impractical to have your battery larger than the device it's powering. At the same time, it will be the driving force behind developing nanoscale building blocks; blocks which are then used to build better macro-, micro- and even nanoscale devices, which will also need better and smaller power supplies. As nanotechnology moves OUT of R&D and into the prototyping and testing phase, the pressure on battery research and power supply development increases dramatically.

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Ascribe News says that "Tiny machines (are) being developed for a variety of purposes - such as 'lab-on-a-zip' devices that sense airborne chemical or biological pathogens - and they will require batteries many times smaller and more powerful than today's smallest batteries".

One of the technologies that may make this possible is based on carbon nanotubes - string-like, cylindrical structures that are made up of layers of carbon atoms arranged tube-like with hexagonal and/or pentagonal patterns, that resemble rolled up chicken wire. When the tube-wall is just ONE layer of atoms thick, it is known as a Single-Walled Nanotube (SWNT), and when composed of multiple layers inside each other (nested like Kachina Dolls) it is known as a Multi-Walled Nanotube (MWNT).

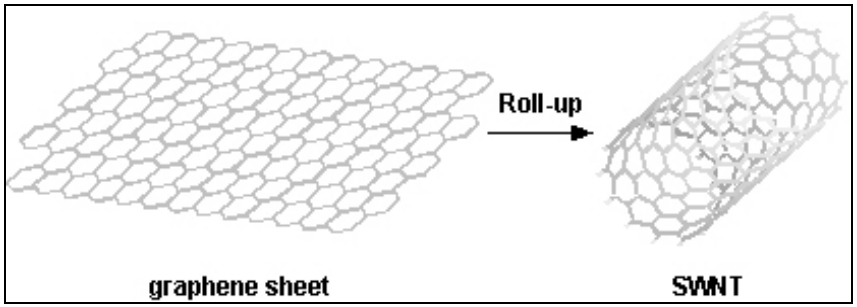

Photo of Single-Walled Nanotube Roll-Up is courtesy of Prof. Charles M. Lieber Group

"When battery technology is viewed in a very broad sense - as a technology that provides portable, reliable energy - then it is pretty clear that this technology will have a significant impact on technology implementation and industrial progress."

--Deb Newberry

Author of *The Next Big Thing is Really Small*, Chairman of the Board of Project Universe, and Executive Director of The Nanotechnology Group

Until recently the varieties were composed of carbon. However, the semiconductor gallium nitride is starting to be used as well. Dr. Sumio Iijima discovered carbon nanotubes in 1991 while doing research for NEC Corporation. The basic properties of carbon nanotubes were at first purely theoretical, but soon their dramatic nature became clear: strength 100 times greater than steel at one sixth the weight; they can act as conductors or semiconductors, leading to nanoscale wires and electrical components. These realizations were recognized as a turning point as they enable one nanoscale "device" to go from theory to a practical, manufacturable technology, for use in electronics and other industries.

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Nanohorns

Dr. Iijima went on to discover a new form of nanotube known as nanohorns, where one end of the tube is sealed and the other is open wider. NEC is moving quickly on the application of nanohorns in fuel cell products.

In March of 2003, NEC demonstrated mockups of nanohorn based fuel cells that it plans to be shipping for laptops in 2004 and for cell phones by 2005.

In addition to NEC - which has a strong but not insurmountable research lead thanks to Dr. Iijima - other contenders are working feverishly to capture a portion of the fuel cell market. Motorola, Toshiba, Samsung, and Casio are all working on rival technologies that they are planning to bring to market in 2004.

