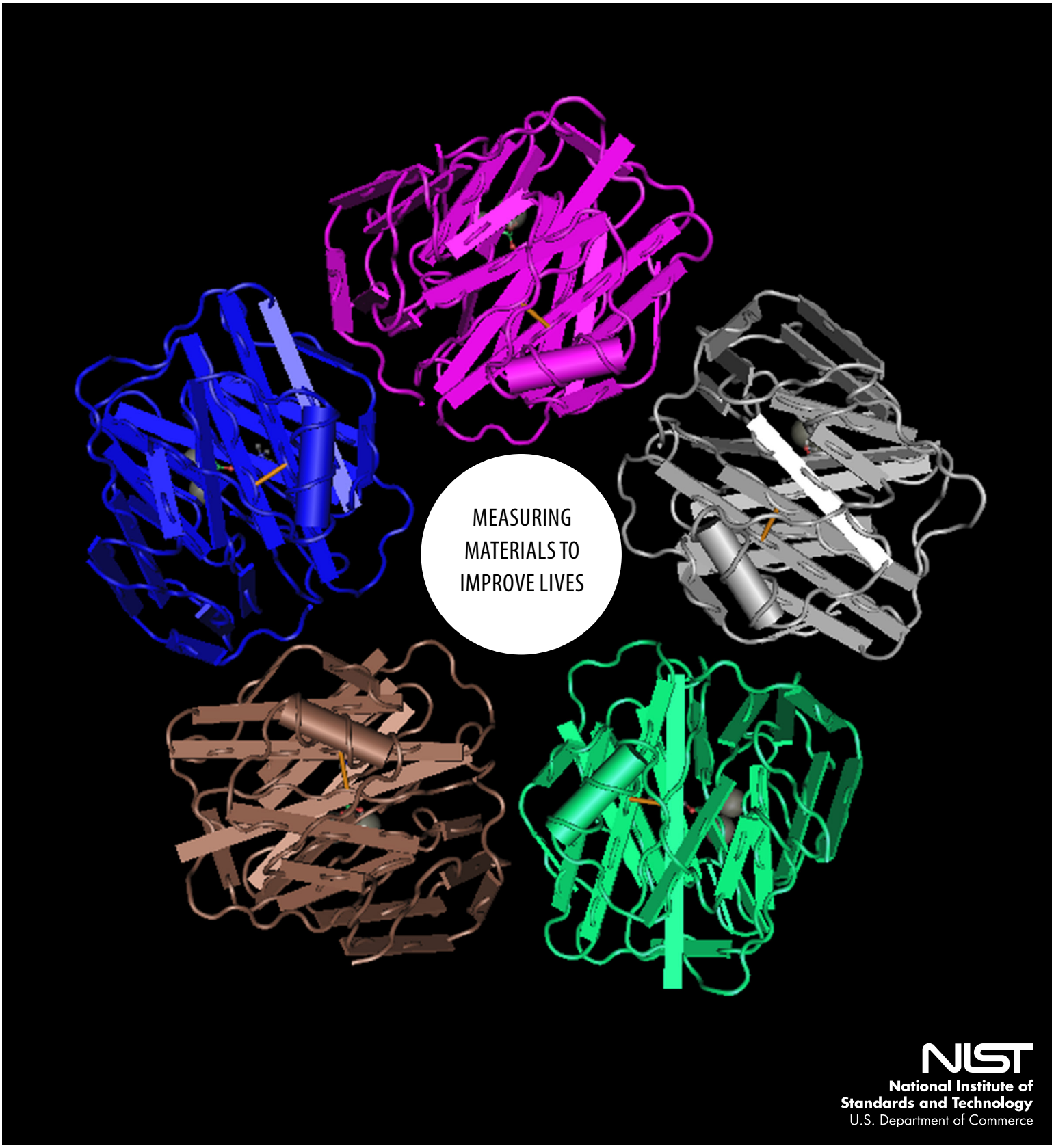
FALL 2017

MATERIAL MATTERS

The Quarterly Magazine of NIST's Material Measurement Laboratory



NIST
National Institute of
Standards and Technology
U.S. Department of Commerce

TABLE OF CONTENTS

Cover Image: Pentameric structure of C-reactive protein complexed with phosphocholine as determined by X-ray diffraction at a resolution of 2.5 Angstroms. Image was created using Cn3D software with Protein Database file 1B09.

CONTRIBUTORS

Editor | Torey Liepa

Contributors | Evelyn Brown | Alison Gillespie | Eric Kilpatrick | Laura Ost | Rich Press

Contact MML | mmlinfo@nist.gov

A MESSAGE FROM THE MML DIRECTOR

Michael Fasolka, Ph.D.
Director*
Material Measurement Laboratory
NIST

A key part of NIST's mission is advancing measurement standards and technology to improve the quality of our lives, and little is more central to the quality of our lives than our personal safety and security. Across MML's research portfolio in the biological, chemical, and materials sciences, from advanced materials development to chemical identification reference data and clinical diagnostic standards, our work helps industry ensure and enhance our personal safety.

MML scientists engage in a wide-range of security-related research, from developing and standardizing contraband screening technologies to developing materials that can protect better, and much more. This past summer MML updated its Mass Spectral Library, used by virtually every manufacturing sector to identify chemicals, and in the identification and detection of chemical weapons. MML researchers also recently demonstrated screening techniques to help prevent accidental exposure to synthetic opioids, including fentanyl, helping law enforcement address the opioid crisis.

In addition to our research focused on threats posed by contraband materials, MML research also helps keep us safe in our everyday lives. With cutting-edge instruments, methods and standards, we accurately determine the composition, structure and properties of materials, and explore how new materials might outperform those used in existing products. In this issue of *Material Matters* you can read about recent research that gives us a better understanding of the fibers used in modern body armor, as well as an effort to develop better materials for helmets and pads to protect against traumatic brain injury.

Other research highlighted in this issue demonstrates less direct, but no less important ways that MML research helps promote our welfare – exploring better treatments for diseases like Alzheimer's, a new test for evaluating antibiotics more quickly, improving a blood test used to evaluate the risk of heart disease, and more accurately determining the sources of carbon dioxide in the atmosphere.

Body, mind, heart – our research is leading to enhancements that promise to help protect us and improve our lives in innumerable ways. Across all of these sectors and disciplines, MML research shares a desire and drive to harness materials to improve human life, making us safer and more secure, so we can focus on the things that really matter.

* *During the search for a new MML director, Michael Fasolka, long-time MML deputy director, is acting director of MML.*

A NEW WAY TO TEST BODY ARMOR

Scientists at NIST have developed a new way to investigate the high-performance fibers used in modern body armor. Described in the *Journal of Polymer Science*, the research may help increase confidence in the apparel that protects military units, police departments, and public figures from gunfire. It may also lead to the development of new, lighter weight materials for body armor in the future.

First responders are among those whose lives depend on body armor—and the ballistics fibers inside of them. Credit: Shutterstock

High-performance polymer fibers have been used in ballistics applications for more than 40 years. Traditionally, these fibers are woven together into a fabric and then layered 15-20 times over to make a vest with a thickness of anywhere from about 6 to 13 millimeters (a quarter to half an inch). Although effective at stopping or slowing down bullets, users have sometimes found these vests, which are worn either under or over clothing, to be heavy and bulky—akin to wearing 15 to 20 shirts at once on a hot summer day. Many would like a more comfortable alternative.

The testing of soft body armor has been a big concern because the deployment of a new kind of fiber—believed to be superior to the previous material—unexpectedly failed in 2003, resulting in the death of a police officer. That and other incidents prompted a 2005 recall of some of the vests made with the new material.

Although the performance of these vests was superior when they were fresh out of the box and in pristine condition, tests later showed that the mechanical properties of the fibers inside the vests began to deteriorate after a few months of normal wear. The new vests were eventually removed from market entirely and the manufacturer was sued by the Department of Justice (DOJ).

The DOJ enlisted NIST to help evaluate the problem and determine why these vests were failing. As the nation's measurement lab, NIST researchers are especially qualified to develop ways to characterize both the fibers and their eventual deterioration.

"The fibers in these ballistic applications cannot fail [in the field], period," said Gale Holmes, a materials research engineer at NIST. "But previously, we had no way to know if they were changing over time as people were wearing and using them."

The ideal mechanical properties for these vests and other gear include a combination of high stiffness, large tensile strength, and a significant strain-to-failure in order to absorb the impact of the bullet. Initial work by Holmes revealed that the natural creasing and folding that a vest would normally encounter while in use led to a significant degradation of these critical mechanical properties, especially in humid environments.

