Published October 2001

Dancing on the Head of a **Pin**

By Terese Brasen

Nano means small -very small, as small as a single molecule. Nanotechnology is the power to work small, manipulating atoms and molecules invisible to the human eye. That concept stirs imaginations. "Imagine being able to cure cancer by drinking a medicine stirred into your favourite fruit juice," write Gayle Pergamit and Chris Peterson in their 1993 feature article published by the Foresight Institute. "Imagine a supercomputer no bigger than a human cell. Imagine a four-person, surface-to-orbit spacecraft no larger or more expensive than the family car. These are just a few products expected from nano.technology ."

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In his book *Engines of Creation*, nano futurest K. Eric Drexler describes self-replicating machines that could reverse global warming and cure any disease. But while some nano enthusiasts expect this new technology to free us from pain and bring eternal life, the scientific community is thinking more practically. Smaller, faster computers. Better health care. Stronger materials.

And some of those revolutionary technologies will be developed in Alberta. In August, Prime Minister Jean Chretien announced a National Institute for Nanotechnology in Edmonton with $120 million in joint federal-provincial funding over the next five years. The Institute will see the National Research Council have its first presence in Alberta. In making the announcement, Chretien was following the lead of former U.S. president, Bill Clinton, who in 1999 established the National Nanotechnology Initiative with $442 million in funding in the first fiscal year. The National Science Foundation estimates that worldwide, countries spent $835 million on nanotechnology last year.

So what's the big deal about working small?

Bruce Alton, director of business development, telecommuni -cations with Micralyne, admits there is currently a lot of hype swirling around nanotechnology. However, at the same time, he insists there is tremendous economic potential. Micralyne is an Edmonton-based microfabrication company -a multimillion-dollar operation and one of the largest independent microfabrication companies in the world. The company develops and manufactures micro products, like the tiny sensors that set off airbags. Since Micralyne is already working small, Alton is confident the company can take the next step, to work even smaller. Scott Kennedy says there is a long list of companies interested in his research but he and his University of Alberta colleagues aren't giving away any tiny secrets. They want to be the first out of the gate, spinning their research into their own company. "This could be so big," says Kennedy. "Or it could go bust."

Kennedy has just moved into the university's Electrical and Computer Engineering Research Facility, a building so new construction crews are installing lights and door handles as scientists unpack. The sixth floor of the building will house the nanotechnology institute until 2005 when the university cuts the -fib,b.oQ. o.n a. 180,000-square-foot nanotech building.

Kennedy is a graduate student working with Dr. Michael Brett, the director of engineering physics at the U of A. Brett's lab is across the hall from the new MicroFab, a facility where researchers manufacture tiny devices at the micro and nano level. In Brett's lab, engineers and physicists rearrange atoms and molecules creating new materials in different shapes - rings, zigzags, springs and spirals that may prove useful in optics and acoustics and as sensors. As one of Brett's grad students, Kennedy is in good company. In 1994, a fourth-year student of Brett's, Kevin Robbie, discovered how to manufacture thin films at the nano scale, a discovery that helped push nanotechnology ahead in Alberta.

"I was trying to understand structures and optimize conventional structures," says Brett. "Out of that understanding and work came the idea to modify these structures on the nano metre scale or how to engineer them. I suggested it to a engineering physics undergraduate student as a project, thinking that it was kind of a silly idea but that it might work and it would be educational. He made it work and made the first engineered structure at that scale."

Thin films aren't new. We experience them every day. They coat dollar bills, protecting them against counterfeiting and line the inside of potato chip bags. However, nano thin films are brand new materials that have the potential to make computers lighter and more powerful.

Kennedy is working on a photonic bandgap crystal, a new type of semiconductor that could replace the silicon semiconductors inside computer transistors. Call it an optical microchip.

Photonic bandgap crystals have the same properties as silicon, but use light instead of electricity. "The modern telecommuni-cations industry uses light to communicate, because light has a very high frequency and moves faster than electricity," says Kennedy. "However, everything we deal with is electronic, so you have to switch from fibre optics back into electricity, a very slow, time-consuming and expensive process."

