

Nanotech Report

Nanotech Could Give Global Warming a Big Chill

Thanks to Al Gore's eye-opening documentary "An Inconvenient Truth", global warming is once again front page news. Our addiction to fossil fuels is in large part responsible for the global warming crisis and has more than a little to do with the current mess in the Middle East and the fact that gasoline costs us more than \$3 per gallon. Yet in all the recent talk of how to deal with the climate crisis, something has been missing. As Ray Kurzweil said in a recent Washington Post online discussion, "None of the global warming discussions mention the word 'nanotechnology'. Yet nanotechnology will eliminate the need for fossil fuels within 20 years." Kurzweil is referring to the potential of nanotechnology to harvest solar power—and only just one of a whole slew of nano-applications that may come to the rescue just in time.

There are two main routes to slowing down and eventually stopping global warming. The first is to get more out of our current fuels—decreasing our consumption while increasing the efficiency of our technology. The second is to stop using fossil fuels altogether and make the transition to clean and renewable energy sources.

To make the most of our current fuels, researchers are designing nanoscale sieves that can filter out environmentally toxic molecules in fuels and fuel byproducts. A promising area is in the custom designing of zeolites, porous nanoparticles that can extract more and cleaner gas from every oil barrel. Scientists are also designing nano-sieves that can be fitted to power plants to capture carbon dioxide before it can enter the atmosphere. Another approach is fuel additives—the U.K. company **Oxonica** [OXN.L], for example, already has its product, Envirox Fuel Borne Catalyst, incorporated into premium commercial diesel which reduces fuel consumption by up to 10% and reduces carbon dioxide emissions by up to 15%.

Nanotech is playing a big role in increasing the efficiency of current technology, as well. There's a whole industry of "green manufacturing" growing up with nanotechnology as a main ingredient. For instance, nanocoatings, like Nansulate, conserve energy in high surface temperature industrial equipment. Buffalo, New York-based NanoDynamics is using nanocoating to make LED lighting more efficient—in May, the company licensed nine patents from Rutgers University related to an energy-reduced plasma process which NanoDynamics plans to use for, among other things, white LED lighting that could eventually replace everyday fluorescent and incandescent lighting. Lighting represents a huge portion of our energy use, and the market, according to NanoDynamics, is approxi-

mately \$12 billion. White LEDs have been unsuccessful so far because they emit too much UV radiation, which lowers their efficiency and durability. The plasma coating that NanoDynamics is commercializing serves to block the UV light, rendering widespread use of white LED lighting potentially viable.

Decreasing energy consumption and increasing efficiency are good solutions for now...but the current crisis is really calling for new disruptive technologies. Take cars—a major source of greenhouse gas emissions. Alternatives to fossil fuel-burning combustion engines will come from powerful batteries or from fuel cells.

Altair Nanotechnologies [ALTI], based in Reno, Nevada, makes high-powered nano-lithium ion batteries that take only six minutes to recharge and can be recharged up to 20,000 times—charge rates and lifecycles up to a hundred times higher than any commercially available batteries. Earlier this month, the company received its first order from Phoenix Motocars, which is aiming to mass produce electric cars over the next few years. It placed a \$750,000 order for Altair's batteries. And that's only a tiny chunk of the high performance battery market, which Altair estimates at \$42 billion.

Beyond batteries, we are finally starting to get our first glimpses of a hydrogen economy. Fuel cells generate power by converting hydrogen into electricity, with only water as a byproduct. Because fuel cells have no moving parts and don't require combustion, they are more reliable than traditional engines. However, high costs are preventing fuel cells from making a big impact on the market. Membranes and catalysts are the two costly factors in fuel cells, so nanotech companies are scrambling to create cost effective versions of each.

On the membrane side, for instance, California-based PolyFuel is making hydrocarbon (rather than the more expensive and less durable fluorocarbon) membranes, both for use in both direct methanol fuel cells for portable devices and for hydrogen fuel cells for cars.

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On the catalyst side, one promising company is California-based QuantumSphere. Fuel cell catalysts are usually made of platinum, which is expensive and a limited resource. QuantumSphere is creating alternatives to platinum, like its patented nanoscale nickel, at a fraction of the cost. High surface area makes nanoscale nickel act more like bulk platinum than bulk nickel. The company has yet to sell its catalysts to manufacturers of fuel cells, but says it met with three large Japanese electronics companies and one is currently testing its product.

QuantumSphere isn't the only one in the catalyst game—others include Nanostellar, Catalytic Solutions, and **Nanophase** [NANX]. Says QuantumSphere's CEO Kevin Maloney, "Catalysts alone have a \$20 billion market, so there's plenty of pie to cut out to many players."