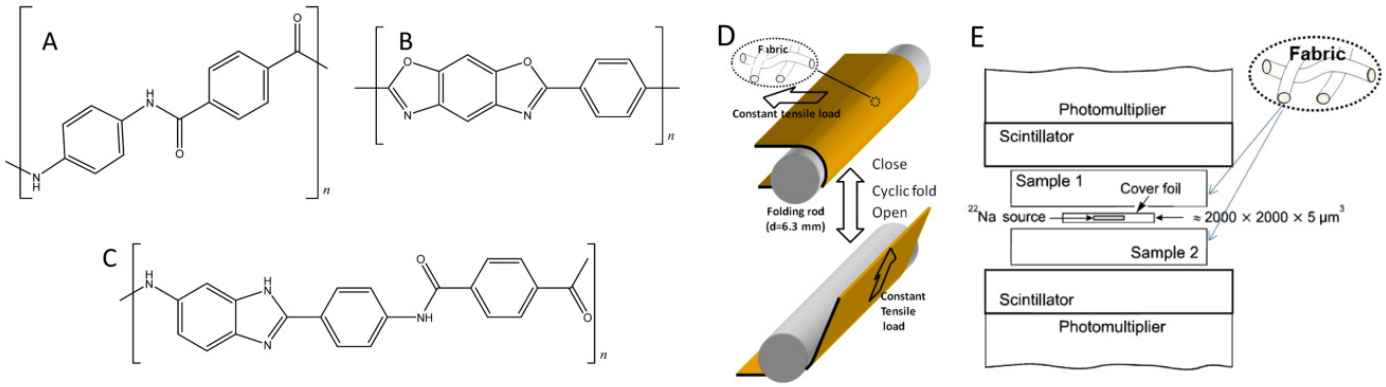
While the degradation in the mechanical properties was self-evident, what was missing was an analytical technique to characterize the structural or chemical differences in the fibers that would account for their loss in performance.

Although there is no material that could be completely "bulletproof" in every circumstance, researchers did want a way to characterize materials for their varying ability to mitigate a bullet's impact, especially after field use.

The characterization method selected by Holmes and Christopher Soles at NIST made use of an intense positron beam facility at North Carolina State University's PULSTAR Nuclear Reactor.

The positron annihilation lifetime spectroscopy (PALS) technique provides a molecular-level view of the structure of materials. It has been used for testing materials in other sectors, including porous membranes and semiconductor insulators. For this work, positrons were injected into ballistic fibers and enabled researchers to determine if any voids were created during folding on a scale of less than 5 nanometers.

Using PALS, Holmes and Soles discovered that void levels are very sensitive indicators of damage sustained by the fibers after folding; a larger population of voids means a better chance of fiber failure. The team previously suspected that void creation was a critical component of mechanical



Chemical structure of the (A) PPTA, (B) PBO, and (C) poly(p-phenylene benzimidazole terephthalamide-co-p-phenylene terephthalamide) (PBIA-co-PPTA) materials used in body armor. Schematic of the fabric folding method for aging ballistic fiber cloths (D) and schematic of positron annihilation lifetime spectroscopy (PALS) setup for measuring the materials. Credit: J.A. Howarter et al., Journal of Polymer Science

degradation, but the small angle X-ray scattering measurements that had been used in the past tended to be less sensitive to voids smaller than 5 nanometers and proved to be inconclusive. The critical damage was occurring on much finer length scales.

"It allowed us to characterize changes in the fibers that you cannot see with other techniques," Holmes said. "We were surprised during our research at how sensitive the technique was."

"Before, we didn't have a really good way to discriminate why some materials broke during folding tests and some didn't," said Soles. "This is the first materials characterization tool that gives insights into why some materials can be folded and still maintain their strength."

The results may act as a design cue for those wanting to develop new alternatives to the current body armor. It may also help fine-tune the amount of fibers currently prescribed for these products, making for more comfortable vests.

J.A. Howarter, M. Liu, W.G. McDonough, C. Soles and G.A. Holmes, Nanostructural Evidence of Mechanical Aging and Performance Loss in Ballistic Fibers, *Journal of Polymer Science*, Published online 28 September 2017, http://dx.doi.org/10.1002/polb.24417

MEASURING LIQUID BODY ARMOR

At the Annual Conference of the North American Thermal Analysis Society, from August 7 to 10, 2017 in Newark, Delaware, Ran Tao of MML's Security Technologies Group presented on her recent work of shear thickening fluids. Shear thickening fluids composed of silica nanoparticles and polyglycol (a liquid polymer) have been investigated as performance enhancement additives for soft body armor. Such material is ideal for damping and energy absorption applications because, at high rate, the fluid undergoes a fluid-like to solid-like transition and, in doing so, the impact energy is dissipated. Tao's research highlighted a method of visualizing the breakdown of fumed silica agglomerates during measurement. Using different data presentation and analysis methods of large amplitude oscillatory shear rheology, the stress instabilities, as an indication of agglomerates breakdown, can be readily obtained. The results indicate that those shear thickening fluids containing fractal fumed silica are not ideal candidates as liquid body armor due to the irreversible agglomerate breakdown under large deformation.

NIST, NFL, GE AND UNDER ARMOUR ANNOUNCE DYNAMIC RESEARCH AND 6D HELMETS AS GRAND PRIZE WINNER IN HEAD HEALTH CHALLENGE III

Two-company team to share $500,000 to invest in more research and further product development

NIST, the National Football League (NFL), GE, and Under Armour, recently selected a collaborative team of materials designers led by Dynamic Research Inc. as the grand prize winner of Head Health Challenge III.

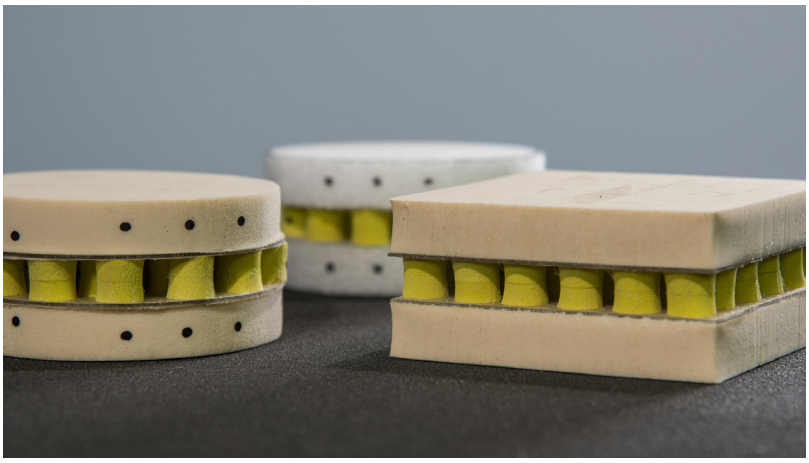
"I congratulate the winning team and the Head Health Challenge III partners for looking for technological solutions to this important national problem," said U.S. Secretary of Commerce Wilbur Ross. "The new materials developed through this competition will have broad applications, protecting everyone from students to athletes to soldiers."

The competition is the third in a series of challenges in the Head Health Initiative, a four-year, $60 million collaboration between GE and the NFL.

Head Health Challenge III was designed to spur the discovery, design, and development of advanced materials to better absorb or mitigate force within helmets, pads and other sports and consumer products that protect against traumatic brain injury.

The $500,000 grand prize winning team used advanced computer modeling and a series of iterative improvements to create a novel material with an unusual geometric structure. The winning entry is a multi-impact material for use in protective gear for athletes, first responders, military personnel and others who face potential impact injuries. The team is:

- Dynamic Research, of Torrance, California, which specializes in applied research, development and consulting in areas such as vehicle safety and biomechanics, including the study of impacts on the human body, and
- 6D Helmets, of Brea, California, developers of the Omni-Directional Suspension,™ a head-protection technology first commercialized for the action sports community for use in motorcycle and bicycle helmets.



Three samples of the winning material from Head Health Challenge III, a competition to spur the discovery, design and development of advanced materials that can absorb or dissipate physical impacts to the head or body. Credit: Webber & Stoughton/NIST

"The goal of this challenge is to support innovation and help stimulate the marketplace with next-generation materials and design, and the impressive work by Dynamic Research and 6D Helmets has the potential to do just that," said Jeff Miller, NFL Executive Vice President of Health and Safety Initiatives. "The NFL's collaboration with GE, Under Armour, and NIST highlights the important leadership role that various industries and organizations can take together to advance the state of equipment safety."

The third Head Health Challenge kicked off in early 2015 and attracted more than 125 diverse companies and academic institutions. NIST was brought on board as a partner to lend its measurement and standards expertise to develop a new methodology for impact testing of materials properties and for comparing the contest submissions.

The novel structure of the winning material is based on a 6D Helmet proprietary technology that includes a middle layer of absorbent posts sandwiched between foam that helps reduce shear forces— impacts that happen at an angle rather than straight on. The material reduced certain measures of impact by more than 70 percent when compared with baseline foam material that has been commonly used in protective gear. The winning concept is also a system that can be fine-tuned to a variety of impact environments and adapted to different body types and applications.

NIST selected an independent panel of expert judges who narrowed the list down to five finalists, each awarded $250,000— and a year of development time—to enhance their materials.

