BY **BETTY BUGUSU**

Improving Food Through NANOSCIENCE

IFT's third International Food Nanoscience conference explored advances in nanoscale science, engineering, and technology of food ingredients, food safety, and food packaging.

The bioavailability of food ingredients, the safety of the food supply, and the barrier properties of food packaging may be greatly enhanced through nanoscience and nanotechnology, according to several presenters at the third annual IFT International Food Nanoscience conference. Held June 27-28, 2008, in New Orleans in conjunction with the Annual Meeting & Food Expo®, the event was organized by the IFT Nanoscience Advisory Panel and sponsored by USDA-CSREES, The Royal Dutch Embassy, and the Advanced Foods & Materials Network (AFMNet) of Canada. It attracted more than 150 food professionals from around the globe.

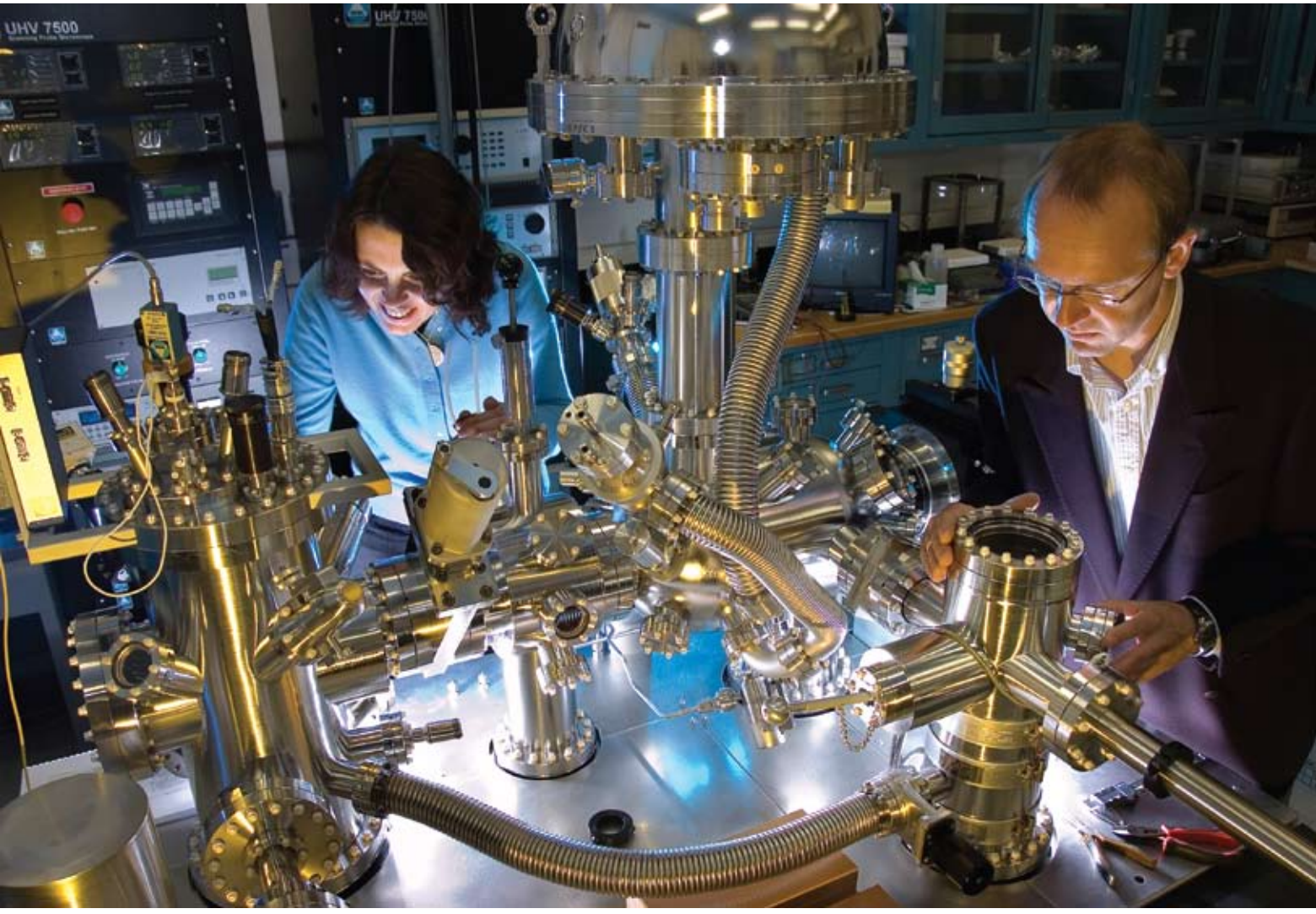
The theme of the conference—Advances in Nanoscale Science and Technology of Food—provided the state of the various applications of nanoscale science and technology in food. The technical presentations featured research data and examples of commercial innovations in three key areas of applications: food ingredient technologies, food safety and defense, and food packaging. Current data on potential implications associated with the use of nanoscience in the food industry, from regulatory issues to ethical and societal concerns, were also explored.