Hydrogen fuel cells, however, require, well, hydrogen. And that's a problem. Hydrogen is not readily available in nature—you have to make it. QuantumSphere is working on that too—its most recent product is a hydrogen generator, which produces hydrogen through water electrolysis. Again, its patented nanonickel can replace platinum in electrodes that break apart water molecules and extract hydrogen, which in turn can power fuel cells. "The performance is incredible," says Maloney. "It's approaching the steam reformation process." But unlike steam reformation, which produces four pounds of greenhouse gases for every pound of hydrogen, the sole byproduct of QuantumSphere's hydrogen generator is plain old oxygen. The initial product is a small unit about 18 inches long and can be built into your car or kept at your house. A person simply feeds it water—sea water, beer, urine, it doesn't matter—and it makes hydrogen as you need it. That saves you the danger of traveling with pressurized hydrogen and it saves the building of a whole new infrastructure for people to fuel up.

For larger scale distribution of hydrogen, however, we have to find a way to store it. There are three basic options for hydro-

gen storage: you can compress it as a gas, which requires very high pressure; you can liquefy it, which requires very low temperatures; or you can store it in a what's called a hydride—a metal with a very porous surface that's capable of absorbing and then releasing hydrogen at practical pressures and temperatures, dramatically reducing operational energy. According to renowned MIT physicist Mildred Dresselhaus, hydrogen storage is one of the most challenging problems in creating a greener world.

Hydrides may well turn out to be a crucial ingredient in the hydrogen economy, and Quebec, Canada-based Hera is right on the ball. In addition to developing hydride materials for hydrogen storage, they're also using them for hydrogen compression. Rather than using electrically powered mechanical compressors, Hera employs hydrides, which require only a third of the energy. The hydrides absorb hydrogen at low pressure and then emit it at a much higher pressure when heated. Hera's hydrides are able to absorb, release, and even compress hydrogen due to novel chemical interactions taking place within them, enabled by their patented nano-catalyst. They believe their nano-catalyst is the key to the next generation of low-cost and lightweight advanced hydrides. The company is also developing advanced batteries for hybrids and hydrogen-powered vehicles. Privately-held Nanomix is another company to keep on eye on for developments in hydrogen storage.

For all of these great potential solutions, there's a catch. Every one of these technologies requires an initial input of energy—energy to manufacture catalysts or membranes in the first place, energy to power a hydrogen generator. If that energy comes from a fossil fuel burning power plant, the problem has not been solved. The ultimate goal for greenies is to have a clean power source at every step. The options? Nuclear or solar power. Nuclear power hasn't been ruled out, but it comes with a batch of big concerns, the main one being that it would make it much harder to regulate the development of nuclear weapons. The ideal

I've been to a half-dozen states this month from coast to coast and the last time I heard this refrain repeated ad infinitum, I was at a bar-mitzvah: people are "feeling hot, hot, hot". Global warming. You can ignore the data, but you can't ignore your senses. Wherever you live, step outside and something's clearly different. Our lead story takes a timely look at the ways a slew of nanotech startups are making a difference in the fight. And if they are successful, you can be sure Al Gore won't just be promoting his hit movie—he'll be claiming he invented nanotech too.

We also take you inside **Motorola's** [MOT] labs. If you've seen their Razr or new Q phone, you know how important innovation is to capturing people's attention and market share. Their scientists are deep in the trenches of nanotech development, doing internal work, sponsoring university research and investing in venture capital funds. *[In full disclosure, Motorola Ventures is one of the corporate investors in my firm Lux Capital's venture fund].*

Head due east about 20 miles from Motorola's lab and you'll end up at Northwestern University inside the lab of nanotech pioneer Chad Mirkin. Mirkin has been a repeat member of the Forbes/Wolfe Nanotech Report annual power broker list. My team has covered him for many years and you'll get up to speed on his heavily funded startup ventures, what new ideas he has brewing and what technology directions he thinks most promising.

Keep cool...and as always here's to thinking big about thinking small...



Toronto Researchers Create Paint-on Semiconductor that Outperforms Chips

Researchers at the University of Toronto used a liquid solution of semiconductor particles only a few nanometers across to create a continuous semiconductor film on a glass slide patterned with gold electrodes. At room temperature, the light-sensitive device was nearly ten times more sensitive to infrared rays than the chip-based photodetectors currently in use. The findings prove that simple, low-cost wet chemistry can produce devices with superior performance. The technology could have tremendous value for a wide range of communications, imaging, and monitoring applications.

power source, then, is the sun, but to harvest it on a mass scale today's solar cells need to increase in efficiency and decrease in cost.

Lots of great nanotech companies are working on the problem—companies like Konarka, Nanosys and Solaix [*In full disclosure: my venture firm Lux Capital is an equity investor in Nanosys*]. The trick to lowering cost is to manufacture thin films rather than using bulk silicon wafers which are expensive to produce and in short supply because of demand from the semiconductor industry. In May, California-based Innovalight raised \$7.5 million in venture capital to develop its thin film silicon ink technology, which taps into the quantum effects of silicon at the nanoscale. Its product consists of silicon nanocrystals suspended in a liquid ink that can be printed onto all kinds of surfaces, including portable devices. Because it uses far less silicon, according to CEO Conrad Burke it has the potential to reduce the cost of solar energy tenfold.