Photonic bandgap crystals will eliminate the need to switch back and forth. "We will have optical computers where there is not a single bit of electricity," says Kennedy. Scientific American
author Gary Stix says IBM and Hewlett-Packard have substantial nano programs, preparing for the day when "conventional silicon electronics goes bust-probably sometime in the next 10 to 25 years."
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Kennedy and Brett's work involves ongoing online collaboration with U of T physics professor Dr. John Sajeev, the first person in the world to conceive of a photonic bandgap crystal. Sajeev conceived of the concept in 1987, and last year, roughly 500 scientific articles dealt with this theme alone. Kennedy and other members of Brett's team are building the actual crystals, translating Sajeev's ideas into a product.

Sajeev echoes Kennedy's confidence in the economic potential of this new nano product. "All the telecommunications companies want to invest in this field," he says. "It would allow more components on a single chip."

In another building at the University of Alberta, engineer Dr. Chris Backhouse is working with medical researchers to develop a microchip to diagnose cancer from a single cell. The technology already exists at the macroscopic level, where oncologists look at larger many-celled samples. At the Cross Cancer Institute, Dr. Linda Pilarski is using macroscopic technology to understand and treat myeloma, a fatal form of bone cancer that has long eluded a cure.

Although macroscopic diagnostics hold promise, they are so labour intensive and costly that few cancer centres can afford the orocedure. Here is where nanotechnoloav steps in.

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Backhouse is looking forward to the day when a microchip will contain a detailed library of personal genetic information. A lab on a chip, he says. We might take our chip to the clinic or drug store and have it tested in real time. Since the technology uses nano amounts of tissue, there will be no need for invasive biopsies or blood tests.

"In the next five years, this initiative could well spearhead major changes in the way health care is delivered," predicts Backhouse. "The economic implications are enormous. The technology will allow us to reduce costs and operate at higher speeds. Conventional procedures take days. Ultimately, we expect to automate the procedure and reduce this to 15 minutes or less."

Our ancestors discovered fire and invented the wheel. The 20th century brought us cars, airplanes and computers. Now, nanotechnology is about to force us to take another leap forward.

Albert Einstein showed us that one sugar molecule is one nanometre in diameter. One billionth of a metre. In 1959, the late physicist and Nobel laureate Richard Feynman delivered a famous lecture entitled, "There's plenty of room at the bottom." Feyman said cells could manufacture substances, store information and "do all kinds of marvellous things." He talked about arranging atoms "one by one the way we want them."

Feynman challenged physicists to improve the electron microscope. Twenty-lwo years later in a Zurich laboratory, two IBM researchers, Gerg Binnig and Heinrich Rohrer, were struggling with a temperamental microscope, when suddenly it displayed sharp images of individual atoms. The researchers had invented the scanning tunnelling microscope -a portal into the molecular world. Scientists now had a tool to see and manipulate atoms.

In Michael Brett's lab, Kennedy is using the scanning tunnelling microscope to create bandgap crystals. The microscope allows Kennedy to both see and manipulate atoms. "We want to make things that are one-millionth the size of a human hair," says Kennedy, explaining that one three-dimensional crystal contains millions of atoms. "We are producing things on such a small scale, you can't touch it or see it without an electron microscope."

The microscope electron beam can move atoms. Another required tool is a sharp electric tip. "When atoms see each other, there is an electrical interaction that causes atoms to move around," says Kennedy.

In the University of Alberta's department of physics, Dr. Mark Freeman heads the Ultrafast Microscopy Group in the Centre for Nanoscale Physics. Frpeman spent six years in the Physical Sciences Department of the IBM Research Division in New York and now his group is working to improve conventional microscopy. Instruments like the scanning tunnelling microscope and its updated variations allow Freeman and other researchers to see what they could only guess at before. "We now have tools that allow us to look under rocks," explains Freeman.

Feynman, who asked physicists to improve the electron microscope, predicted that scientific research would converge at the nanoscale or, as he put it, meet "at the bottom." His
prediction came true. Engineers began working with medical researchers, physicists and chemists. "In some universities, professors in different departments are at odds with each other," says Brett, explaining that Alberta's facility with nanotech partly reflects the co-operative climate inside the University of Alberta's science faculties.