To support the finalist's development efforts, NIST established a dedicated testing facility to provide a common measure of the materials' performance. Each team submitted refined materials to NIST for

Continued on page 13

NEW NIST TOOL AIMS TO IMPROVE ACCURACY OF TEST TO DETERMINE CARDIOVASCULAR DISEASE RISK

Cardiovascular disease caused one out of three deaths in the United States in 2016, and for decades it has been the leading killer for both men and women. Hoping to reduce these numbers, researchers at NIST have developed a new Standard Reference Material (SRM) that can improve the results of a common blood test used to assess a person's risk of heart disease.

The blood test measures C-reactive protein (CRP), which is a marker for inflammation in the body. While the precise relationship between slightly elevated CRP levels and cardiovascular disease is still being determined, research suggests that inflammation in arteries can lead to plaque buildup, and then to heart attacks and strokes. Some studies indicate that high-sensitivity CRP (hsCRP) tests—which detect minute amounts of the protein in blood—may have advantages for predicting heart disease when cholesterol counts are normal.

The hsCRP test kits are made from antibodies that attach to CRP in a blood sample like a lock and key to provide an accurate count of the protein. However, depending on their source and quality, some of these antibodies attach better than others, leading to variable results between batches and kit makers.

"We began developing a reference material for the hsCRP test when we recognized that a patient's test results might depend on which test kit was used," said Eric Kilpatrick, a biologist who has specialized in protein measurement at NIST for more than a decade. "Repeatable, reliable results, no matter when or where the blood test is performed, are critical to health, and without them, it is difficult for doctors to use hsCRP to decide treatment options and to follow a patient's progress accurately," he said.

NIST's SRM 2924 C-Reactive Protein Solution provides a tool to improve the consistency of results for a test used to calculate the risk of cardiovascular disease. Credit: K. Irvine, M. Williamson/NIST

NIST's SRM 2924 C-Reactive Protein Solution provides a reference benchmark tool that manufacturers can use to ensure their kit test results are consistent from batch to batch by confirming that the antibodies going into the kits correctly bind CRP.

When the results of hsCRP tests can be traced to the NIST SRM, doctors can have greater trust in the test scores, and treat and advise their patients with confidence.

Researchers are continuing their quest for ultimate accuracy. "The gold standard for CRP will be an SRM in serum, the liquid component of blood," Kilpatrick said. That work will begin soon, and SRM 2924 is leading the way.

SRMs are among the most widely used NIST products. The institute prepares, analyzes and sells more than 1,200 carefully characterized materials used to check the accuracy of instruments and test procedures used in manufacturing, clinical chemistry, environmental monitoring, electronics, criminal forensics and dozens of other fields.

Read more about SRM 2924 on page 18.

HOW THE CONE SNAIL'S DEADLY VENOM CAN HELP US BUILD BETTER MEDICINES

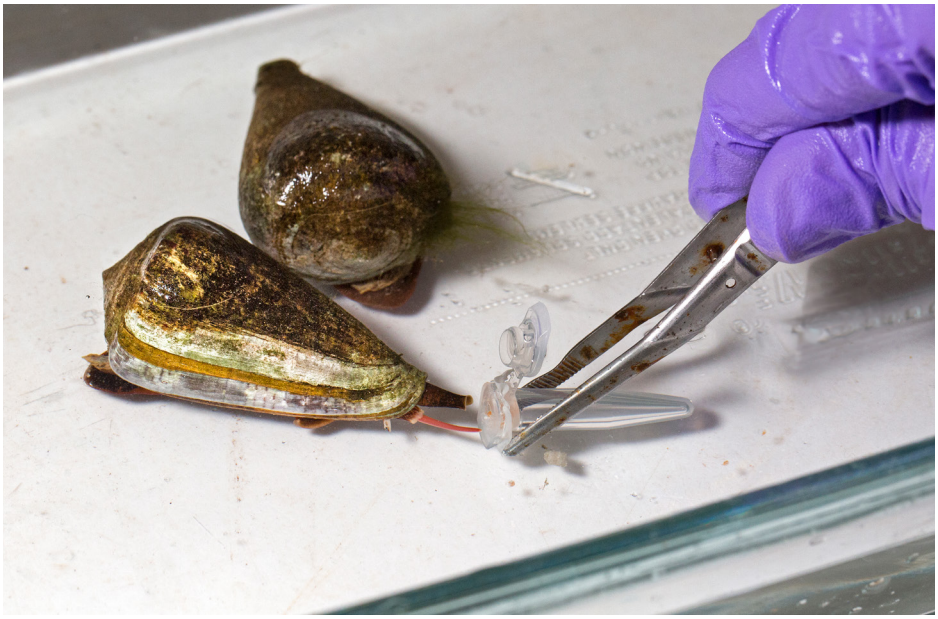
Cone snails have inspired humans for centuries. Coastal communities have often traded their beautiful shells like money and put them in jewelry. Many artists, including Rembrandt, have featured them in sketches and paintings. Now, scientists at NIST are finding these deadly predators inspiring, too, as they seek new ways to cure old medical problems using the poisonous snails as models.

"This is the same venom used to kill dinosaurs in 'Jurassic Park,'" says NIST biochemist Frank Marí, with a chuckle. "It is scary stuff, but that power could be used for a different kind of good in real life."

Like all NIST scientists, Marí measures things. Specifically, he measures RNA and the associated proteins at work inside marine animals. As technology has improved over the years, he and his team have become better able to examine, analyze and catalog the molecules at work in some of the ocean's lesser-known creatures, including cone snails. This year, his lab made several significant discoveries about their venom, discoveries that might ultimately lead to the development of new medicines for hard-to-treat diseases. By imitating the way that these small, quiet creatures deliver poison, scientists may be able to better deliver cures.

On any given day, Marí can be found walking up and down the rows of burbling aquarium tanks at the Hollings Marine Laboratory in Charleston, South Carolina, checking on the 60 individual cone snails that have lived in his lab for the past 15 years. Once a week, he and his staff make a kind of delicate negotiation with them, trading a dead fish for a dose of poison to be gathered in a tube and stored away for use in ongoing scientific measurements and investigations.

"Cone snails are so unusual," Marí says. "They are not really like any other creature on Earth, and working with them is almost like working with an extraterrestrial. But that's also fun. The cone snail system is like a candy store to someone like me."



In the wild, cone snails harpoon their prey as it swims by. In the lab, the cone snail has learned to exchange venom for dinner. Here, a snail extends its proboscis and discharges a shot of venom into a latex-topped tube. Credit: Alex Holt/NIST

More than 800 species of cone snails have been found worldwide, mostly in warmer, tropical areas. They are reclusive, faceless creatures and not aggressive, but will sting defensively when picked up by an unwitting shell collector. The smallest cone snails impart a sting that is about as powerful as a bee sting, but the sting of larger species can kill an adult human in a matter of hours. The deadliest cone snail is thought to be the "cigarette snail" of the Indo-Pacific, a snail roughly the length of a man's thumb that can deliver a toxin so strong that you'd only have time to finish one cigarette before dying from its attack.

Although his collection includes several species, Marí's special area of focus is the purple cone snail (Conus purpurascens). It's a creature mostly found in the Eastern Pacific coastal waters off the Gulf of California down to Peru and offshore around the Galapagos Islands, slowly moving along the rocky bottom where it grows to be a few inches long. Like all snails from the Conus genus, these nocturnal animals are common, but often go unseen by casual beachgoers.

Despite their own slow tendencies, these snails have evolved to skillfully hunt far speedier animals in the dark by firing a single harpoon-like tooth into other snails, fish and worms. Once injected, the prey becomes instantly paralyzed and unable to make a getaway. The snail then slowly pulls the immobilized meal inside its shell to be digested, whole. Each tooth is discarded after use and immediately replaced by another. Some cone snails travel with 20 or so of these teeth embedded in their systems, loaded and ready to be fired off when the next meal happens to swim along.

In its native state, cone snail venom would obviously not make a great treatment for human ailments. But by unpacking it bit by bit and measuring each component on the molecular level, Marí and his team aim to understand and

catalog how each aspect of this poison does its job.

"There's a lot we are just learning about them," Marí says.

Why, for instance, is cone snail venom able to penetrate another animal's nervous system so quickly? And how does it paralyze a victim so effectively? Even more puzzling, some individual purple cone snails are not toxic at all, which Marí thinks might be related to stages of development in the snails.

The answers to all of these cone snail questions could be used to create new medicines that move through a patient's body in a quicker and more efficient manner, such as new types of insulin for the treatment of diabetes or better treatments for neurological diseases like Alzheimer's. Some think venom research can provide new delivery systems for drugs that would aim to curtail quick-spreading forms of cancer. Others want to use the venom's ingredients for the treatment of addiction. One component of cone snail venom has even been used in anti-wrinkle creams now on the market that put the power of inflammation to work under the skin, puffing out creases and fine lines on human faces.

