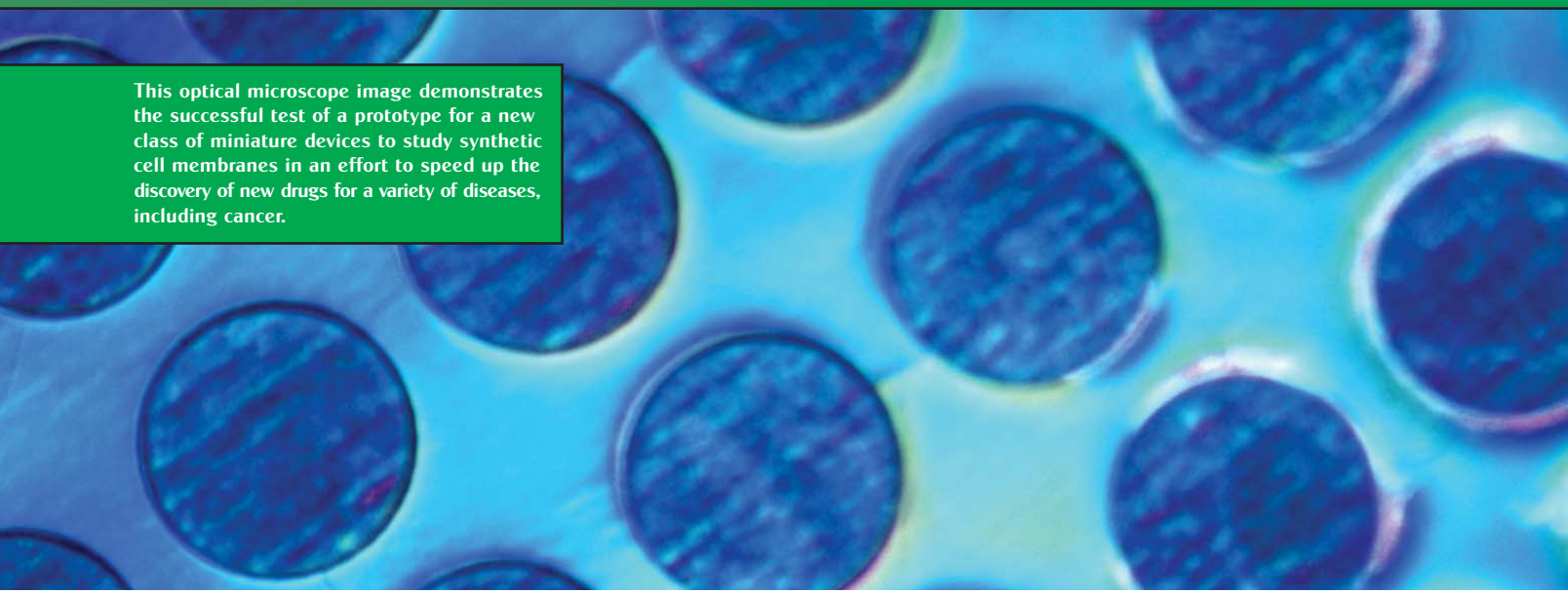

This optical microscope image demonstrates the successful test of a prototype for a new class of miniature devices to study synthetic cell membranes in an effort to speed up the discovery of new drugs for a variety of diseases, including cancer.

Small Scale; Huge Impact

Nanotechnology is Here Today and Tomorrow

By Tom Schuman

Look up the term "micro" in the dictionary and the various definitions include the following words or phrases: very small, minute, microscopic, infinitesimal.

In other words, micro (and the more than 130 dictionary entries that begin with the prefix) means little. But if that is the case, how does one describe nano – and the emerging field of nanotechnology, expected to, in one researcher's words, "affect almost every area of society."

- A nanometer is one-billionth of a meter. One inch equals 25 million nanometers
- While microelectronics might be classified as working with miniaturized electronic circuits and components, nanoelectronics is 1,000 times smaller
- Or, imagine a chain of aspirin lying side-by-side between New York and Los Angeles. The ratio of a nanometer to a meter equals the size of one aspirin in that approximate 3,000-mile long chain

Purdue's George Adams uses chalk and a shell to begin to explain the intricacies of nanotechnology and its impact.

The field of nanotechnology is defined as research in the scale of one to 100 nanometers. According to the National Nanotechnology Initiative (NNI), a nanometer-sized particle can only be seen with the most powerful microscopes available.

So, it's smaller than small. But the anticipated impact is so large that experts struggle to describe the long-range outlook.

George Adams, research development manager for the Birck Nanotechnology Center at Purdue University, says the evolution of electronics dates back to 1947. Nearly 60 years later, electronic systems continue to change rapidly.

