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NANOTECH'S FIRST LINE OF DEFENSE

Some nanotech materials firms try to achieve business-as-usual by garnering defense contracts

[VIVIEN MARX, C&EN NORTHEAST NEWS BUREAU](#)



TWISTED NanoSonic's Claus (from left), Lalli, and Jeff Mecham demonstrate the flexibility of Metal Rubber, which also is reflective and conducts electricity.

COURTESY OF Rick Claus/NanoSonic

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"All sizzle and no steak." "Vaporware." "Running with another bubble." These are some of the name-calling darts thrown at nanotech company [Nanosys](#) by analysts, venture capitalists, and nanotech company executives. The derisive chant was under way when Nanosys announced this spring that it was going public and subsided only when the company withdrew the initial public offering (IPO) in August, citing "the volatility of the public capital markets."

Views differ on the event's impact on the nanotech sector. But while Nanosys and its backers regroup, a number of companies are choosing to build their business more traditionally, without venture capital or an IPO. These companies seek to find and fill a niche—often as defense contractors—and then move to a larger market.

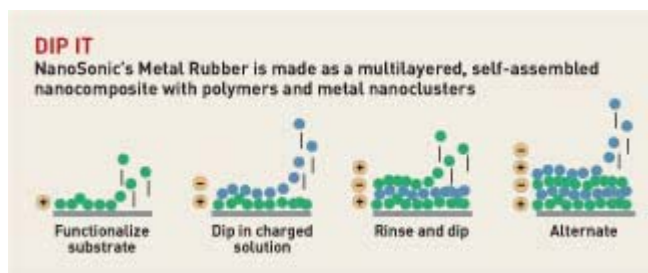
If founded today, [NanoSonic](#), spun out of Virginia Polytechnic Institute & State University in 1997 by Rick Claus, a professor of electrical and computer engineering, might not carry the hot-sometimes too hot-prefix "nano" in its name. "Material-O-Sonic would be fine and just as descriptive," says Claus, who has founded 20 companies and enjoys wearing both his academic and entrepreneurial hats.

His small team of polymer chemists and electrical and chemical engineers has developed Metal Rubber, a multilayered, self-assembled nanocomposite made with polymers and metal nanoclusters. The material, Claus says, is mechanically robust in that it resists wrinkling when deformed, much like rubber, and shows high electrical conductivity.

Jennifer Lalli, a polymer chemist who directs the company's nanocomposites group, says she joined the company for its creative possibilities and does not see herself as part of the nanotech bubble. She and her colleagues "find new ways of designing molecules and new ways of processing these molecules into nanocomposites," Lalli says. "We look at this as well-designed chemistry."

In electrostatic self-assembly, a substrate is first dipped in solution with positive ions, rinsed, and then dipped in solution with negative ions. Alternating layers are built up with electrostatic attraction as the glue between layers. A variety of molecules-polymers, metals, metal oxides, biomolecules-can be stacked with this method.

Traditionally, Claus explains, only thin films were thought possible through self-assembly. He quotes a colleague who said at a scientific meeting: "Self-assembly will really not be of any use for making anything larger than a few hundred nanometers." Not so, says Claus, who has shown that the stability of the growth process can be controlled and has made tailored, layered materials as thick as 1 cm.



"We were looking for a way to scale up self-assembly into something that is more realistic for actual products-go from nano to macro," he says. "We think that sets us apart from other companies."

The scale-up pertains to material thickness and also surface area. Instead of just immersing a 1- X 3-inch microscope slide into a small beaker of solution, Claus, Lalli, and colleagues have been able to scale the process up to 20 L and can coat a 2- X 2-foot substrate. "This is a big deal," Lalli says. That task entailed figuring out how to alter the nanoparticles' surface chemistry to keep the particles in solution from agglomerating, she says.

The company is now seeking to take its method into demanding engineering applications that require concept, design, synthesis, and testing all the way to fabrication, integration with other materials, and quality control. "That is the next step, moving from big R, little D, to little R, big D," Claus says. "That is real development as opposed to a research task."

[Lockheed Martin](#) has taken a liking to the company's chemistry and sees its potential in its own, undisclosed, applications. This summer, Lockheed and NanoSonic entered into a two-year nonexclusive collaboration of

undisclosed financial dimensions. On a given day, 20 to 40 potential investors contact NanoSonic and close to a dozen venture capitalists have come calling in recent months, Claus says.

There are a number of nanotech companies finding customers in the defense sector, where there are "interesting problems that require solutions," as Claus puts it. For example, Nanosys' first post-IPO-withdrawal project is a [Defense Advanced Research Projects Agency \(DARPA\)](#) contract to develop flexible, low-cost solar cells with an initial one-year phase of \$2.2 million in funding.

QuantumSphere, a company with eight employees in Costa Mesa, Calif., was contacted by the military to create better propellants and advanced munitions with higher explosive yields—"a bigger punch with less weight"—as Chief Executive Officer Kevin Maloney says. In August, the company opened a facility to make aluminum and nickel nanopowders. The first product to find a defense customer is nanoaluminum.