For a paper just published in *Scientific Reports*, Marí and his team used cone snail toxins as molecular probes to identify an important overlap between the immune and central nervous systems in humans. Their work demonstrated for the first time that a classic toxin—one usually associated with the central nervous system—can also have an impact in the immune system, whereby some cells are signaled in specific ways once certain kinds of cone snail peptides, known as conotoxins, enter the body. The new information may aid in the development of therapies for eradicating gastric, breast and lung cancers, as well as in the control of tuberculosis, since all of those illnesses trigger overproduction of some cells.

Rather than using the toxin as an actual cure, the work would provide a road map for better understanding (and maybe controlling) the growth of undesirable cells.

For another study published recently in the *Journal of Proteomics*, Marí and his team worked on the isolation and characterization of an enzyme in the cone snail venom called Conohyal-P1. They used an ultrahigh-resolution mass spectrometer, one of the most powerful tools available to identify and count proteins in a sample. A similar enzyme is found in both lionfish and bee venoms. Surprisingly, it is also found in many kinds of mammalian sperm, where it helps to weaken cell walls of ovaries and facilitate entry of the sperm and successful reproduction.

"We knew that this enzyme was able to break down extracellular tissue," says Marí, referring to the outermost membranes of cells. "We now have been able to carefully evaluate the activity of the enzyme for anyone to use in future work. In addition, we have identified a new subtype that had not been known before."

In a third paper, published recently in the journal *Neuropharmacology*, Marí and his team evaluated toxins in the cone snail venom by testing them on the central nervous systems of fruit flies. Although the fruit fly is very different from humans in many ways, its central nervous system can provide a great model for a wide variety of medical studies because the basic structure of cells in fruit fly brains is similar to the structure of cells in human brains. So, if a fruit fly brain cell reacts one way, scientists know a human cell will, too.

Marí's team specifically wanted to know how conotoxins interact with a variety of molecular targets in the nervous system of their prey. Purple cone snail venom contains a large number of these protein building blocks – more than 2,000 of them.

"The venom is incredibly complex," Marí says. "We wanted to answer the question: which parts could be used as medicine?"

In this case, they found that the flies' response to injections of cone snail venom primarily took place in the receptors that govern muscle movement and addiction. Such details could be useful in the development of new drugs for Parkinson's disease, which often ravages the muscular-skeletal system, impairing a patient's ability to control basic body movements. It might also help with the development of effective nicotine addiction treatments.

"The pattern on a cone snail shell is very beautiful," Marí says. "But I think the biology and biochemistry are even more beautiful, and as we explore all the different aspects of the venom, we can open all kinds of new opportunities for medical use. We are finally able to crack the code."

A. Padilla, P. Keating, J.X. Hartmann and F. Marí, Effects of α-conotoxin ImI on TNF-α, IL-8 and TGF-β expression by human macrophage-like cells derived from THP-1 pre-monocytic leukemic cells, *Scientific Reports*, Published online 6 October 2017, http://dx.doi.org/10.1038/s41598-017-11586-2

C. Möller, E. Clark, H. Safavi-Hemani, A. DeCaprio and F. Marí, Isolation and characterization of Conohyal-P1, a hyaluronidase from the injected venom of Conus purpurascens, *Journal of Proteomics*, Published online 5 July 2017, http://dx.doi.org/10.1016/j.jprot.2017.05.002

M. F. Hoggard, A. Rodriguez, H. Cano, E. Clark, Han-Shen, T. David, J. Adams, T.A. Godenschwegee and F. Marí, *In vivo* and *in vitro* testing of native α-conotoxins from the injected venom of *Conus purpurascens*, *Neuropharmacology*, Published online 14 September 2017, http://dx.doi.org/10.1016/j.neuropharm.2017.09.020

NEW METHOD FOR IDENTIFYING CARBON COMPOUNDS DERIVED FROM FOSSIL FUELS

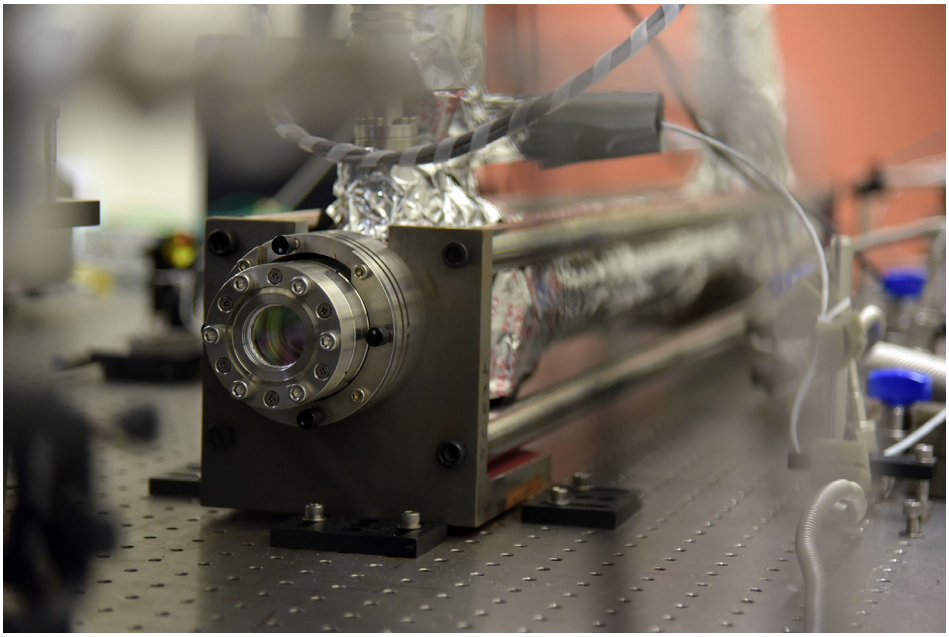
Technique may find many industrial applications and can be used to estimate greenhouse gas emissions.

Scientists at NIST have developed a laboratory instrument that can measure how much of the carbon in many carbon-containing materials was derived from fossil fuels. This will open the way for new methods in the biofuels and bioplastics industries, in scientific research, and environmental monitoring. Among other things, it will allow scientists to measure how much of the carbon dioxide (CO_2) in the atmosphere came from burning fossil fuels, and to estimate fossil fuel emissions in an area as small as a city or as large as a continent.

This is possible because carbon atoms occur in heavy and light forms, or isotopes, and measuring the relative amounts of each can reveal the source of the carbon. Using carbon isotopes in this way is not a new idea, but it requires extremely precise—and expensive—measurements. The new instrument, developed by NIST chemists Adam Fleisher and David Long and based on a technology called cavity ringdown spectroscopy (CRDS), promises to dramatically reduce the cost of those measurements. They described the instrument's performance in *The Journal of Physical Chemistry Letters*.

"Measuring carbon isotopes is an extremely useful technique, but until now, it has found limited use because of the cost," said Long. "Lowering the cost will open the way for new applications, especially ones that require testing a large number of samples."

The key to these measurements is carbon-14, a radioactive (yet harmless) isotope of carbon that is formed in the upper atmosphere. That carbon-14 finds its way into all living things. Unlike regular carbon, carbon-14 is unstable,



This photo of the NIST instrument that enables optical measurement of "heavy" carbon dioxide (14CO2) shows the instrument's ultra-stable optical cavity and cold sample cell. Credit: Rich Press/NIST

with a half-life of 5,730 years. When living things die, they stop incorporating carbon into their bodies, and their carbon-14 starts to decay away.

Scientists can calculate how long ago something died by measuring how much carbon-14 is in its remains. That technique is called carbon dating, and scientists use it to date things like Neanderthal bones and ancient plant fibers.

Fossil fuels also are the remains of living things, mainly plants that died hundreds of millions of years ago. Virtually all their carbon-14 decayed away eons ago, so anything derived from them is marked by the absence of measurable amounts of carbon-14.