"Our understanding of nanotechnology is growing. With the probe microscope, now that we can see (at the nano scale), we can understand what goes on," he notes. "But we'll be studying this for at least the next 50 years or the whole century, I imagine. We'll still be making dramatic improvements. With something this powerful, it takes awhile."

Present and future

As consumers, we don't realize it but nanotechnology is already having an impact on products we use. NNI lists the following as some of the current uses already in the marketplace:

- Burn and wound dressings
- Dental bonding agents
- Bumpers and catalytic converters on cars
- Sunscreens and cosmetics
- Longer-lasting tennis balls and lightweight, stronger tennis racquets
- Protective and glare-reducing coatings for eyeglasses and cars
- Stain-free clothing and mattresses

Wilson is making the double core tennis balls that hold their bounce longer by reducing the gas leaks through the rubbery walls. Nanoparticles of clay are utilized with the rubber to extend the life span of the product.

If tennis balls and cosmetics, in your opinion, don't justify the nanotechnology hype, listen to Ron Cosby, a faculty member in the department of physics and astronomy at Ball State and a nanotechnology researcher.

Students interact with a LEGO nanotechnology exhibit at the Children's Museum of Oak Ridge in Oak Ridge, Tennessee. The exhibit was constructed by a team of Purdue students and faculty.

"There's a nanotech revolution going on. Transportation, energy, communication, defense, medicine. It's almost you name it, and it will be affected," he declares. "It's developing technology from the bottom up. If you can control development at the molecular level, the possibilities are really mind boggling."

Cosby believes medical advances may receive the most attention over the next five years. He cites Indiana University research and the potential to destroy cancer cells directly by attaching or inserting drug treatments on living cells inside the body.

Defense implications involve direct assistance for soldiers on the battlefield. The possibilities include camouflage that would change patterns automatically or sensors that detect the condition of the individual solider and relay that information back to the base.

"Communications and electronics have already been significantly impacted, but there will be much more in the future," Cosby adds. "If you think computer technology is outstanding now, you haven't seen anything yet."

Purdue's Adams lists manufacturing, pharmaceuticals and agriculture as prime beneficiaries. "There will be new materials, new techniques in manufacturing that will lead to a competitive advantage. I expect major advances in sensor technology in the next couple of years."

In describing specific examples, Adams referred to the BioVitesse microchip (also referenced by Purdue's John Sullivan on Page 10 as an example of advanced manufacturing) and its nanoscale abilities to quickly detect food poisoning. Two disciplines working together on one solution. In a nutshell, that's the reason for the development of Purdue's Discovery Park.

Ron Cosby, Ball State University, is seeing a more entrepreneurial approach to research efforts.

Center of attention

The Birck Nanotechnology Center was scheduled to open in Discovery Park in August, with official dedication ceremonies planned for October. The $58 million facility will include nearly 130 faculty who represent more than two dozen schools across the campus, according to Adams.

"This brings together labs and equipment that couldn't be justified for a single investigator and set of students," he notes. "The world-class labs go beyond what we can do in labs across campus. We intend to be among the world leaders (in nanotechnology). This facility is helping us recruit the best faculty and students already, even before the doors opened."

Vibration and temperature control in the laboratories will be unmatched. Adams says the filtered air in the cleanrooms will be up to 10,000 times cleaner than the air in his campus office. Such precise levels of care are necessary to most accurately and effectively work with nanomaterials.

Adams cites a unique combination of a semiconductor cleanroom next to a pharmaceutical cleanroom. A partition will allow for separation, but also permit people from both areas to work on projects simultaneously.

Lab space will be dedicated for both instructional (training of undergraduate and graduate students in state-of-the-art nanotechnology) and incubator use. Company scientists can work side-by-side with university researchers on projects, potentially determining how a promising laboratory idea might work when scaled up to business production levels.

Delphi Electronics in Kokomo and Eli Lilly in Indianapolis were partners in helping design the cleanrooms, Adams reports. Industry involvement is critical moving forward, as is ongoing collaboration with other universities.

The NASA Institute for Nanoelectronics and Computing has, for the past three years, paired Purdue researchers with colleagues at Northwestern, Cornell, Yale, Florida, Texas A&M and California-San Diego. It is one of several collaborative efforts for the university.

"Each school brings in areas of expertise," Adams points

Nanotechnology Q&A

(Information from the National Nanotechnology Initiative)

How much money is the U.S. government spending on nanotechnology?
In the United States, the federal investment in nanotechnology R&D has increased from $116 million in fiscal year 1997 to a budget request of $1.05 billion in fiscal year 2006. The five federal agencies investing the most in nanotechnology are the National Science Foundation, Department of Defense, Department of Energy, National Institutes of Health and National Institute for Standards and Technology. Private industry is investing at least as much as the government, according to estimates.