THE FIRM is currently manufacturing around 200 lb of nanoaluminum a month but can ramp up to 2,500 lb per month, explains Douglas Carpenter, the company's chief scientific officer. QuantumSphere ships the powder in cans, and the military takes over the explosive modification and compounding.

QuantumSphere has two main competitors, but Carpenter claims they cannot deliver the volumes or the narrow distribution of particle sizes that his company achieves. For nanoaluminum, particle sizes from 20 to 80 nm can be produced.

The company has adapted a gas-phase condensation method and made it a computer-controlled process in which aluminum is vaporized. By introducing oxygen into the reactor stream, the nanoparticles obtain an aluminum oxide layer and are safer for customers to handle, Carpenter explains. "We can specify both particle size and oxide thickness," he says. "We can control the oxide layer down to a few atomic thicknesses of material."

QuantumSphere believes its vapor condensation technique is readily adaptable. "Any element with a boiling point within a certain range can be used in our reactor to make nanomaterial," Carpenter explains. "We have made nanozinc, nanocopper, nanonickel, and nanoaluminum by modifying different parameters of our input." The system is modular: Up to seven reactors can go around one collector, Maloney says. "The heating elements are inside the reactor and are really the core technology; they give it scalability."

On the business end, Maloney says his company, "a manufacturer of products, not doing pie-in-the-sky research," has two angel investors—California Institute of Technology professors who came on board in January 2003. "Our investors are really excited about the fact that we are here rolling up our sleeves. We built a reactor, we're producing material, we're working on partnerships, and we're delivering orders in October," says Maloney, who grew up near Caltech, took classes there, and has kept close ties with the university.

QuantumSphere has become a defense contractor as part of its commercialization strategy and plans to stay true to its military customers. The real passion for both Carpenter and Maloney, however, is the energy sector. Nanonickel is a replacement for platinum, for example, that can potentially reduce the cost of producing hydrogen fuel cells as well as generally improve energy storage possibilities, they say. Carpenter believes that demand for nanonickel will eventually exceed that for nanoaluminum.

Nanotech firms like QuantumSphere can look at companies such as [Inframat](#) in Farmington, Conn., to see their possible futures. Inframat, founded in 1996 by chemical physicist David Reisner, focuses on nanostructured materials. The firm has used government R&D contracts from, among others, the Air Force, DARPA, the Environmental Protection Agency, and the National Aeronautics & Space Administration as bootstrap financing for its business. "Materials companies generally do not qualify for venture capital, for private investment, in the early going, because the development times for materials are so long," Reisner says. It can take 20 years to bring a new material from initial concept to actual placement in an original-equipment-manufacturer product.

Inframat's intellectual property revolves around low-cost wet chemistry for synthesizing nanomaterials coupled with a thermal spray technique using nanoscale grains to create nanocoatings. Its 2,500-sq-ft thermal spray facility is leased from nearby University of Connecticut.

The firm began working on ceramic nanocoatings for the Navy in 1997. This past summer, minesweeper boats with Inframat's ceramic nanocoatings on propeller and propulsion shafts were pulled out of the Persian Gulf and checked. As Reisner says, after-three years of use in a war theater, the coatings-"showed no signs of wear." The company's product has received official certification by the Navy for shipboard repair of moving parts, "a nanotech first," he says.

No venture capitalist would have funded that kind of work, Reisner maintains, because the exact degree to which the nanocoating would enhance material properties was not foreseeable. "We did not have a good concept of what a viable product would be; we were opening up virgin territory."

CERAMIC NANOCOATINGS are not the kind of products that give a huge return on investment quickly, Reisner points out, although they could ultimately become a \$100 million business. Other products based on this technology are thermal-barrier coatings for hot sections of jet engines and land-based turbines. Future applications include medical prostheses such as hip and knee joints. "That is a huge marketplace, and we have got a huge company that is very aggressively pursuing us for exclusive licensing," Reisner claims.

Government R&D helped to generate revenues at Inframat and also created a technology platform that can serve, in Reisner's words, "as a



POWERED UP
QuantumSphere makes metallic nanopowders for the military and, potentially, for energy storage. The reactor is on the right; the collector, on the left.

COURTESY OF Rick Claus/NanoSonic

springboard by which a multitude of products can emerge." The company is now pursuing different strategies for its technologies-its own manufacturing projects as well as licensing opportunities. It recently formed a subsidiary, Inframat Advanced Materials, for the commercialization and sales of its materials.

The military has an interest in funding dual-use technology. As Reisner explains, the practice gives companies incentive to develop military technology that later can be deployed in the commercial marketplace. "Then the economics will be favorable, because the military can buy from the company at commercial prices," he says.

Nanosys' IPO cancellation, Reisner believes, has done materials companies in the nanotech sector a favor. "We have been teasing all these investors for the last couple of years that nanotech is the next big thing, and I think it is. But they have pent up demand to make investments." Such investors, he believes, will now be looking for companies with sound fundamentals.

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