When it comes to thin films, the biggest newsmaker is Nanosolar. Last month, the company secured a whopping \$100 million in funding led by hedge funds SAC Capital and GLG Partners—and announced that it is building what will be the world's largest solar cell manufacturing factory. Produc-

tion of their plastic photovoltaic sheets will cost only 1/10 of what standard silicon solar panels cost to produce. The manufacturing facility will be located in California; in addition, the company plans to build a plant in Berlin where their solar cells will be made into solar panels in various product forms. There's no question Nanosolar is going to be a big player when it comes to harvesting solar power. What's more, it is a prime example of the fact that green nanotech is not only a technology of the future, but of the present.

Thin film solar cells are cheaper than silicon panels, but they're less efficient at absorbing light. Because of that, the next revolution in solar energy will come from quantum dots, which are poised to up solar cell efficiency significantly. In a solar cell, each incoming photon from the sun strikes the cell's surface and knocks off an electron—electrons flow through the material and, voila, electricity. But in ordinary semiconductor materials, there's a limit of only one electron knocked off per photon. Now, several research groups have found that at the nanoscale a single photon might free as many as seven electrons, greatly increasing the potential efficiency of solar cells.

New York-based Evident Technologies is using quantum dots to try to cut the costs of solar power. By exploiting the quantum

effects at the nanoscale, it can fine-tune the absorptive properties of the material to capture more of the sun's energy, rendering them cheaper and more efficient than thin films or bulk silicon solar panels. Quantum dots can be made into flexible sheets, liquids, or transparent material.

This is just a sample of what's going on in nanotech regarding a greener planet. To be sure, nanotech is a front line technology in the fight against global warming. Says QuantumSphere's Director of Fuel Cell Research Kim McGrath. "It's going to bring these new technologies down to a palatable price point. It will enhance performance too, but at the end of the day it comes down to economics. If we can meet these price points, this will take off, and nanotech is on the road toward doing that."

"People ask, how high does gas have to be for these other applications to make sense? We're trying to get people to look at it differently," says Maloney. "We prefer to think about how low oil prices can go. Because when oil drops again, all of these technologies still have to make sense, otherwise they will fall by the wayside and funding disappears. So we're looking to be the best solution even at really low prices. Once huge companies figure out how to make money from this, it's going to take off way quicker than anyone thinks." **N**

Will Nanotech Bring the Buzz Back to Motorola?

Motorola [MOT] is a company that—like the late comedian Rodney Dangerfield—isn't getting much respect on Wall Street these days. Motorola recently reported strong earnings of \$0.55 per share for the second quarter, up 49% over Q2 2005 and surpassing analyst estimates. Plus, its mobile communications business has been on a roll, ringing up record sales and increasing market share across the globe. Yet Motorola's stock price languishes at \$20, not far from its 52-week low of \$18.66 and over the last two months Motorola's chart has pretty much tracked the NASDAQ. That's not very impressive for a company that has the hottest phone on the market - the Razzr with 50 million units sold - and seems to be firing on all cylinders.

Despite Razzr's success, Motorola suffers

from a classic tech device maker's challenge. In the stiffly competitive world of mobile phones, you are only as good as your next hot design. Indeed already, competitors like Nokia are slimming down their designs and making Razzr clones.

Nanotech Could Boost Motorola's Image

But Motorola has at least one ace up its sleeve, thanks to the new science of the small. That's where Motorola Labs come in. Established as a centralized organization in 1998, it is responsible for cross-disciplinary research focused on emerging technologies with potential applications in the mid- to long-term range. Think of it as a sort of in-house bridge between basic research that the company helps fund at the university level,



Motorola Lab's nano emissive display could change the picture for LCD and plasma screens.

and nearer term product development work underway at Motorola's four business units. In full disclosure, Motorola Ventures is also one of the corporate investors in Lux Capital's venture capital fund. As most of you are already aware, I am one of the founding

partners of Lux Capital.

Work at Motorola Labs is divided into six Centers of Excellence. Two of them, Embedded System and Physical Realization, include nanotechnology among their fields of study.

I had a chance this month to speak with Dr. Vida Ilderem, Vice President of Embedded Systems research, which pursues a diverse patch of R&D initiatives at Motorola. It was Embedded Systems that drove development last year of a prototypical 5-inch Nano Emissive Display (NED). The energy-efficient, high-definition prototype was created through a proprietary low-temperature method of growing carbon nanotubes (CNTs) directly on glass.

The process is as important as the product. By growing CNTs directly on glass, it eliminates the conventional approach of spreading on nanotubes in a paste, and then removing the carrier material in an extra step. Fewer steps generally means faster, lower-cost manufacturing. Also, because it's a low-temperature process, it prevents the glass from warping. Lastly, Motorola's patented process plants the CNTs accurately. Once applied, they act as electron guns that paint images on the screen.

The technology could theoretically enable large, flat panel displays with superior picture, extended lifetimes and lower manufacturing costs compared to current LCD or plasma screens. That theory remains largely unproven for now, while the company shops its prototype around for a display manufacturer interested in bringing it to market. With over 160 patents issued on the technology, Motorola is opting to license it out rather than fielding it under its own label. But the new technology could eventually find its way into a range of Motorola products, although the company hasn't announced any plans to that effect.