In his opening remarks, John Floros, 07–08 President of IFT, echoed the potential for food nanoscale science and technology to impact every part of the food supply chain—from raw material selection to processing and product development to marketing and distribution. He hailed IFT's continued efforts to provide a forum for scientists from around the world to discuss the latest developments in nanoscience and its applicability to food and agriculture.

Altaf Carim, Program Manager of the Nanoscale Science and Electron Scattering Centers, U.S. Dept. of Energy (DOE), delivered the keynote address on "Prospects and Tools for Nanoscience: Applications, Characterization, and User Facilities." He discussed opportunities and challenges of applying nanotechnology in various industries, especially in the agrifood industry, as well as resources available to explore them.

The opportunities include innovations in food applications such as improved flavor, texture, and bioavailability of food additives and supplements; sensors for detection of contaminants (microbiological and chemical); and controlled release of fertilizer and nutrients. The major challenges are broadly related to limited financial and human capital, inadequate manufacturability standards (definitions, characterizations, mthodologies, etc.), and limitations in available information on environmental health and safety concerns.

Carim also highlighted the available financial and informational resources through the U.S. federal government, particularly the National Nanotechnology Initiative. Physical resources, especially user facilities that are available to researchers, were outlined. The facilities are spread throughout the United States and are available for free for work that would directly



Researchers conduct *nanotechnology experiments on freezing tiny droplets of metal at Brookhaven National Laboratory. The lab is one of five U.S. Dept. of Energy user facilities charged with providing support to nanoscience researchers in academia, government, and industry.*
Photo courtesy of Brookhaven National Laboratory

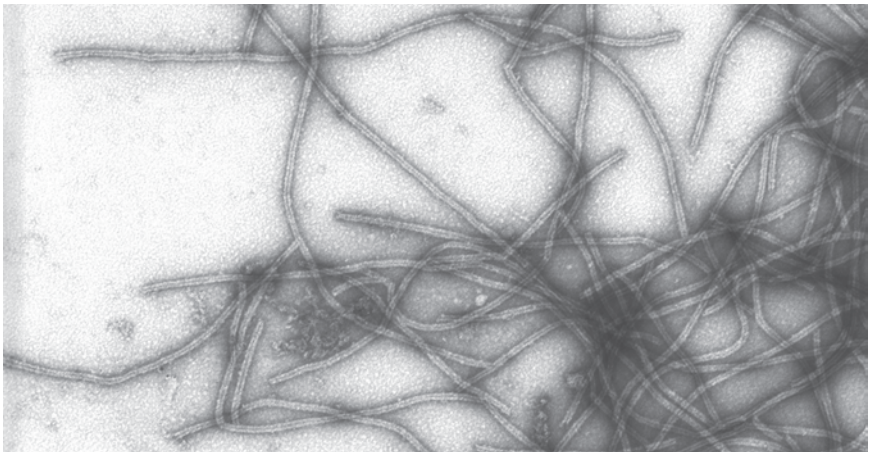
benefit the public and for full cost recovery for proprietary work. Facility access, especially the five DOE user facilities, is determined through a peer-review process.

Food Ingredients

Dérick Rousseau, Associate Professor, Dept. of Chemistry and Biology, Ryerson Univ., Toronto, Canada, discussed "Nanoscale Methods for Controlled Release of Bioactive Compounds." His talk focused on the development of various food-grade nano (and micro) vehicles for controlled release of bioactive compounds, such as omega-3 fatty acids, antioxidants, and phytosterols. These vehicles include emulsions (micro, pickering, and multiple), phase-separated hydrogels, solid-lipid nanoparticles, and thin films. Development of these vehicles follows the lead by the pharmaceutical industry for drug delivery. Some of the potential problems with these delivery systems include low loading capacity and efficiency, poor size distribution, possible toxicity, immunogenecity, and potential instability during circulation in the body.

Robert Nicolosi, Director of NanoMedicine, Center for Health & Disease Research, Univ. of Massachusetts–Lowell, explored "Application of Nanoemulsion Technology for the Delivery of Nutraceuticals, Pharmaceuticals, and Cosmeceuticals." His presentation examined industries that are more advanced in applying nanoscience to their products as a means for the food industry to learn from their experiences and challenges.