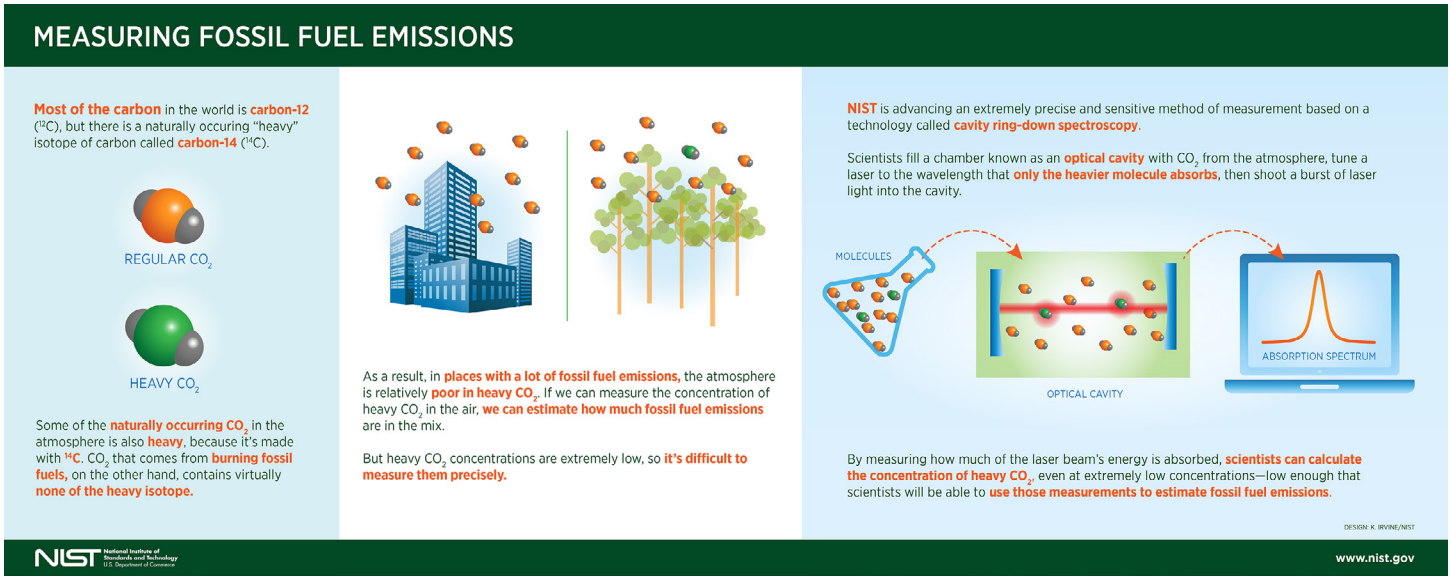
But carbon-14 is extremely rare, and to use it for identifying fossil fuels, scientists need to be able to measure it at concentrations as low as 1 part in 10 trillion. That's the equivalent of a single grain of sand in 60 dump trucks full of the stuff.

To measure concentrations that low, you need an extremely sensitive measurement technique, and such a technique already exists. Archaeologists have been relying on it for decades. But that technique requires a particle accelerator to separate the isotopes (the heavier carbon-14 accelerates more slowly than everyday carbon-12), along with a facility to house it and a team of PhDs to run it.

The CRDS instrument that Fleisher and Long have developed can sit on a laboratory benchtop and is relatively inexpensive to operate.

CRDS instruments analyze gases by detecting the wavelengths of light they absorb. For instance, CO_2that contains carbon-14—so-called heavy CO_2—absorbs a slightly different wavelength than regular CO_2.

To measure how much heavy CO_2 you have in a CO_2 sample, you first inject the sample into the instrument's measurement cavity (the "C" in CRDS), which is a tube with mirrors inside at either end. You then tune a laser to the exact wavelength that only



Credit: Kelly Irvine/NIST

heavy CO_2 absorbs and shoot a burst of it into the cavity. As the laser light bounces between the mirrors, some of its energy is absorbed by the gas. The greater the absorption, the greater the concentration of heavy CO_2.

To achieve the required sensitivity, Fleisher and Long enhanced existing CRDS technology by engineering a system that chills the cavity to a uniform minus 55 degrees Celsius and minimizes temperature fluctuations that would throw off the measurement. Making the cavity very cold allows their instrument to detect very faint signals of light absorption, the same way that you might be able to hear a pin drop if you made a room extremely quiet.

This and other improvements boosted the instrument's sensitivity enough for accurate carbon dating.

To test biofuels and bioplastics, you would first burn those materials, then collect the resulting CO_2 for analysis. This would allow you to test a fuel mixture to determine what fraction of it is biofuel. In the airline industry, for example, this would be useful because some countries require that aviation fuels include a specific biofuel percentage. Such tests could also be used to verify that bioplastics, which sell for a premium, do not contain petroleum-derived compounds.

To estimate fossil fuel emissions in a geographic area, you would collect many air samples across that area and analyze the atmospheric CO_2 in those samples. Areas with high fossil fuel emissions, such as cities and industrial zones, will have below-normal concentrations of heavy CO_2.

"Fossil fuel emissions dilute the concentration of heavy CO_2 in the air," said Fleisher. "If we can accurately measure that concentration after it's been diluted, we can calculate how much fossil fuel emissions are in the mix."

A report from the National Academy of Sciences estimated that 10,000 samples a year, collected at carefully chosen locations around the United States, would be enough to estimate national fossil fuel emissions to within 10 percent of the actual value. Such a system of measurements can increase the reliability of national emissions estimates. This would be especially useful in parts of the world where high-quality emissions data are not readily available.

"There is a need for this type of measurement in many industries," Fleisher said. "We've demonstrated a path to meeting that need in a cost-effective way."

A. Fleisher, D. Long, Q. Liu, L. Gameson and J. Hodges, Optical Measurement of Radiocarbon below Unity Fraction Modern by Linear Absorption Spectroscopy, *The Journal of Physical Chemistry Letters*, Published online 7 September 2017, http://dx.doi.org/10.1021/acs.jpclett.7b02105

NIST'S QUICK TEST MAY SPEED ANTIBIOTIC TREATMENT AND COMBAT DRUG RESISTANCE

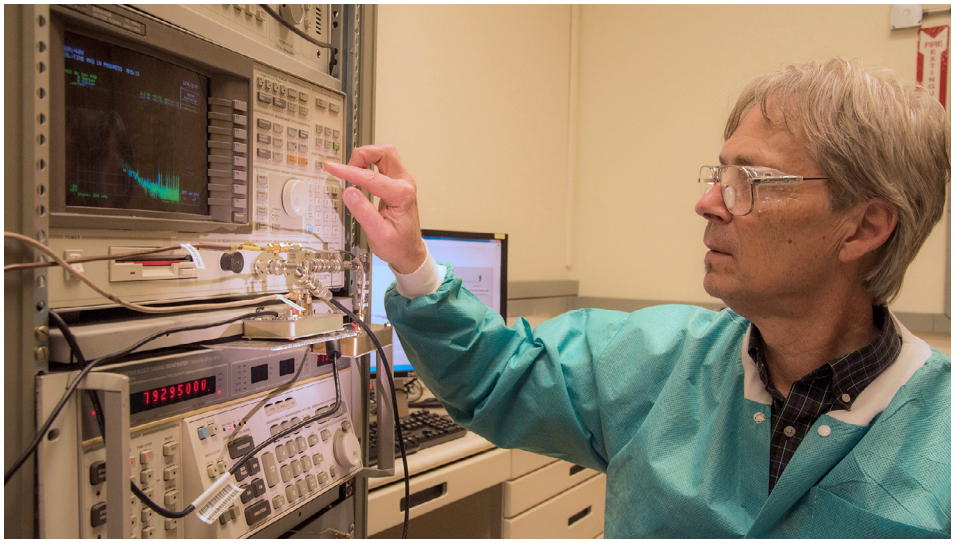
Researchers at NIST have demonstrated a potential new tactic for rapidly determining whether an antibiotic combats a given infection, thus hastening effective medical treatment and limiting the development of drug-resistant bacteria. Their method can quickly sense mechanical fluctuations of bacterial cells and any changes induced by an antibiotic.

Described in *Scientific Reports*, NIST's prototype sensor provides results in less than an hour, much faster than conventional antimicrobial tests, which typically require days to grow colonies of bacterial cells. Delayed results from conventional tests allow dangerous infections to progress before effective treatments can be found and provides a time window for bacteria to develop drug resistance.

Improperly prescribed antibiotics and antibiotic-resistant bacteria pose serious threats to public health. At least 2 million illnesses and 23,000 deaths are attributed to antibiotic-resistant bacterial infections in the United States each year, according to a 2013 report from the Centers for Disease Control and Prevention.

One solution may be the new NIST sensing approach, based on a quartz-crystal resonator whose vibrations vary in measurable ways when particles on the surface change. The method, which involves bacterial cells adhered to a resonator, represents a new way of using these supersensitive crystals, which NIST researchers previously demonstrated for applications such as measuring carbon nanotube purity.

The new NIST technique senses the mechanical motion of microbes and their response to antibiotics. Other researchers previously found that some bacterial motion becomes weaker in the presence of some antibiotics, but until now such changes have been detected only with microscale sensors and generally in motile bacteria (propelled by threadlike appendages called flagella). The NIST method may be more useful in clinical settings because it collects electronic data cost-effectively and, since it senses large bacterial colonies, can be macroscopic and robust.



NIST physicist Ward Johnson observes signals generated by bacteria coating quartz crystals, a novel method of sensing whether an antibiotic kills the bacteria. The new NIST technique senses mechanical fluctuations of bacterial cells and any changes induced by an antibiotic. With further development, the technique could hasten the identification of effective medical treatments in clinical settings and drug development. Credit: J. Burrus/NIST

The sensor is piezoelectric, which means its dimensions change when exposed to an electric field. A thin piezoelectric quartz disk is sandwiched between two electrodes. An alternating voltage at a stable frequency near the crystal's resonant frequency is applied to one electrode to excite crystal vibrations. From another electrode on the opposite side of the crystal, researchers record oscillating voltages of the crystal response, a signal that shows fluctuations in the resonant frequency (or frequency noise) arising from microbial mechanical activity coupled to the crystal surface.