Other nano initiatives

In addition to displays, Motorola's Embedded Systems lab is exploring nanotech's potential value along other paths. Research in the area of structural nanocomposites, for example, promises to create stronger,

thinner, and more environmentally-friendly housings. Nanoparticle coatings can also create antibacterial, self-cleaning, smudge-proof surfaces for mobile devices. Motorola's i870 phone, for example, already sports an antimicrobial coating made from silver zeolite nanoparticles and supplied by AgION Technologies in Wakefield, MA.

In the field of energy sources, Motorola is exploring the application of CNT materials as catalyst support and components for fuel cell electrodes. The mechanical strength, high surface area, and high conductivity of CNTs could lead to more efficient, longer-lasting power sources for products spanning Motorola's Mobile Devices, Networking and Connected Home Solutions businesses. "Phones are adding more and more functionality, so they're draining energy faster," Ilderem said. "What's the ultimate goal? It's never having to charge my battery. I just take the phone and go."

That sounds like heady stuff, but nanotech is already improving the performance of Li-ion batteries. As we mentioned in May (see "Nanotechnology Energizes the Battery Business", May 2006), Motorola and MIT were both among the earliest backers of A123 Systems in Watertown, MA. The start-up is using nanoscale components to develop Li-ion batteries that discharge more efficiently and recharge in a matter of minutes.

Motorola is also exploring the application of nanosensors able to detect chemical and biological gases. Based on nanotubes and nanowires that change their electronic properties in the presence of a few target molecules, such sensors are small enough to integrate into many devices. They can also be organized into miniature arrays for multi-analyte detection, offering enormous potential for warning emergency first responders of hazards in their environment.

Lastly, and perhaps farther out, is Motorola's research into using nanotubes and nanowires to enhance the active and passive RF components at the heart of mobile communications.

Nanotechnology keeps Motorola's i870 phone free of bacteria and smudges.



Looking ahead

Despite Motorola's many nanotech applications, Ilderem estimates that the field's practical value to mobile communications is still between five to ten years away. Hence, most research remains in the university labs, where it's less risky and costly to pursue.

Another way to spread the risk is through partnerships, which Motorola pursues with start-ups, academia and government alike. Given the diversity and unpredictability of the challenges and solutions emerging from the nanotech field, partnering is essential for research. Ilderem concedes that no one can afford to effectively do all the prospective research by themselves. Plus, given the amount of government funding in nanotech, it would be foolish to try.

R&D expenditures for the second quarter this year topped \$1 billion across all of Motorola's segments. That's up 3.7% over the previous quarter, and 9% of Q2's net sales. Still only a fraction of that budget goes into nanotech research. **N**

Nanosys Expands Flash Memory Collaboration with Intel and Micron Technology

Nanosys recently expanded its collaboration with **Intel** [INTC] and **Micron Technology Inc.** [MU] to develop nanotechnology-enabled NAND flash memory. The collaboration utilizes Nanosys' proprietary nanostructures to create non-volatile memory with higher storage densities and lower cost per bit than current devices, while at the same time increasing reliability. The technology is designed to be compatible with current manufacturing processes and equipment, and has applications in consumer electronics, portable storage, and personal communications. [Full Disclosure: Lux Capital is an equity investor in Nanosys]

Thinking Small: Chad Mirkin

Chad Mirkin is one of the leading figures in nanotechnology research and commercialization. He has been consistently recognized as one of the *Forbes/Wolfe Nanotech Report's* Power Brokers, and his research is often published by top academic journals. At the time of this interview, Chad's company, Nanosphere, had recently raised \$57 million from Bain Capital and Allen & Co. It's one of the biggest venture rounds in the history of nanotechnology investing, and is a great indication of the success of their efforts.

Chad is also the author or co-author of over 260 publications and 150 patents as well as the founder of two companies, Nanosphere and NanoInk, and co-founder of the journal, *Small*.

Tell me about the Institute for Nanotechnology and your work there.

We oversee \$330 million of research support and infrastructure for nanotechnology. There is a heavy emphasis on bio-nanotechnology, but it covers all areas of research. There is a lot of diverse expertise not just on hard fabrication like the semiconductor side of things, but also soft matter relating to medical diagnostics and therapeutics. There is a strong alliance with Argonne National Labs. In addition, we have about 30 major collaborations with industry, along with hundreds of international and domestic academic collaborations.

What drew you to the area of nanotech research? Was there an inspiration or was it an evolution?

It was more of an evolution. Over the course of my 20 year career, I've been working in the microchemical space. With the advent of the scanning tunneling microscope (STM), its variants, and additional tools that have been developed over the last decade, we've moved into nano. We developed some of the capabilities ourselves like the dip pen lithography (DPN) tool, and some have come from elsewhere. It's more evolutionary but it has been catalyzed by the development of tools.

What do you think will be delivered in the next five to ten years through control at the nanoscale?