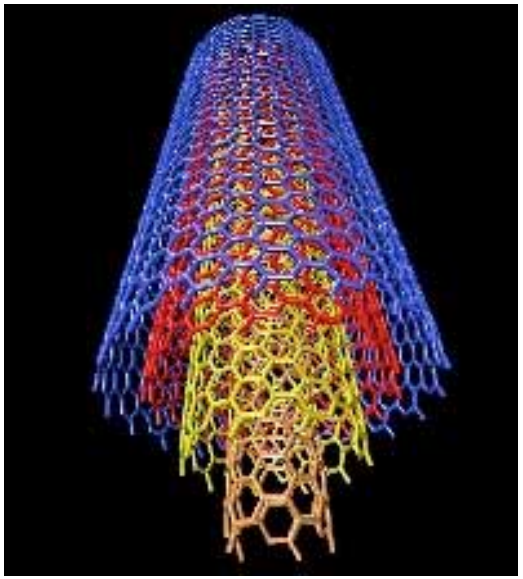

Photo of multiwall nanotube is courtesy of Alain Rochefort Nanostructure Group, CERCA

"In the short term, nanotechnology will contribute to the growth and improvement in the traditional batteries that we have all come to know and love - whether represented by a bunny or a copper top. What I expect to happen is that improvements in processing, thin films and material purity - which may be occurring because of nanotechnology - will continue to improve efficiency, lifetime and quality. Remember, nanotechnology is not a new science or technology - it is an enabling technology that supplements and enhances physics, chemistry, biology etc.

The work in Japan on small fuel cells applicable to hand-carried electronics, the work at Berkeley on embedded carbon nanorods for solar cells and work at MIT on thin films and thermoelectric power are drastically going to change the "battery" market. All of these advances have the potential to significantly change the current battery market forecasts and are a result of being able to understand and control phenomena at the lowest levels. Every day there are new advances made in the technology that will compete with traditional batteries."

-- Deb Newberry

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Longer Lasting Batteries or Smaller Batteries or Perhaps Both

Because of their ability to be created in significantly smaller sizes and their capability to hold a greater charge than conventional cells, nanotube and nanohorn based fuel cells will, at first, be able to offer a difficult trade-off: longer lasting batteries or smaller batteries. As mobile communications and computing becomes more and more ubiquitous, the primary desire of the market is for significant amounts of battery power to help these relatively large devices last longer. The first application of nanohorn technology to fuel cells delivered a 100% increase in storage capability, but many researchers believe that the practical limit for the technology could be ten times higher. This would allow devices using them to last all day, and eliminate the most irritating problem of most mobile computing warriors - recharging or plugging in.

Meanwhile, other nanotechnology advances are allowing for the creation of increasingly smaller and smaller technological devices - MEMS (**m**icro-**e**lectro-**m**echanical **s**ystems) - which will require equally small power sources in order to operate effectively. Here, the ability of nanohorn fuel cells to deliver sufficient energy in nanoscale sizes will allow for the evolution, prototyping, manufacture and distribution of MEMS-based products. Already, NanoGram Devices US has been granted a patent on power sources for pacemakers and implantable defribillators, which employ nanoparticles. In the case of creating fuel supplies for tiny machines,

Disruptions Ahead for the Battery Industry

"The disruptive impact of nanotechnology on the battery industry could truly be significant…Those cylindrical units may become collector items. Again - the need for portable power will increase and nanotechnology will supply sources (other than batteries) for that power. The rapid development of fuel cells is amazing and four years ago many would not have guessed that by 2003 we would have fuel cells for laptops. The advances in hydrogen generation and containment have caused quantum leaps in cell fuel technology.

Similar developments in solar power and improved efficiency - due to nanotech work - will create solar energy that is cost efficient and with the ability to generate usable amounts of power with smaller and smaller arrays. We have an artificial waterfall in our backyard and I would love to have that powered by the sun rather than an electric pump (powered by the local utility company).

Scientists are evaluating the energy generated by the chemical reactions within our bodies as a potential source of power for implantable medical devices. At the atomic scale, there is a lot of energy involved (both used and generated) in interactions of individual atoms – to be able to take advantage of that inherent energy and put it to use in small systems will certainly be disruptive."
--Deb Newberry

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scientists are attempting to create what could be called the 100A battery. As one of the researchers at UF explained: "If you have a circuit the size of a pinhead and you need a battery the size of a triple A, then it won't be very useful."