That collaboration led to the formation of the MicroFab lab. "We got together to form this facility, get funding for it and make it work," says Brett. "That brought us together and kept us together. Here we form a very advantageous liaison between -Ph,.v.s!E.s.. electrical engineering, chemistry and medicine."

The MicroFab lab is part of the reason why the University of Alberta is now home to the national nanotechnology institute. The lab is an open access facility , which means pay your entrance fee, take the basic training and you are free to use the space and the equipment. During the last two years, the lab attracted 178 different researchers from different companies, research groups and other universities.

Dr. Ken Westra, who manages the lab, describes it as the machine shop of the 21st century. In the MicroFab, university researchers and industry partners can collaborate in real time on new products. "We are helping a veterinarian from the University of Saskatchewan develop miniature hypodermic syringes," says Brett, giving examples of MicroFab research.

Westra explains that these new syringes look like patches. "If you inject a drug into someone, the blood system takes it to your liver first. A lot of drugs are metabolized by your liver, so drugs you inject, have to survive your liver." Slap a patch on a porous substance coated with a drug. The drug will bypass the liver and enter the bloodstream directly through a thin layer below the skin's surface.

Announcing the new National Institute for Nanotechnology, University of Alberta President Dr. Rod Fraser said the institute aims to be "internationally competitive with the nanotechnology clusters being created in the United States, Europe and Asia. Our target is to be among the top five nanotechnology initiatives in the world."

"I look forward to this institute becoming famous for breakthroughs that will help the patient at the bedside, the country's energy sector, and its computer technology research," enthused Premier Ralph Klein.

Prime Minister Jean Chretien said the institute represents a bright future. "With the creation of this institute, Canada will be poised to playa leading role in this exciting new technology - widely considered to rival the impact of the 19th century industrial revolution."

There are certainly economic benefits. John Martin, who manages the Edmonton Research Park for Economic Development Edmonton (EDE), estimates the institute will directly employ several hundred workers independent of the National Research Councilor the U of A. The world market for microsystem devices alone could range from $8 billion to $34 billion in 2002. "The institute will catalyze a profound structural change in the region that might otherwise take longer to achieve," said Martin. However, beyond the research activity, what is the potential for commercialization, which would have much more significant long-term value for the province?

Nanotech boosters point to northern California and Stanford University. A small private university outside San Francisco, Stanford University has spun-off more than 350 high-tech companies, starting with Hewlett Packard. One of Stanford's most famous spin-offs is Cisco Systems, founded in 1984 by a group of Stanford computer scientists. The development of Silicon Valley is rooted in Stanford's R&D departments. Will a similar phenomenon happen here? Craig Estman, product development manager with software company DBR International, says nanotechnology requires a mentality change and Alberta is probably the best place in Canada to lead that change.

"I have been in and *out* of Stanford and Berkeley for years and the model they use is good facilities, good people and talent," says Estman. "The other component they have is venture capital money ."

Venture capitalists provide a combination of expertise and
dollars and for that reason, VG money usually stays close to home. However, Edmonton, with leading scientists and now the nano institute. could be a strong enough draw to entice some of

that money away from its comfort zone. And Estman adds,
.", *j* ...P?9~e,are starting to look here. Some of the stuff developed
I here IS truly leading edge in nanotechnology, and I think we are going to get people coming up from the U.S."

Estman explains that Alberta has a definite advantage in this area because we have the space to develop research and manufacturing facilities and, compared to California, our cost of living is reasonable and affordable. "I go down into the valley and I know how expensive it is to set up a business. People are saying we can't find people to come into the valley because they can't afford to live there."

The EDE's Greater Edmonton Competitiveness Strategy aims to capitalize on University of Alberta research, and Jim Edwards, EDE president and CEO, has lobbied long and hard for the National Institute for Nanotechnology. Now, both Estman and Alton agree that the next step in this nano initiative is to develop our own venture capital pool. American dollars are good and welcome but local investors must be convinced to support new entrepreneurs translating nano research into new products. "That's really where we should put our efforts," says Alton.