It is already paying huge dividends in electronics. I think the biggest advances will

be in diagnostics and therapeutics. The diagnostic systems being developed are extraordinarily sensitive, much more accurate, and remarkably easy to implement. It is not just about making old tests better; the real opportunity is to fish for markers that the old fishing lines didn't work for. Or we use them to develop tests for diseases we haven't been able to diagnose. It will allow us to do things that weren't scientifically possible before.

You've been very active as an entrepreneur. What was your interest in starting Nanosphere and Nanoink?

Both companies were based on key inventions in our lab. With Nanosphere, it was the development of nanoparticle biodiagnostics. We were the first to report on nanoparticle bioconjugate diagnostics, which we published in *Nature* in '96. We modified gold particles that worked well as probes. They gave you a nice colorimetric response. We knew that it would be difficult to develop tools that could be used by the masses if we kept it in the lab. We started Nanosphere to create point of care detection systems that are very accurate, very sensitive. Our proposition was aimed at using nanostructures to compete with PCR (a commonly used method in medical and biological research labs to do things such as detect hereditary diseases, identify genetic fingerprints, identify DNA and clone genes).

What evolved from that was the development of the barcode assay that allows us to do protein and DNA detection all in one system. 80% of markers are based on proteins. It was a huge scientific advance but it was also a business advance. PCR revolutionized detection—it opened up field of forensic diagnostics. It gave us new ways of looking at genetic material. We developed it to create something as good as PCR but much cheaper. Nanosphere will launch its first systems very shortly. You can completely change the way you think about the use of these tools.

For instance, people identified markers for Alzheimer's, but a brain biopsy is not a suitable diagnostic. What if those markers are found in the cerebral spinal fluid but it's more difficult to detect? Those do become reasonable places to run a diagnostic. If I create a less invasive tool and identify at a


place that isn't high concentration but less invasive, I can use my diagnostic because it can now recognize the concentration.

NanoInk is commercializing the dip pen lithography tool we invented. It's a universal patterning tool that allows you to pattern on the scale of ebeam lithography regardless of the material. It's good for things like repairing flat panel displays. Another problem it addresses is if you want to repair a mask that has damage in the form of both positive and negative defects. Our tool allows you to read the mask, find that scratch, deposit and fill it. We can read and write effectively with chemical reagents.

What key breakthroughs and insights are emanating from your work at the institute?

Well, we have a major report in *Science* where nanoparticles are being used as anti-sense agents. The particles are very similar to the diagnostic ones. They are naturally taken up by cells and can be used like a chemically specific Velcro to latch onto cellular machinery that are responsible for causing problems. It can be used as a therapy that goes in and binds to mRNA, which is responsible for encoding production of materials that are not good for the cell. We can use it for a type of gene knockout therapy. Much more efficient than current tools and nontoxic so far, which is really exciting because most of these approaches are highly toxic and have lots of side effects.

What keeps you up at night?

Waiting for the next result. Nanosphere has raised \$108 million, NanoInk \$33 million. NanoInk is going to be in the black late this year or early next year. Nanosphere is poised to change the diagnostics industry. But we need to get the technology refined to point where it can do clinical studies that convince the medical community that it is going to change what those guys do. 



Companies to Watch

Unidym

[private]

www.unidym.com

626-304-3400

Los Angeles, CA

Chief Executive: R. Bruce Stewart

What it does: Combines intellectual property for carbon nanotubes with strategic product development resources.

Although commercial applications for carbon nanotubes (CNTs) are rare, the unique combination of electrical, mechanical and thermal properties that they present means that the technology could have broad applications in the future. Carbon nanotubes, which are hollow, nanoscale carbon cylinders, could enable faster computer chips, brighter displays and more efficient solar cells.

Formerly NanoPolaris, Unidym aims to play a key role in the emerging CNT market. The company, which is a subsidiary of **Arrowhead Research's** [ARWR], is developing flat panel displays and solar cells that substitute nanotubes for the indium tin oxide (ITO) materials in use today. Even before ITO began increasing in price, its brittle nature posed a compromise to the transparency of electrodes in displays, touch screens, and solar cells. In contrast, Unidym's CNT-based films are mechanically flexible, can be deposited on lightweight plastics instead of heavy glass, and could be substantially more conductive than ITO.

Another CNT technology under development at Unidym is thin film transistors for flexible electronics. If successful, these devices could disrupt organic transistors and enable electronic brochures or displays that roll up.

In addition to pursuing display and electronics applications, Unidym has also compiled a portfolio of strategic IP centered on the efficient manufacturing and processing of CNTs, which is an area of expertise that few companies have. Forming its portfolio are licensed commercial rights on work done at a number of academic centers. Among them: The California Institute of Technology, Duke University, Penn State, the University at Buffalo, UCLA, the University of Toronto, RPI, and Tsinghua University.

Although product revenue remains in the distant future, the company's IP portfolio could generate early licensing income from customers who need nanotube technology for research and development.