Proof of concept tests at NIST used two quartz-crystal resonators coated with several million bacterial cells. One resonator was used to test the effect of an antibiotic on the cells, while the second resonator was used as a control without the antibiotic.

The ultra-sensitive approach enabled detection of cell-generated frequency fluctuations at a level of less than one part in 10 billion. The experiments showed that the amount of frequency noise was correlated with the density of living bacterial cells. When the bacteria were then exposed to antibiotics, frequency noise sharply decreased. Bacteria with paralyzed flagella were used in the experiments to eliminate effects of swimming motion. This enabled the researchers to conclude that the detected cell-generated frequency fluctuations arise from vibrations of cell walls.

NIST researchers sensed the response of Escherichia coli (E. coli) to two antibiotics, polymyxin B (PMB) and ampicillin. Cell-generated frequency noise dropped close to zero within seven minutes after the introduction of PMB. Frequency noise began decreasing within 15 minutes of adding ampicillin and then dropped more rapidly as cells broke apart and died. These time scales reflect the normal speeds at which these antibiotics work.

After the sensor measurements, the effectiveness of the antibiotics was confirmed by growth of colonies from the remaining bacteria. Both antibiotics greatly reduced the numbers of live cells.

To determine how broadly useful the technique might be, further studies will be needed using a number of bacterial species and antibiotics that work in different ways. NIST researchers have been granted a patent on the technique: RESONATOR AND PROCESS FOR PERFORMING BIOLOGICAL ASSAY, U. S. Patent No. 9,725,752, issued August 8, 2017. Ultimately, the NIST sensor may be suitable for rapid antimicrobial susceptibility testing (called AST) in clinical settings and drug development.

W.L. Johnson, D.C. France, N.S. Rentz, W.T. Cordell, and F.L. Walls, Sensing bacterial vibrations and early response to antibiotics with phase noise of a resonant crystal, *Scientific Reports*. Sept. 22, 2017; http://dx.doi.org/10.1038/s41598-017-12063-6

ASSESSING THE HIGHER ORDER STRUCTURE OF MONOCLONAL ANTIBODIES

The sale of innovative and generic biologic medicines is a major driver of U.S. economic activity. Ten of the top-selling 20 drugs are protein therapeutics. Of these, seven are monoclonal antibodies (mAbs), by far the largest class of protein therapeutics. The development and manufacture of therapeutic mAbs presents many analytical challenges. Characterization of mAbs requires assessing their higher order structure, since misfolding or aggregation can lead to loss of efficacy or cause potentially life-threatening immune responses. Techniques for accurate and precise characterization of mAb higher order structure for establishing consistency in drug manufacturing, detecting process-related drug-product variations and establishing comparability of biosimilars to innovator reference products are therefore of great interest to regulators and the biopharmaceutical industry. An MML team has developed a nuclear magnetic resonance (NMR) method that produces spectral 'fingerprints' to establish higher order structure comparability between mAb samples. This work is described in a recently published article entitled "Multivariate Analysis of Two-Dimensional 1H, 13C Methyl NMR Spectra of Monoclonal Antibody Therapeutics To Facilitate Assessment of Higher Order Structure" (http://dx.doi.org/10.1021/acs.analchem.7b03571), that was selected by American Chemical Society journal editors to be featured in *ACS Editors' Choice*.

Using a benchmark 2D NMR experiment, with principle component analysis applied directly to the spectral data matrix, spectra from highly similar species are successfully discriminated, with low limits of detection, that cannot be distinguished by visual inspection or simple intensity based statistical approaches. The MML team is further able to use this approach to identify the sources of spectral variation between species and assign these differences to alterations in structure. The team also previously demonstrated that the NMR analysis can be performed in an hour or less, which makes this a practical method for higher order structure determination in the manufacturing environment.

NIST, NFL, GE AND UNDER ARMOUR ANNOUNCE DYNAMIC RESEARCH AND 6D HELMETS AS GRAND PRIZE WINNER IN HEAD HEALTH CHALLENGE III (CONT.D)

testing at several points during the year, and NIST test data was provided back to them as feedback to modify their materials towards improved performance.

"The testing data collected by NIST researchers using this new measurement platform also helped the judges to fairly evaluate the diverse materials concepts developed by the finalists," said Michael Fasolka, Deputy Director of the NIST Material Measurement Lab.

The finalists and winner were identified through a rigorous, scientific process based on their respective materials' innovative impact-absorbing properties and commercial potential. Many participants in the competition are now using NIST's data to adjust their materials to expand into new product lines or markets and to attract new commercial partners.

For more information about the GE-NFL Head Health Initiative and Head Health Challenges, visit PlaySmart. PlaySafe.

OUTREACH AND PARTNERING

NIST-EPA INTER-AGENCY AGREEMENT ON FECAL WASTE CONTAMINANTS IN WATER

Scott Jackson, leader of MML's Complex Microbial Systems Group is working with scientists from the U.S. Environmental Protection Agency's (EPA) National Risk Management Research Laboratory, Water Supply and Water Resources Division to develop molecular genetic reference materials for validating analytical methods developed at the EPA for the detection of fecal waste contaminates in our waterways. Fecal microbes are the most common biological contaminants in U.S. waters and pose serious public and ecological health risks. A nationwide network of regional and state laboratories uses the EPA-developed methods to monitor local recreational waters for safety and for evaluating best management practices. The NIST-developed reference material will be used to assess the analytical sensitivity and specificity of the EPA-developed methods as well as ensuring interlaboratory competency through annual performance testing.

CDC HUMAN MICROBIOME DISRUPTION MEETING

On September 18, 2017 MML Group Leader Scott Jackson visited the Centers for Disease Control and Prevention in Atlanta, to develop a set of standard practices for assessing, during drug development, the degree and significance of human microbiome disruption or restoration resulting from exposure to medications such as antibiotics, microbiome protectants, or microbiome restoratives. Several pre-calls with invited participants were hosted in advance to develop a starting draft of standard practices and define current gaps in approaches to assess drug-related microbiome disruption and gaps in evidence linking potential microbiome indices to outcomes. During this meeting, Jackson gave a presentation on the ongoing activities at NIST surrounding standards for microbiome measurements as well current antibiotic resistance research. The meeting was hosted by the CDC's Division of Healthcare Quality Promotion.

NIST JOINS JOINT AGENCY MICROBIOME GROUP

Last year the FDA and NIH partnered to form the Joint Agency Microbiome Working Group. The group, composed of scientists interested in microbiome research, recently expanded their strategic document to officially include NIST as a member. MML's Scott Jackson is representing NIST in the group. The goals of the group are to:

1. Promote trans-agency collaborations in advancing microbiome related science
2. Keep the three agencies appraised of current microbiome-related research
3. Keep the three agencies appraised of scientific gaps related to regulatory questions/needs
4. Keep the three agencies updated on past and upcoming microbiome related meetings
5. Provide updated general information about the regulation of microbiome-related resources such as probiotics and fecal microbial transplants
6. Coordinate minisymposium or retreat to share intramural research

INDUSTRY ENGAGEMENT ON NEUTRON AND X-RAY MEASUREMENTS

During the week of September 18, 2017, MML staff visited, in succession, the Toyota Research Institute of North America (Ann Arbor, Michigan), Dow Chemical (Midland, Michigan), and the former Dow Corning (Midland, Michigan). Both Toyota and Dow Chemical are members of the NIST public-private consortium nSoft, and Dow Chemical has had a 20+ year cooperative research and development agreement with the NIST Synchrotron Science Group located at Brookhaven National Laboratory. After recent visits to the Gaithersburg campus, there was a request for a reverse site visit to discuss emerging capabilities in neutron and X-ray measurements. In addition to interests in characterization of membranes for water purification and energy storage, all three companies expressed great interest in applying new NIST capabilities for X-ray spectroscopic microscopy to the characterization of catalysts.

OUTREACH AND PARTNERING

NIST AGREEMENT ON NON-ANIMAL ASSAY FOR ASSESSING SKIN SENSITIVITY TO CHEMICALS

Scientists from MML's Biosystems and Biomaterials Division will work with scientists from the U.S. Consumer Product Safety Commission (CPSC) through an interagency agreement to improve the measurement assurance of a non-animal alternative assay focused on assessing the potential skin sensitization risk for chemicals. This assay is currently being evaluated with a three-laboratory comparison through the Interagency Coordinating Committee for the Validation of Alternative Methods (ICCVAM). The work being conducted at NIST will focus on how to use measurement science approaches (cause and effect analysis, robustness testing, and quantifying different sources of variability) to enhance the quality of the assay. This work has already uncovered unexpected sources of variability that were not highlighted in the original protocol (e.g., photodegradation of assay reagents, variable quality of key reagents among suppliers, impact of different cuvettes) and enabled the design of potential in-line process control measurements to ensure confidence in the assay result. Furthermore, the NIST/CPSC team will evaluate the feasibility of using this assay to test more complex compounds such as nanomaterials. This work and the interlaboratory comparison results will be used to statistically determine specification ranges to ensure assay performance.