Nicolosi discussed two technologies for making nanoemulsions: high-shear force and self-assembly (by heat). High-shear force technology can be used to encapsulate several compounds, including drugs to treat breast cancer and melanoma and nutraceuticals such as plant sterol sitostanol, antioxidants tocopherol and lycopene, and omega-3 fatty acids. Though relatively new, the self-assembly technology has been applied to omega-3 fatty acids and nutraceuticals such



Enzyme-modified α-lactalbumin *forms protein nanotubes, which may provide viscosity enhancement, encapsulation, and controlled release of nutrients.*
Photo courtesy of Kees de Kruif/NIZO Food Research/University of Utrecht

The Science of Small

IFT's third International Food Nanoscience conference kicked off on Friday evening with a welcome reception, which featured opening remarks from Colien Hefferan, Administrator of the Cooperative State Research, Education, and Extension Service of the U.S. Dept. of Agriculture (USDA-CSREES), and Frans Kampers, Director of the Bionanotechnology Centre for Food and Health Innovation, Univ. of Wageningen, The Netherlands. Both speakers addressed the potential for nanoscale science, engineering, and technology to contribute to solving the challenges facing the agrifood industry, such as producing more high-quality food in a sustainable way and providing consumers with more healthful foods. The reception also highlighted a video titled "The Science of Small," produced by USDA-CSREES. It showcased four research stories of nanotechnology applications in food and agriculture, including "super cloth," a fabric that can detect biohazards, such as *E. coli* and other pathogens, created by Cornell Univ. scientists; a nanoscale biosensor that can detect diseases on farms and in hospitals; "new skin," created from corn protein by scientists at Univ. of Illinois; and nanoscale tracers that can uncover the sources of pollution in farm fields and waters. For more details, visit http://www.csrees.usda.gov/newsroom/news/2008news/05011_partners_nano.html.

as curcumin and quercetin. These nanoemulsions have been shown to increase bioavailability and efficacy of the various compounds through *in vitro* cell culture and animal models.

Kees de Kruif, Research Strategist, NIZO Food Research, The Netherlands, and Professor at the University of Utrecht, examined "Milk Nanotubes and Self-Assembled Structures in Food Applications." He described new nanoscale processes for self-assembly of various proteins, which can be used to structure and stabilize food systems. The self-assembled structures include α-lactalbumin nanotubes, caseins micelles, and β-lactoglobulin fibrils. Self-assembly of milk proteins is common in nature through weak interactions that lead to protein folding or formation micelles or crystals. The new structures provide novel functionalities in food and pharmaceutical applications, such as viscosity enhancement, encapsulation, and controlled release of nutrients or drugs.

Food Safety

Food safety application technologies range from nanosensors to diagnostic devices and traceability technologies. Nanosensor technology is one of the most rapidly growing areas of application and has great prospects for commercialization. Margaret Frey, Assistant Professor, Cornell Univ. detailed the basic principles behind "super cloth," a biohazard detection system that was featured in the USDA-CSREES video at the Friday evening welcome reception. Super cloth is a high-surface area and high-absorbency non-woven fabric made from very fine fibers incorporated with bio-recognition agents such as DNA strands, RNA strands, or antibodies. The detection systems are based on biotin-protein binding. Polylactic acid and streptavidin are used as the fiber and protein, respectively. The bio-recognition agents provide high specificity for detecting target biohazards while the synergy between the large surface area and a lipsome-based signal amplification system results in high sensitivity and selectivity.

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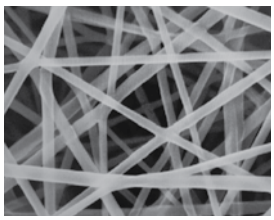
Stephen Nightingale of Burntside Partners outlined the potential for nanotechnology to intervene in food chain vulnerabilities—such as bioterrorism, theft, counterfeiting, etc.—through development of diagnostic devices and traceability technologies. He discussed recent advances in diagnostics, such as nanoplasmonic molecular ruler

for measuring nuclease activity, DNA footprinting developed from quantum dots, and a ganglioside-liposome assay for detection of cholera toxin in seafood. He pointed out that application to traceability is still problematic because nanotechnologies lack in key areas needed for an effective tracer. According to Nightingale, an effective tracer should have large vocabulary; no effect on the function of the marked product; service life equal to but not greater or lesser than the marked product; readily machine-readable; and be inexpensive. Overall, the uncertain regulatory climate magnifies the risks faced by early developers or adopters.