The current company arose when Arrowhead's subsidiary NanoPolaris acquired Unidym in June. In conjunction with the sale, Arrowhead purchased 11% of NanoPolaris's outstanding stock and, in exchange, made an initial investment of \$3 million into the new business. Arrowhead also promised that it would pay another \$2 million on the next two anniversaries of the merger. The bulk of that investment is intended for developing CNT technology for commercial display devices. NanoPolaris changed its name to Unidym this month.

Arrowhead's Vice President of IP, John Miller, wouldn't disclose how long the road to commercialization might be, except to say two years seemed hopeful while five years seemed too long.

Looking further out, Unidym also hopes to develop CNT technology to replace the copper interconnects on semiconductor chips. Although the engineering challenges to carbon-based interconnects are anything but trivial, CNTs could potentially help IC devices continue to multiply functionality well into the 21st century.

Nanoident Technologies AG

[private]

www.nanoident.com

+43 732 9010 2200

Linz, Austria

Chief Executive: Klaus Schroeter

What it does: Develops and produces custom-specific nanotechnology-based photonic sensors for industrial high volume applications.

Founded in 2004, Austria-based Nanoident has been making waves throughout Europe. The company has developed an organic semiconductor platform for photonic sensors and targets the fast-growing biometric security and life-sciences markets. Nanoident encompasses design, simulation and characterization of organic semiconductor based photonic devices, deposition technology, micro-structuring, interface technologies, sensor design, and digital electronic design. The photodiodes embedded in the company's sensors convert light into signals and can employ multicolor OLED light sources to illuminate measurement objects and provide various "smart sensor" functionalities. The company has 3 patents granted, 12 filed, and 20 others at the idea stage.

Perhaps most interesting, Nanoident has developed an ultra-cheap, scalable production process using ink-jet printing techniques. In late 2005, the company launched a fabrication facility capable of printing the sensors onto flexible plastic films. The plant can produce up to 100,000 m² (1,000,000 ft²) chip surface per year—a capacity more than double that of Europe's most sophisticated silicon chip plant. Nanoident's first products will be ready some time later this year.

Nanoident CEO Klaus Schroeter is a seasoned entrepreneur who founded BioID AG, a European biometrics company. But Mr. Schroeter believes that Nanoident's technology could "open up a new world of printed transistor circuits."

For example, the company's biometric sensor product handles namely recognition accuracy and fraud protection. The sensor can simultaneously acquire biometric traits such as fingerprint, skin properties, and blood parameters. Products for application include next generation PDAs, smart phones, and smart cards.

In addition, Nanoident's biochip sensor product will be integrated with various types of biochips and microarrays. The sensors will detect fluorescence and eliminate the need for hundred thousand dollar biochip readers. Schroeter believes Nanoident will develop printed chip readers that cost almost nothing within the next year or two. That would enable mobile and disposable biochips for real-time field analysis, opening up a new potentially multi-billion dollar market.

To lead its biometrics division, the company recently nabbed Alain Jutant of ATMEL-Grenoble. Nanoident also recently launched a life sciences division in Menlo Park, California, where executives are exploring partnership opportunities to commercialize their biochip sensor technology.

Nanoident is entirely privately financed, but has stirred little attention. Its newly launched biometrics and California-based life sciences divisions may provide the needed leverage to bring the company into the mainstream of the sensor space. **N**

Follow the Money

A monthly look at who in nanospace is getting funding and who's giving it.

Venture Capital Funding

NanoMed Pharmaceuticals

www.nanomedpharm.com

Location: Kalamazoo, MI

CEO: Stephen Benoit

Funding Announced: 7/6/2006

Investors: Southwest Michigan First (SWMF) Life Science Venture Fund

Funding Amount: Undisclosed (Series A)

Notes: NanoMed Pharmaceuticals develops nanoparticle-based therapeutic and diagnostic products to treat and detect disease. The company's core technology, called Nanotemplate Engineering, is a scalable manufacturing process used to formulate small molecules, proteins, peptides, and plasmid DNA. The key advantage is the production of nanoparticles enabling the targeted delivery of drugs to specific tissues and cells, such as tumors.

Outlook: NanoMed was founded in May 2000 and represents the first portfolio company in the SWMF Life Science Fund. While the amount of funding was undisclosed, CEO Stephen Benoit expects the investment should keep the company afloat for at least a year. The company plans to initially target cancer therapeutics and diagnostics, and is in the process of completing pre-clinical development for a leukemia product. It hopes to begin FDA clinical trials in approximately 18 months. Additionally, the company is working on a therapeutic vaccine for the HIV-1 virus. Still, the company will need to raise additional capital within the next 15 months if it has any hopes of progressing through FDA trials.

SiOnyx Inc.

Location: Woburn, MA

Lead Scientist: Jim Carey

Funding Announced: 6/23/2006

Investors: Harris & Harris Group [TINY]

Funding Amount: \$750,000 (Seed)

Notes: SiOnyx is a Harvard University spinout commercializing optoelectronic devices enabled by their propriety "black silicon." Black silicon photodetectors have a high response to visible wavelengths and extend the useful range of silicon detectors into the infrared.