Longer-Lived Batteries

The charge-holding properties of the nanotube and nanohorn promise to make rechargeable batteries more efficient. The current crop of rechargeable batteries that power mobile phones, PDAs, or laptop computer systems have a singular defect that batteries utilizing nanotechnology seem to be capable of overcoming. Standard rechargeable batteries tend to lose their effectiveness after they have been cycled (drained and recharged) around 500 times. However, nano-based batteries have already been shown in tests at the University of Florida under the direction of Dr. Charles Martin to be able to sustain their charge after 1,000 and 1,400+ rechargings. Beyond that, new thin, flexible film batteries being developed by a number of different companies are able to be recharged as many as 50,000 times - essentially for the life of the product. In addition, they are small enough that they may be able to be integrated directly into (or onto) miniature devices, including implantable medical devices such as pacemakers and insulin pumps.

UCLA Materials Sciences Professor Bruce Dunn is working on a nanometer scale battery that would provide 24 hours of 100 microwatts from a 1mm battery. As he puts it, "Portable power is so huge that whatever you can do that works well, somebody is going to use it." That some of the larger players in the world of battery production appear to be virtually ignoring the possible disruptive effects that nanotechnology-based businesses and trends could have on their core business is quite staggering.

Deb Newberry's Advice on how to Proceed

"My advice to those in the battery industry is… PAY ATTENTION!!!! You will not be able to slide through or into the nanotech era…it will make a difference. You should also plan to invest - both in understanding and development dollars. There are a multitude of nanotech web sites that offer more information than you may want. More than likely the local university has some departments involved in nanotechnology and they would be good sources of information. Another good bet is to assign on of your advanced engineers the job of finding out about NT and how it will impact the battery or energy industry. Or, you could hire a nanotech savvy consultant to help you understand where the applicable research is and where the threats and opportunities are. The important thing again is - don't ignore nanotechnology. Sooner or later you will be effected. Being aware and involved increases the chance of a positive impact, hoping it will pass by may have much worse results."

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Fuel Cells as an Indicator

Battery and fuel cell technology is increasingly important as an "indicator industry" for nanotechnology. Ground-breaking work by Dr. Iijima led to the development of nanotube and nanohorn-based fuel cells that appear to many to represent the "energy source of the next generation." Dr. Iijima's fuel cell works by directly transforming the chemical reaction energy between hydrogen and oxygen into electric energy. In this process, water vapor and heat are produced WITHOUT COMBUSTION. Beginning with batteries and fuel cells, this technology has the potential to become the energy source of the future for automobiles and even energy-generation for the home. All of this from one of the first practical utilizations of nanotechnology.

The Size of the Market

Batteries are small, but the market for them is not. Rechargeable batteries represent a $6 billion dollar per year business. Disposable batteries are a $30 billion dollar per year business, as well as representing a significant ecological problem when all those batteries end up being "disposed of" in a less than ideal fashion. The promise of micro fuel cells beckons, and all the major players -- Samsung, NEC, Motorola, and Manhattan Scientifics - as wall as lots of smaller innovators and start-ups are going after their share of the market.

Tiny Engines

Worthwhile noting here is recent developments in miniature engines - potential candidates in the race to replace batteries as we know them today.

In another issue, we will cover fuel cells and miniature engines in depth.

Summary

What we see in the evolution of battery technology and the way it has been impacted by nanotechnology is similar to what occurred to the typewriter and carriage industries. Technology advances (the PC and the automobile) wiped out both, virtually overnight, as they failed to recognize a new technology that could replace them.

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Nanotechnologies act as an enabling set of technologies that allows disruptive changes to occur in a given industry; the business players who choose not to follow the trends and discoveries related to nanotechnology can find themselves severely hampered. Nanotechnology has exhibited in many industries - and that of battery and fuel cell storage specifically - an incredible evolutionary speed, from raw R&D to practical applications and uses.

Our conclusion is that the battery industry is bound for the dustbin of history (sooner, rather than later, and possibly as soon as 5 years from now), for the very same reasons as the typewriter and carriage - disruptive technology. This does not mean, however, that it cannot move itself into areas where it can still compete, such as fuel cells and other nanoscale devices.