MML'S APPLIED CHEMICALS AND MATERIALS DIVISION BEGINS SBIR PHASE II WITH INNOVEERING

On September 5, 2017, Elisabeth Mansfield, leader of MML's Thermophysical Properties of Fluids Group kicked off a Phase II Small Business Innovation Research (SBIR) project with Innoveering LLC to design a high-temperature, low-uncertainty pressure sensor. Innoveering is a small business based in New York that has a history of designing pressure sensors for oil and gas applications. They are applying their knowledge developed for previous applications to the development of a new sensor for NIST. The Thermophysical Properties of Fluids group has an interest in a new pressure sensor to overcome some of the challenges with current pressure sensor size and calibrations. The new pressure sensor is much smaller (1 in x 1 in), has a pressure range up to 7MPa, and is based on MEMS technology. It is expected that this sensor will allow NIST to develop smaller instrumentation for thermophysical property measurements and improve the uncertainties in current instrumentation. The finalized sensor is expected to be delivered at NIST by August 31, 2019. The SBIR program encourages domestic small businesses to engage in federal research/research and development that has the potential for commercialization.

MML LEADS MICROSCOPY & MICROANALYSIS SYMPOSIUM ON ADVANCES IN SCANNING ELECTRON MICROSCOPY

Bob Keller, leader of MML's Nanoscale Reliability Group, teamed with Professors Raynald Gauvin (McGill University) and Shirin Kaboli (University of Nevada-Las Vegas) to organize and run a symposium entitled *Advances in Scanning Electron Microscopy: Transmission Modes and Channeling Effects* at the Microscopy & Microanalysis Meeting, held in St. Louis, August 7-9, 2017. The Symposium drew many of the world's experts in both transmission and electron channeling methods, which share numerous common aspects of electron scattering and detection physics. This was the first symposium at the Microscopy & Microanalysis conference that included transmission scanning electron microscope (SEM) methods as a primary focus. The historically uncommon transmission approach has seen rapid research and commercial growth during the past five years, since the NIST development of transmission-EBSD (aka transmission Kikuchi diffraction) was first reported. Transmission-centric topics included imaging methods, electron diffraction methods, and electron energy loss spectrometry in the SEM, for characterization of a wide variety of substances, including metals, semiconductors, ceramics, rocks and minerals, and biological material. Channeling-centric topics included electron channeling contrast imaging and electron channeling pattern methods, used primarily for studies of deformation in metals and semiconductors. The program can be found at http://www.microscopy.org/MandM/2017/program/Scientific_Program.pdf.

AWARDS

STAFFORD SELECTED AS 2017 AMERICAN PHYSICAL SOCIETY FELLOW

MML project leader Chris Stafford (Functional Polymers Group) has been selected as a 2017 Fellow of the American Physical Society (APS). Stafford is being recognized for "developing innovative techniques to enhance physical understanding of polymer thin films, including combinatorial arrays with controlled gradients, buckling methods to quantify modulus, and layer-by-layer methods to deduce structure-property relationships in polymer membranes." APS Fellowships are a distinct honor given after extensive review by the Fellowship committee of the appropriate APS division, topical group or forum, and by the APS Fellowship Committee.

MARINO HONORED BY AMERICAN CHEMICAL SOCIETY FOR TALK

John Marino, leader of MML's Biomolecular Structure & Function Group, was honored by the Division of Biochemical Technology (BIOT) in the American Chemical Society (ACS) with the "Best of BIOT" award for his talk presented at the 2017 ACS National Meeting in San Francisco titled "Addressing the challenge of higher-order structure assessment of biologics with 2D NMR." In addition to the honor, Marino was featured in the "Best of BIOT" webinar series.

Credit: Netexplo

MML TEAM RECEIVES NETEXPLO AWARD FOR GLOBAL INNOVATION

The Netexplo Observatory (netexplo.org) has awarded Matthew Staymates (left, left), Jessica Staymates, Bill MacCrehan, Greg Gillen, Roderick Kunz, Thomas Mendum, Ta-Hsuan Ong, Geoffrey Geurtsen, and Brent Craven a Netexplo Innovation 2017 award for their work in understanding canine olfaction with an artificial dog's nose and implications for biomimicry and improved contraband detection. The Netexplo awards 10 individuals/organizations whose work represents the 10 most innovative and promising global digital initiatives of the year. The award ceremony was held at the United Nations Educational, Scientific and Cultural Organization (UNESCO) house in Paris, France on April 26 and 27, 2017.

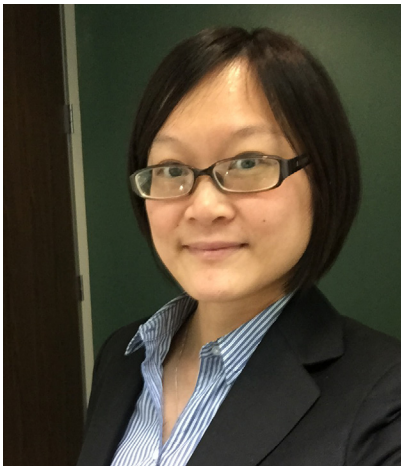
AWARDS

GLOVER NAMED ASTM EMERGING PROFESSIONAL

Jack Glover of MML's Security Technologies Group was recently selected as an ASTM International Emerging Professional for his contribution to the revision of the ASTM F792, a widely-used international standard that defines test methods for assessing the imaging performance of the X-ray systems that are used to inspect small baggage, such as the carry-on baggage in air transportation. This competitive recognition is awarded for new ASTM members who have demonstrated the potential to be committee leaders. Glover improved existing test methods, developed new test methods, developed algorithms to automatically compute values for the performance metrics, updated and identified new performance metrics, and designed and validated test artifacts. He was also the chair of the F792 working group that revised ASTM's F792 standard.

GORHAM NAMED ASTM EMERGING PROFESSIONAL

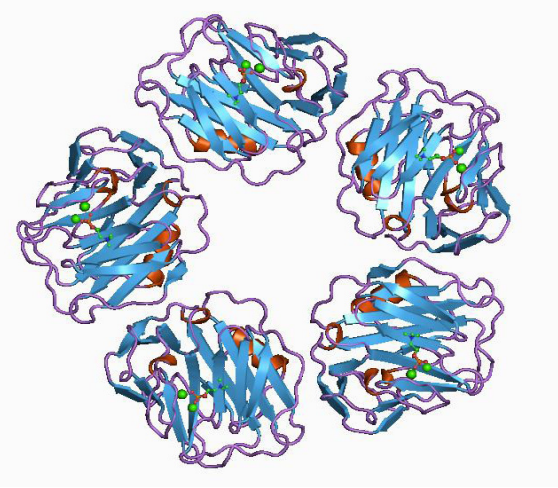
Justin Gorham of MML's Nano Materials Research Group has recently been selected as an ASTM International Emerging Professional. This competitive recognition is awarded for new ASTM members who have demonstrated the potential to be committee leaders. Gorham joined ASTM in 2015 and has contributed significantly to the development of one published standard and one work item in Committee E56 on Nanotechnology, Subcommittee E56.06 on Nano-Enabled Consumer Products. These are *A Standard Guide for Tiered Approach to Detection and Characterization of Silver Nanomaterials in Textiles* and *A New Test Method for Detection of Total Silver in Textiles by ICP Analysis.* These two standards are critical to industries that manufacture textile products containing silver nanomaterials and to agencies that regulate such products. In addition to his standards work with ASTM, Gorham has co-led the production of a NIST silver nanoparticle reference material.



CHIANG NAMED DISTINGUISHED SPEAKER BY THE SOCIETY OF PETROPHYSICISTS

Wei-Shan Chiang, a NIST guest researcher (sponsored by Aramco) at the NIST Center for Neutron Research, has been named a Distinguished Speaker by the Society of Petrophysicists and Well Log Analysts (SPWLA) for 2017-2018. She was selected for her paper entitled "Simultaneous Neutron and X-ray Imaging of 3D Kerogen and Fracture Structure for Flow Path in Shales," which she presented at the 58th Annual SPWLA Symposium. As a Distinguished Speaker Chiang will visit and speak at local chapters of SPWLA throughout the coming year. This honor represents an important achievement for NIST's nSoft, as a definitive advance in the imaging of shale. Aramco North America Services (Houston, TX) has been a member of nSoft since 2015. This work was highlighted at the recent nSoft annual meeting.

STANDARD STORY



The liver creates C-reactive protein in response to inflammation. Credit: courtesy European Bioinformatics Institute

MATTERS OF THE HEART

NIST scientists have thoroughly measured and characterized more than 1,300 physical products, NIST Standard Reference Materials, to help people in industry, academia, and government agencies calibrate instruments, verify their test methods, and develop new measurement methods. NIST reference materials, for example, help manufacturers make interoperable parts in far-flung facilities, medical labs check the accuracy of cholesterol and other clinical tests, and scientists monitor environmental threats.