How does this spending compare to other countries?
The United States is not the only country to recognize the tremendous economic potential of nanotechnology. While difficult to measure accurately, some have estimated that worldwide government funding has increased to about five times what it was in 1997. Asian countries, including Japan, China and Korea, as well as several European countries, have made leadership in nanotechnology national priorities.

Why fund nanotechnology?
Nanotechnology has the potential to profoundly change our economy and to improve our standard of living, in a manner not unlike the impact made by advances over the past two decades in information technology. While commercial products are starting to come to market, some of the major applications for nanotechnology are five to 10 years out. Private investors look for shorter-term returns on investment, more in the range of one to three years. Consequently, government support for basic research and development in its early stages is required in order to realize nanotechnology's full potential and to maintain a competitive position in the worldwide nanotechnology marketplace.

What products will be available in the next few years?
Watch for solar cells in roofing tiles and siding that provide electricity for homes and facilities. Prototype tires exist today that provide improved skid resistance, reduced abrasion and resulting longer wear, although a date for market introduction has yet to be announced. The nanocomposites being used in tires can be used in other consumer products as well, according to experts, including high performance footwear, exercise equipment and car parts such as belts, wiper blades and seals.

Next 10-20 years?
It's hard to predict what products will move from the laboratory to the marketplace over such a long period, but today's predictions center on pervasive computing applications. It is believed that nanotechnology will facilitate the production of ever-smaller computers that store vastly greater amounts of information and process data much more quickly than those available today.

How many researchers are working in nanotechnology today?
The current estimate is about 20,000 worldwide.

What are future workforce needs?
The National Science Foundation has estimated that two million workers will be needed to support nanotechnology industries worldwide within 15 years.

out. "Indiana and its neighbors in the Midwest are well positioned for commercial success in nanotechnology. Phillip Bond, undersecretary for technology (with the U.S. Department of Commerce) said the Midwest stands to benefit the most."

Research and instruction

Ball State is the lead institution in the Network for Computational Nanoscience, which also includes Purdue, Notre Dame, Valparaiso and Ohio. Cosby and colleagues have been involved in nanotechnology research for more than a decade.

Cosby says Ball State's efforts focus on quantum dot technology, including the optical and electrical properties of the very tiny structures. "We do a lot of modeling and simulation to try and understand those structures and particles."

While acknowledging Purdue's role as the lead research university, he says Ball State is a "player in the game," particularly in the instructional area. Cosby introduced course work for students several years ago, and the university incorporated a minor in physics with a nanoscience option. There are students at the master's level and doctoral candidates in education.

"I've worked with teachers in National Science Foundation-funded research, and we've had high school physics teachers who have received their master's here," he adds. "Part of their project was developing instructional materials for introductory nanoscience classes. It's impacted the whole instructional program. Every course I teach has the basics of nanotechnology."

An entrepreneurial approach is also gaining momentum at both universities. Ball State has been working with the Muncie Innovation Connector, a community incubator.

"That's somewhat of a change for us. We were previously focused on the science of the work," Cosby admits. "But we have a goal of making our department (students and faculty) more aware of the opportunities for business development, establishing a culture of entrepreneurism. We want to transfer our results into businesses."

The same holds true at Purdue, Adams contends, with the School of Entrepreneurship engaged in the process. Researchers don't always recognize the possibilities, he says, giving the example of 3M researchers trying to develop a stronger adhesive. What they ended up with was something that stuck to objects, but could easily be lifted off. It did not meet their needs, but emerging from the effort several years later was Post-it Notes.

It's here!

Nanotechnology was among the topics at a recent Michigan Growth Capital Symposium. The consensus was that nanotechnology is here to stay, although the lengthy time frames for development are an obstacle to potential investors.

While funding is welcome, one venture capitalist said, "An investor who writes a check just because a company has 'nano' in its name … scares me." The consensus among 13 Michigan companies is that it takes about six years to roll out a product.

Adams has been at Purdue since 1987 and working on development of the Birck Nanotechnology Center for more than five years. Pointing out that nanotechnology is not really new (IBM physicists developed a semiconductor "nanoage" tool in the early 1980s), he cites a favorite quote from William Gibson: "The future is here today; it's just unevenly distributed."

As an example, Adams says he had the opportunity to send e-mail and use the Internet while in graduate school in the early 1980s – long before widespread acceptance and usage. Similarly, nanotechnology is quietly here today, but with a much brighter, promising future in the years ahead.

The Birck Nanotechnology Center will be a world-class research facility at Purdue University. *(Mark Simons, Purdue Marketing Communications).*

INFORMATION LINK

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Ron Cosby, Ball State University, at (765) 285-8864 or www.bsu.edu/ccn/