In the months ahead we shall be looking at other industries that will be impacted and perhaps dramatically disrupted by advances in nanotechnology. We will explore the sometimes-swift move of nanotech discoveries from the mind of the scientist, to the R&D lab, to the drawing board, to the prototype product, and ultimately to market.

In the meantime, if the advances in portable power and miniature power sources are of importance to YOUR business, we invite you to explore some of the articles and white papers listed in the <links> section this month. And, if you need additional research or professional consultation from industry-leading nanotechnology experts, contact Nanotechnology Now for more information about NanoStrategies - our professional information and consulting service.

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We'd like to hear from you.
To comment on this feature article or any other content in NanoNews-Now or to submit a "Letter to the Editor" please send your e-mail to editor@nanotech-now.com.
For confirmation purposes, please include a business number where you can be reached -- letters will not be printed without confirmation.

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Our Exclusive Interview with Senator Ron Wyden

Sen. Wyden (D-Oregon) serves on the Commerce, Science and Transportation Committee of the US Senate and on the Subcommittee on Science, Technology and Space. Recently we had a chance to pose some questions to the Senator. Here's what he had to say.

NNN: How will the Nanotechnology Research and Development Act of 2002 (HR 766) accelerate the pace at which nanotechnology is developed?

Sen. Wyden: Historically, the Federal government has played a key role in developing nascent technologies such as astrophysics, computer technology, and others. My bill ensures that the Federal government will support nanotechnology at a time when venture capital may be scarce for such a far-reaching new science.

The Wyden-Allen legislation creates a National Nanotechnology Research Program to support long-term nanoscale research and development, increase America's competitiveness in nanoscale technology, and promotes effective education and training for the next generation of nanotechnology researchers and professionals. It would also create a Presidential National Nanotechnology Advisory Panel and National Nanotechnology Coordination Office, which would provide administrative and technical support for the Advisory Panel and the Council.

NNN: How does the (Senate) legislation that you and George Allen sponsored differ from HR 776, and where is it similar?

Sen. Wyden: As was noted at the House nanotechnology hearing, there are nano-differences between the two bills. There are really only two significant differences. First, slightly modified language in the House bill would allow the President to designate the existing PCAST, or the Presidential Commission of Advisors on Science and Technology, to serve as his advisory committee on nanotechnology. My bill with Senator Allen specifically creates a separate nanotechnology advisory panel for the President, comprised of nanotechnology experts. Second, the Wyden-Allen bill creates a new Center for Societal, Ethical, Educational, Legal and Workforce Issues Related to Nanotechnology to address various social and other concerns related to nanotechnology.

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NNN: Does the Nanotechnology Research and Development Act (and the Senate proposal - "21st Century Nanotechnology Research and Development Act") supplement the NNI, or replace it?

Sen. Wyden: My bill incorporates the NNI into a larger national nanotechnology effort. In effect, NNI will become the National Nanotechnology Research Program described in the legislation.

NNN: During the debate in the House, Sheila Jackson Lee offered and then withdrew an amendment that would have created a "Center for Societal, Ethical, Educational, Environmental, Legal, and Workforce Issues Related to Nanotechnology." How will these issues be addressed?

Sen. Wyden: The Senate bill already creates that center to address those issues.

NNN: Is there any credible opposition to either bill?

Sen. Wyden: My bill not only enjoys bipartisan sponsorship, but has broad bipartisan support across the Senate.

NNN: According to reports, one of HR 766's mandates is to create a "National Nanotechnology Coordination Office", to become a central point of contact for government organizations, academia, industry, professional societies, and others to exchange technical and programmatic information. Who will be working in this office, and who will they report to?

Sen. Wyden: This office was originally created in the Wyden-Allen bill; this will be an administrative office to provide support to national researchers, so the makeup of the staff will be determined by the director of the office, to whom they will report. Ultimately, the National Science Foundation will oversee the efforts of this office.