What

Standard Reference Material 2924
C-Reactive Protein (CRP) Solution
A unit of the SRM contains 3 vials, each with 1 milliliter of a solution of recombinant CRP. A certified concentration value for CRP is reported along with reference density, relative average mass and concentration values (expressed in terms of grams per liter). This SRM is primarily intended for use in calibrating procedures and devices for the determination of C-reactive protein (CRP) in human serum. It can also be used for value-assignment of in-house calibrator solutions and control materials.

Why

C-reactive protein (CRP) is a biomarker for inflammation due to infections or other medical conditions (e.g. rheumatoid arthritis or lupus). Because persistent low levels of inflammation can also be associated with cardiovascular disease, high-sensitivity CRP (hs-CRP) assays, that can detect low levels of CRP in serum, are used to predict risk of heart disease combined with other mitigating factors. In a healthy individual, CRP is found at a level less than 1 milligram per liter (mg/L) in serum. Recent evidence suggests that a CRP level between 1 mg/L and 3 mg/L indicates a moderate risk of cardiovascular disease while a level greater than 3 mg/L predicts a high risk. The NIST team produced the certified reference material of pure CRP for the intended purpose of calibrating diagnostic tools and procedures that measure these low levels of CRP with greater accuracy, precision and traceability to SI units.

Who

Ideally, all clinical diagnostic tests would be traceable to a 'higher-order' reference material to ensure the validity of the test results. Higher-order reference materials are those that have been reviewed and approved by the Joint Committee for Traceability in Laboratory Medicine (JCTLM) as meeting specific criteria. Many common diagnostic tests currently lack suitable higher-order reference materials, and NIST plays an important role in filling this gap. In-vitro diagnostic companies as well as research laboratories may use SRM 2924 to develop calibrator solutions and control materials at low CRP concentrations. The NIST researchers will also use SRM 2924 as a 'higher-order' reference material to produce a follow-on SRM for CRP in serum, that will directly feed into the measurement traceability chain for CRP in clinical laboratories everywhere.

How

SRM 2924 was certified for concentration by amino acid analysis involving isotope dilution liquid chromatography-tandem mass spectrometry (ID-LC-MS/MS). This advanced measurement method was optimized and rigorously tested against an existing higher concentration certified reference material for CRP from the National Metrology Institute of Japan (NMIJ). Stability of the SRM was also carefully assessed through chromatographic and mass spectrometric techniques. SRM 2924 is one of several protein SRMs being developed by NIST to meet the needs of the in-vitro diagnostic and research communities. The SRM is stored and shipped frozen and thawed at room temperature before use.

PUBLICATIONS

N. Mast, J. Lin, K. W. Anderson, I. Bjorkhem, I. A. Pikuleva, "Transcriptional and post-translational changes in the brain of mice deficient in cholesterol removal mediated by cytochrome P450 46A1 (CYP46A1)" *PLoS One*, (26-Oct-2017)

L. W. Arbogast, F. Delaglio, J. E. Schiel, J. P. Marino, "Multivariate Analysis of 2D 1H, 13C methyl NMR Spectra of Monoclonal Antibody Therapeutics to Facilitate Assessment of Higher Order Structure" *Analytical Chemistry*, (22-Sep-2017)

W. L. Johnson, D. C. France, N. S. Rentz, W. T. Cordell, F. L. Walls, "Sensing bacterial vibrations and early response to antibiotics with phase noise of a resonant crystal" *Scientific Reports*, Vol. 7, 12 pp., (22-Sep-2017)

A. Krishnamurthy, D. L. Hunston, A. L. Forster, B.N. Natarajan, S. Wicks, P. E. Stutzman, J. A. Liddle, A. M. Forster, B. L. Wardle, "Enhanced durability of CNT based hierarchical composites subjected to accelerated aging environments." *Carbon*, Vol. 125, pp. 63-75, (21-Sep-2017)

T. Keller, G. K. Lindwall, S. Ghosh, L. Ma, B. M. Lane, F. Zhang, U. R. Kattner, E. Lass, Y. S. Idell, M. E. Williams, A. J. Allen, J. E. Guyer, L. E. Levine, "Application of Finite Element, Phase-field, and CALPHAD-based Methods to Additive Manufacturing of Ni-based Superalloys" *Acta Materialia*, Vol. 139, pp. 244-253, (21-Sep-2017)

J. M. Gorham, J. P. Killgore, M. Omidvar, H. Lin, F. W. DelRio, L. M. Cox, Z. Zhang, "Formation of a crack-free, hybrid skin layer with tunable surface topography and improved gas permeation selectivity on elastomers using gel-liquid infiltration polymerization" *ACS Applied Materials and Interfaces*, Vol. 9, No. 33, pp. 28100-28106, (11-Sep-2017)

E. J. Garboczi, E. Lucon, W. Grell, Z. Loftus, M. Kumosa, E. Solis-Ramos, P. Predecki, E. Clark, "Effects of Powder Oxidation on Impact Toughness of Electron Beam Melt Ti-6Al-4V" *ACTA Materialia*, (25-Aug-2017)

W. A. Osborn, L. H. Friedman, M. D. Vaudin, "Strain Measurement of 3D Structured Nanodevices by EBSD" *Nature Materials*, (20-Aug-2017)

J. M. Lynch, "Persistent Organic Pollutants in Fat of Three Species of Pacific Pelagic Longline Caught Sea Turtles: Accumulation in Relation to Ingested Plastic Marine Debris" *Science of the Total Environment*, Vol. 610-611, pp. 402-411, (27-Jul-2017)

L. M. Pitkanen, A. R. Montoro Bustos, K. E. Murphy, M. R. Winchester, A. M. Striegel, "Quantitative characterization of gold nanoparticles by size-exclusion and hydrodynamic chromatography, coupled to inductively coupled plasma mass spectrometry and quasi-elastic light scattering" *Journal of Chromatography A*, Vol. 1511, pp. 59-67, (14-Jul-2017)

F. Nilsen, J. E. Dorsey, S. E. Long, T. B. Schock, J. A. Bowden, R. H. Lowers, L. J. Guillette Jr., "Seasonal variation of total mercury burden in the American alligator (Alligator mississippiensis) at Merritt Island National Wildlife Refuge (MINWR), Florida" *Science of the Total Environment,* (08-Jul-2017)

W. P. Krekelberg, D. W. Siderius, V. K. Shen, T. M. Truskett, J. R. Errington, "Connection between thermodynamics and dynamics of simple fluids in pores: impact of fluid-fluid interaction range and fluid-solid interaction strength" *Journal of Physical Chemistry C*, Vol. 121, No. 30, pp. 16316-16327, (05-Jul-2017)

W. B. Wilson, H. Hayes, L. C. Sander, A. Campiglia, S. A. Wise, "Qualitative characterization of SRM 1597a Coal Tar for polycyclic aromatic hydrocarbons and methyl-substituted derivatives via normal-phase liquid chromatography and gas chromatography/mass spectrometry" *Analytical and Bioanalytical Chemistry*, (29-Jun-2017)

P. Jaruga, E. Coskun, M.M. Dizdar, W. E. Johnson, K. Kimbrough, "Biomarkers of oxidatively induced DNA damage in dreissenid mussels: An ecosystem health assessment tool for the Laurentian Great Lakes" *Environmental Toxicology,* Vol. 32, No. 9, pp. 2144-2153, (01-Jun-2017)

T. P. Forbes, E. R. Sisco, M. E. Staymates, J. G. Gillen, "DART-MS analysis of inorganic explosives using high temperature thermal desorption" *Analytical Methods*, Vol. 9, No. 34, pp. 4988-4996, (04-May-2017)

MATERIAL MEASUREMENT LABORATORY

The Material Measurement Laboratory supports the NIST mission by serving as the national reference laboratory for measurements of matter, providing broad support for chemical, biological, and materials sciences. Our fundamental and applied measurement science research expands possibilities for determining the composition, structure, and properties of manufactured, biological, and environmental materials, and the processes that create them. In addition, MML drives the development and dissemination of tools—including measurement protocols, certified reference materials, critically evaluated data, and best practice guides—that help assure quality measurements of matter. Our research and measurement services support progress in areas of national importance including advanced materials, energy, environment, food safety and nutrition, forensic science, health care, manufacturing, physical infrastructure, and safety and security. MML also coordinates the NIST-wide Standard Reference Materials® (SRM) and Standard Reference Data programs.

TO LEARN MORE, CONTACT:

Material Measurement Laboratory
100 Bureau Drive, M/S 8300
Gaithersburg, MD 20899-8300
Tel: 301-975-8300
mmlinfo@nist.gov
or visit http://www.nist.gov/mml

NIST
National Institute of Standards and Technology
U.S. Department of Commerce