Outlook: Scientists and investors involved with SiOnyx have remained largely secretive about the company's black silicon technology. Based on patent literature, it seems their invention relies on a specially structured surface layer comprised of doped silicon nanocrystals as small as 10 nanometers in diameter. The surface layer in turn forms a highly sensitive diode with the underlying bulk silicon, which is good for detecting a wide range of light. If effective, the market potential for such a device could be enormous, with applications spanning consumer electronics, optical communications equipment, and medical imaging devices.

Government Funding

Russian Government

Funding: Nanotechnology Development Center, Various Universities

Funding Announced: 7/13/2006

Funding Amount: \$400 million

Notes: Funded by the Russian Federation, the multimillion dollar Pilot Scientific and Technical Center of Excellence for Nanotechnology Development recently opened its doors in Moscow. The state-of-the-art center will give researchers and developers access to advanced nanoscale imaging, analysis and manipulation capabilities. **FEI Company** [FEIC] (see "Nanotech Toolmakers' Wild Ride", February 2006), a leading U.S. manufacturer of transmission and scanning electron microscopes, has been selected as a key tool provider for the center. The center expands on an anticipated \$400 million overall Russian investment in nanotechnology by 2007.

National Science Foundation

Funding: University of Oregon

Funding Announced: 7/6/2006

Funding Amount: \$3.2 million

Notes: University of Oregon was recently awarded a five-year, \$3.2 million grant from the National Science Foundation (NSF) meant to unite Oregon universities with international technology companies. The money will fund graduate studies in materials sciences, helping to accelerate the transition from school to industry. In February, the Oregon Nanoscience and Microtechnologies Institute (ONAMI), a collaborative effort among several Oregon universities, the state of Oregon, and the high-tech industry cluster of Oregon and southwest Washington, received \$8 million in funding from the White House.

Commonwealth of Pennsylvania

Funding: Venture Capital Firms

Funding Announced: 7/17/2006

Funding Amount: \$23.1 million

Notes: Pennsylvania Governor Ed Rendell announced that the commonwealth is investing over \$23 million in eight venture capital firms that will help Pennsylvania-related companies specializing in nanotechnology and life sciences. Firms receiving the money include Boston-based Oxford BioScience Partners; Psilos Group Partners in Erie County; Brook Ventures and Innovation Ventures LP in Lancaster County; and Philadelphia-based firms Edison Venture Fund, MentorTech Management LLC, and New Spring Ventures. The funding comes as part of the New PA Venture Capital Investment Program, a key element of Gov. Rendell's economic stimulus plan. The program will invest a total of \$240 million to encourage the growth of young companies.

The Nanosphere

Company [symbol]	Technology	Coverage Initiated	Current Price	52 Week Range	Market Cap (\$mil)	Buy/Hold/Sell
Intellectual Property Incumbents <i>Leading researchers in nanotech, with big potential for spin-offs and revolutionary breakthroughs.</i>						
IBM [IBM]	Nanoscale storage and nanotube transistors	3/02	\$75.83	\$72.73 - \$89.94	\$117,570.00	Buy
Hewlett-Packard [HPQ]	Molecular transistors and switches	3/02	31.75	23.66 - 34.52	88,570.00	Buy
Instrumentation <i>Tools that allow researchers to view and manipulate nanoscale matter.</i>						
Veeco [VECO]	Atomic force microscopes	3/02	21.92	14.71 - 27.55	663.06	Buy
FEI [FEIC]	Focused ion and electron beam microscopes	1/03	21.41	17.75 - 26.00	726.38	Buy
Materials <i>Companies producing nanoscale materials with novel properties that have applications across a wide range of industries.</i>						
Symyx [SMMX]	Novel materials discovery	3/02	24.03	22.21 - 31.09	810.63	Buy
Modeling <i>Companies developing software to visualize, model and simulate matter and activity at the nanoscale.</i>						
Accelrys [ACCL]	Molecular rendering and analysis software	3/02	6.30	5.00 - 8.74	165.13	Buy
Platform Technologies <i>Companies that have corralled key intellectual property that will be the foundation of future developments.</i>						
Nanosys [private]	Nanowires and nanostructure-enabled devices	3/02	n/a	n/a	n/a	n/a
NVE Corporation [NVEC]	Spintronics-based MRAM	7/03	16.64	12.36 - 18.86	76.81	Hold
Investment Firms <i>Companies that are investing in promising early-stage nanotechnology startups.</i>						
Harris & Harris Group [TINY]	Non-volatile RAM, drug delivery, nano-optics	5/02	9.76	9.43 - 16.10	202.58	Buy
Nanobiotechnology <i>Companies that are working at the intersection of nano- and bio-technology.</i>						
SkyePharma [SKYE]	Nanoparticle solubilization for drug delivery	8/02	5.60	5.09 - 11.19	422.11	Buy
Flamel Technologies [FLML]	Nano-encapsulation for drug delivery	8/02	18.27	14.35 - 24.48	433.66	Hold
Immunicon [IMMC]	Nanoparticles for medical diagnostics	5/04	4.73	3.05 - 6.05	130.56	Buy
Starpharma [SPHRY]	Nanoscale dendrimers	1/05	4.10	2.85 - 4.70	58.53	Buy
Invitrogen [IVGN]	Nanoscale labeling and detection	11/05	63.51	60.14 - 88.50	3,380.00	Buy
Nucryst Pharmaceuticals [NCST]	Nanocrystalline silver	04/06	15.16	8.88 - 16.88	276.49	Buy