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NNN: How can nanotechnology be used to pull Oregon out of recession? What can we do better than Silicon Valley or Seattle, for example, and if we don't take a leadership role, where does that leave our state 10-20 years from now?

Sen. Wyden: At the statewide economic summit I organized with the Oregon Business Council in December of 2002, I proposed making Oregon a national center for nanotechnology research and development. My legislation provides a pro-active response to Oregon's economic situation by providing for ten national research centers, the goals of which include "the employment of underutilized manufacturing facilities in areas of high unemployment as production engineering and research test beds for micron-scale technologies." Oregon has facilities ready-made for research centers like the ones envisioned in my bill, and I believe our state also has the tools and the talent to emerge as a nanotechnology hub.

Oregon already has created the Multi-Scale Materials and Devices Initiative. It has my support, as well as the support of the governor and industry, and it's leveraging Oregon's expertise in both nanotechnology and microscale technology. Oregon has a proven expertise in material sciences, and this dual initiative has the potential to allow our state to compete right alongside other technology hubs like the Silicon Valley and Seattle in this science.

You're absolutely right in asserting that Oregon needs to take a leadership role now. That's why I'm going to keep working with Oregon universities and economic development agencies, as well as the rest of the state's congressional delegation, to establish Oregon as a leader in nanotechnology.

NNN: Given the strong testimony on HR 766 of Representatives Sherman and Bell, and the additional testimony presented by various leaders in the academic and research communities, would you consider proposing an Amendment in the Senate to return the provision that 5% percent of research funds, the same as in the Human Genome Project, be set aside to study the societal and ethical implications of nanotechnology?"

Sen. Wyden: My bill already creates the Center for Societal, Ethical, Educational, Environmental, Legal, and Workforce Issues Related to Nanotechnology, and funds it at a level of $5 million per year. I'm confident that this provision provides the framework and the funding to adequately address societal and ethical concerns.

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We look forward to hearing more from Senator Wyden in the future, and will keep our readers informed on the progress of legislation such as those mentioned in the interview.

For more information on the "21st Century Nanotechnology Research and Development Act" (S. 189) and the "Nanotechnology Research and Development Act of 2002" (HR 766), see:

Nanotechnology Bill Clears House
Senate Committee Approves Nanotech R&D Bill

S. 189 (the full bill)
Statement of Senator Joe Lieberman on HR766

HR 766 (the full bill)
Experts Endorse Nanotechnology Bill

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Update

In our Update section we follow-up on previous subjects and continue to explore the boundaries of research and industrial development. Because we can't cover every subject in-depth every month, and since the world of nanotechnology doesn't stop and wait for our editorial schedule, we will use "Update" to keep you posted.

This month, **Update** is bringing you the continuation of the interview between *Nanotechnology Now* Editor Rocky Rawstern and Douglas Mulhall (Author of *Our Molecular Future: How Nanotechnology, Robotics, Genetics, and Artificial Intelligence Will Transform Our World.*) on the subject of "Disruptive Technology." This is the second in a two-part interview that follows on the heels of a major industry survey conducted by Nanotechnology Now in the Spring of 2003. Results of that survey are available at Nanotech-Now.com, here.

In Part II we talked about disruptive technologies past and present. In this, Part III, we will cover some informed speculation on what lies ahead regarding molecular nanotechnology (MNT). We will also focus on the differences between today's nanotechnology and MNT.

As is covered in our Current Uses page and in our Disruptive Technologies Part II interviews, nanotechnology today is rather mundane, and is seen (or not seen as it were) in many consumer products, none of which has proven disruptive, yet.

RR: What are the differences between today's nanotech and MNT?

DM: Most of today's nanotech builds things from the top down by using big tools to scale down to smaller ones. MNT uses atoms and molecules to build from the bottom up, as for example DNA does with the human body. The main differences between top down and bottom up are in energy and materials. Top down takes a relatively large amount of energy and materials because lots of big things have to be made to construct little ones. To make a computer chip for example requires mining, transport, manufacturing etc. Building the same thing from the bottom up involves comparatively little waste, because everything is constructed precisely, molecule by molecule. There is still waste, but it can be recycled locally and far more effectively.