Food Packaging

Ted Slaghek, Program Manager, TNO Quality of Life, described two innovative approaches developed at his organization—inorganic nanoparticle delivery systems and materials and *BioSwitch*, a release-on-demand delivery system. Both innovations are currently being fine-tuned for various food applications such as packaging and ingredient technology systems. The inorganic particles have surface characteristics that allow loading of active ingredients. There are 2 types: clays (sheet-like materials that are made of a layer of mixed metal oxide sandwiched between two layers of silicon oxide) and layered double hydroxide systems (similar to clays but without the silicon oxide layers). The modified clays are used in polymer-clay nanocomposite materials and coating matrix for surfaces through spraying dipping or flowing. *BioSwitch* is a cross-linked three dimensional structure made from natural polymers such as starch, cellulose, or proteins. Cross-linking results in formation of small cavities of nanometer dimensions that could carry active ingredients. The ingredients are released by a specific activity (e.g., release of metabolites) or change in the environment (e.g., pH), which triggers the breakdown of the polymer.

Tie Lan, General Manager, Nanocor, discussed nanocomposite materials and their application in food packaging. Nanocomposites are made from plastic polymers and clay through in-situ polymerization or melt-compounding processes. The most significant benefit of nanocomposites is enhanced barrier properties. Other beneficial properties are mechanical reinforcement, chemical and thermal stability, flame retardation, and ease of processing. Lan discussed several commercial examples, including *Nano-PA6* made by in-situ polymerization and used in flexible packaging (cast and blown film), extrusion coating of paperboards, and stand-up pouches. Nano-nylon MXD6, commercially known as *Imperm 103* and *105*, is made by an extrusion process and used in multilayer bottles and films. Both materials have FDA approval for use as direct food contact materials; additionally *Nano-PA6* has European Union approval.



Margaret Frey, *Assistant Professor, Cornell Univ. inspects "super cloth," a fabric that can detect biohazards such as E. coli and other pathogens. (Left) Microscopic close-up of the biodegradable absorbent cloth containing nanofibers.*
Photos courtesy of Patrick Holian, CSREES-USDA

Ethical and Societal Issues

A session on "Ethical and Societal Considerations" explored potential implications associated with the application of nanoscale science and technology in food, with issues ranging from nanomaterials characterization methodologies to regulatory issues, risk assessment, and consumer acceptance. Scott McNeil of the Nanotechnology Characterization Laboratory (NCL) of the National Cancer Institute (NCI) described the preclinical efficacy and toxicity testing of nanoparticles intended for cancer therapeutics and diagnostics. The testing includes physicochemical characterization, *in vitro,* and *in vivo* cascades. Characterization of the nanomaterials is important for the assessment of batch-to-batch variability, development of standards, and determination of properties that greatly affect toxicity. Some of the developed methodologies could be applied to nanomaterials intended for food uses. This is especially true for methodologies applied to orally ingested therapeutics, which is similar exposure as food.

Lori Sheremeta, Research Officer, National Institute for Nanotechnology, Alberta Ingenuity Fund, Canada, addressed the issue of managing public trust. She recognized the increasing novel applications of nanotechnology in food. She also discussed current concerns, including the increasing body of scientific evidence suggesting that the behavior of nanoparticles in biological systems may not be presumed from knowledge of the behavior of their micro or macroscale counterparts and the uncertainty in the regulatory environment. Sheremeta emphasized the importance of appropriately addressing the concerns of the relevant public groups and reflecting the concerns into law,

regulation, and policy. She cited public action groups that are actively raising questions about the potential impact of nanomaterials on human health and safety and the environment. She made reference to recent focus group discussions in Canada, which suggest that there is a window of opportunity for governments to "get nanotechnology right."

Lynn Frewer, Professor of Food Safety and Consumer Behavior, Univ. of Wageningen, The Netherlands, focused her talk on consumer perspectives of food and nanotechnology. She concurred with previous speakers on the potential for nanoscale science and technology to revolutionize the food industry. However, she reiterated that successful implementation and commercialization is contingent on societal acceptance of the technology, as well as consumer responses to specific applications.

Frewer emphasized the importance of understanding how society conceptualizes risks, benefits, and ethical issues associated with a new technology. She also emphasized the importance of having realistic alternatives to create a situation in which better informed and more rational choices could be made about development and commercialization priorities as well as developing stakeholder and consumer trust in risk assessment and management practices. Both Frewer and Sheremeta emphasized the need for experts, industry, and the public to work together in advancing nanoscale science and technology in food.

In his closing remarks, Rickey Yada with Advanced Foods & Materials Network (AFMNet) of Canada thanked the speakers and the participants for a successful conference. He quoted from the book *The End of Food* by Paul Roberts: "Clearly, what is needed is an aggressive coordinated effort by all players in the food system itself … to assess how and whether the current food economy can adapt to so many challenges on so many fronts, and if it can't, what alternatives might be feasible in a world that will be fundamentally more constrained than the one we acknowledge today." He affirmed to the participants that their attendance at the nanoscience conference represented a coordinated effort, and that nanoscale science and technology may just be the solution to the problems facing the food supply chain. **FT**

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