Word on the Street

IBM: Big Blue announced a 14% increase Q2 EPS, generating \$1.30 per share in profit, versus \$1.14 in the prior year period. However, the impact of the divested PC business and reduced software sales led IBM to a 6% decline in revenues over Q2 2005. IBM's net income was offset by an increase in gross margins, decreased SG&A expense and the inclusion of \$775M legal settlement received from **Microsoft** [MSFT].

HPQ: Hewlett-Packard announced the purchase of Mercury Interactive Corp., an IT management software and services company, for approximately \$4.5 billion (\$52 per share). Following the sentiments of the broader market, HP's stock price was trimmed more than 2% on the month.

VECO: Veeco announced its Q2 2006 financial results. Led by a 21% increase in bookings and surging data storage demand, VECO was able to beat company guidance. Veeco earned EPS of \$0.10 on \$111.6 million in revenues, versus a \$0.02 loss on revenues of \$103.4 million in the same period last year. Revenues were also above prior guidance of \$105-\$110 million, while bookings of \$143.2 million blew past the company's projected range of \$125-\$130 million. Veeco raised 2006 revenue guidance to \$455-\$465 million. In other news, President Don Kania will be leaving for **FEI Company** [FEIC]. Kania had been expected to succeed 66-year-old Chairman and CEO Ed Braun. Still, I reiterate my Buy rating: VECO trades for less than 1.5x projected 2006 revenues.

FEIC: Veeco's Don Kania has been named FEI's new CEO. Kania replaces Vahe Sarkissian, who resigned on April 3. The move sends strong signals that the com-

pany is not actively looking to be purchased after much merger chatter. While slightly positive year-to-date, the stock price has slid more than 6% in recent weeks.

SMMX: Symyx reported its Q2 results, in which net income nearly doubled (to \$765,000 or \$0.02 per share) on an 18% increase in revenues to \$28.4 million. The stock dropped in trading following the report as the company issued lower than expected Q3 revenue guidance of \$28-\$30 million, below consensus estimates of \$36 million. SMMX has slipped with the market over the past few months. With flat guidance for the second half of 2006 and benefits from the Autodose acquisition months away, I would expect the stock to be range-bound in the near term.

ACCL: Molecular modeling leader Accelrys announced that science pioneers Dr. Robert Langer and Dr. Leroy Hood have joined the Scientific Advisory Committee of the company's NanoBiology Initiative.

NVEC: NVE reported Q1 2007 results, with revenues rising 20.1% over the prior year period to \$3.6 million. Net income grew to \$891,806, up from \$412,649 in Q1 2006. In related news, **Freescall** [FSL] announced the first commercial roll-out of MRAM devices. The potential for a new licensing agreement reinvigorated NVEC shares.

TINY: Despite my recent upgrade, shares of Harris & Harris Group have slipped back near its 52-week low. I reiterate my Buy rating on TINY.

SKYE: SkyePharma has completed negotiations with Mundipharma International, which will allow the company to reacquire the rights for the distribution of DepoBupivacaine in Europe and other international

markets. The stock price remained flat on the month, but is still down nearly 37% year-to-date.

FLML: Flamel shares have been trading up 4.6% in recent days, fighting back from mid-month lows of \$15.95 to close at \$18.27. I am reiterating my Hold rating on FLML until I see additional traction from the company's Medusa drug delivery platform.

IMMC: Immunicon set a 52-week high of \$6.05 in July, only to tumble to \$4.70 in its biggest percentage loss of the year (14.2%). Shares are still up nearly 23.5% year-to-date. The company reports quarterly results August 2.

SPHRY: Starpharma shares surged 44% on the month following my positive June cover story and are up nearly 21% year-to-date. Starpharma announced that CEO John Raff would retire from his executive role, allowing his successor Jackie Fairley to assume the role effective July 1, 2006. SPHRY also announced that the IND for the clinical development of SPL7013 gel (VivaGel) for prevention of genital herpes has successfully completed the mandatory review period within the FDA.

IVGN: Invitrogen and the Human Proteome Organization have entered a collaboration focused on advancing proteomic research through education initiatives, standardization of research protocols and development of advanced proteomic products. Financial terms were not disclosed.

NCST: Despite a rocky July, Nucryst is back north of its Nanosphere entry point, and is up nearly 33% year-to-date. I believe NCST's first half 2006 financials will prove to be solid and expect the company will remain on track for the remainder of the year. Stock prices as of July 26, 2006

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Editor: Josh Wolfe Contributing Editors: Dan McCarthy, Amanda Gefter, Clayton Brown, Zack Schildhorn, Richard Tapolaga

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