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RR: Given our existing understanding of nanoscale science, and the extremely rapid growth rate at which we are discovering and applying new technologies, what do you see in terms of changes coming in the next ten to twenty years in the areas of…

…Consumer products
DM: Desktop manufacturing that lets everyone build products such as toys at home with prepackaged software.

…The worlds militaries
DM: Warfare that targets the enemy individual by individual by using stealthy, airborne, undetectable nanobots. The Saddams of the world won't stand a chance, but neither may opposing leaders. Technology rules.

…Humanitarian efforts
DM: These will depend heavily on ethical choices instead of technology. Cars, guns, AIDS, heart attacks, and malaria are the big killers in developing nations. We might be able to fix them, but will we fund them as humanitarian issues?

…Criminological pursuits
DM: As with the military, street criminals will be individually targeted and caught more easily. The big unsolved crimes may be economic, such as executives causing companies to crash while getting big payouts. Nanotechnology will accelerate the effects of such malevolent activities.

…Medicine/health/longevity
DM: End of malaria, which kills more kids - three thousand a day in Africa alone - than everything else. End of atherosclerosis, which kills one in three of us now. See www.calcify.com for how to do that.

…Society
DM: Profound impacts from emergence of human beings with enhanced intelligence, brought on by neurological interface with massive computing capacity. This may have greater impacts than everything else above put together.

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DM: The rest of those answers take a whole book, which I wrote. It's Our Molecular Future. The key probability - if we don't disable ourselves or get disabled by natural forces - is this: It's not just what we'll do that will change, but rather what we are. The emergence of new subspecies of Homo sapiens, plants and animals has already begun. We are programming our genes and adding computing capacity to the human brain. This is the quantum leap that we may see in the next decades. Still, it is hard to tell what we'll have in twenty years because it will depend on choices that we do or don't make now. These are options, not predictions.

RR: What are some of the advantages and dangers that may result from mature MNT?

DM: **Advantages**: Developing sufficient intelligence to avoid accidentally crippling our advanced civilization. **Disadvantages**: Not developing the right kind of intelligence and accidentally crippling ourselves, or being unprepared for a historically recurring natural event that disables our society.

The core issue will be the type of enhanced intelligence that we develop, and how we use it.

RR: It is widely accepted that no other set of technological advances has the potential to disrupt as many industries as nanoscale technologies. Can you talk about future nanoscale technologies, in terms of the industries they will disrupt, in the next ten to twenty years?

DM: The oil industry may go out of business if someone perfects a photovoltaic paint that has already been invented. Many types of manufacturing may disappear if existing desktop factories continue to develop at the same rate. Stockbrokers may go out of business (none too soon) if genetic algorithms continue to forecast markets more accurately.

RR: In general, what should the business community be doing today to prepare for these technologies?

DM: Start a project in every company to track artificial and enhanced intelligence, and try to figure out what it means.

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RR: In general, what should governments be doing today to prepare for these technologies?

DM: Apply artificial and enhanced intelligence to solving the biggest threat that taxpayers face today: heart disease.

RR: In general, what should the public and NGOs be doing today to prepare for these technologies?

DM: Environmental NGO's must understand that nanomanufacturing is going to alter every preconception that we have about the "natural" ecology, because our machines are becoming part of the ecology, rather than separate from it. Generally, the public might think about what are the right questions to ask regarding these new technologies. For a list of those questions, read my book, and for starters go to the Center for Responsible Nanotechnology, who have put some of those questions on their website at: http://www.crnano.org/ideas.htm#Questions

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LINKS

Space-age computer power

First lithium pictures could aid battery research

Small science has some thinking big, some thinking bad

Carbon Nanotubes Could Lengthen Battery Life

Bye-bye to batteries

Nanotechnology means nano prices for flat-screen TVs

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**In our next issue we will cover *regulation and ethics*,
and present several interviews
with nanotech leaders from around the world.**