SUMMER 2017

MATERIAL MATTERS

The Quarterly Magazine of NIST's Material Measurement Laboratory

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

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Cover Image: NIST Reference Materials, Credit: K. Irvine/NIST

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A MESSAGE FROM THE MML DIRECTOR

Laurie Locascio, Ph.D.
Director
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NIST

For the past five years, it has been an incredible honor to serve as MML Director, and most recently as NIST's Acting Associate Director for Laboratory Programs. This fall, I will start a new phase in my career, as Vice President for Research at the University of Maryland.

It was a difficult decision to leave a beloved institution where so much of my professional development has been nurtured, and where I have so many close scientific collaborations and personal relationships. Ultimately, my decision to join UMD hinged on the job's rich opportunities for developing and nurturing new research programs and partnerships. Fortunately, these duties at the University of Maryland will mean frequent interactions with NIST.

My years at NIST have been fulfilling, creative, and full of engaging technical challenges and wonderful friendships. I have loved almost every day in every job that I have worked in at NIST. Even those days that I have found to be most challenging provided me with great opportunity for learning and growing.

I have particularly enjoyed serving as MML Director working with so many people across the Laboratory to foster a culture of openness, inclusiveness, and technical and administrative excellence. We have created a thriving and reinvigorated MML, become a critical player in the Materials Genome Initiative, and launched our own Office of Data and Informatics. We have greatly expanded our portfolio in biomanufacturing and precision medicine, and continued our outstanding work providing critical support for accurate measurements for commodities trading, physical infrastructure, chemical monitoring, and national security. We have built a strong leadership team across MML with a unified innovative strategy.

We have achieved all this in just a few short years because of the dedication of NIST staff to the NIST mission and support of world-class science. Going forward, the MML Strategic Plan will continue to guide our efforts. Our plan is resilient to change, because it continues to be aligned with national priorities.

It has been a pleasure to work with such an amazing staff in MML and at NIST. I am confident that MML will be in good hands going forward, and look forward to seeing it continue to excel in fulfilling its vital mission.

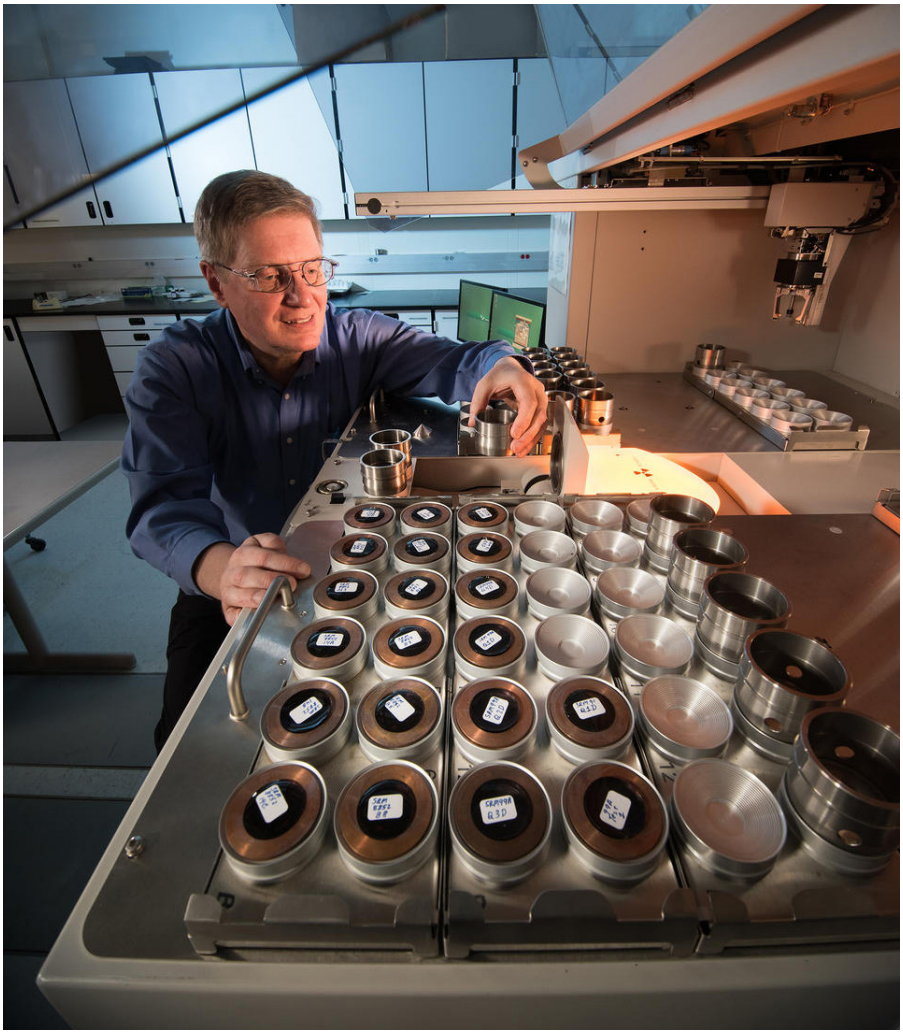
MEASUREMENTS MATTER: HOW NIST REFERENCE MATERIALS AFFECT YOU

In 2012, *Consumer Reports* announced startling findings—with potentially serious public health ramifications. The publication investigated arsenic levels in apple juice and rice and found levels of the toxin above those allowed in water by the Environmental Protection Agency. The articles pointed out that there were no rules about allowable levels for arsenic in food. The Food and Drug Administration responded by issuing a limit for arsenic levels in apple juice and, in 2016, for infant rice cereal. But the damage was already done.

It's a funny quirk of human psychology: we take the most important things for granted—until it all goes wrong. You probably don't often question whether the food you buy in the grocery store is safe. Or if the lab where your doctor sends your samples accurately calculated your vitamin D levels. But imagine, for a moment, how much more difficult it would be to go about your daily life if you didn't have the information those measurements provide. How would you decide what is safe and healthy to eat? How would you know if you were getting enough vitamin D or if your cholesterol levels were too high? That's one of the big reasons NIST exists—to reduce uncertainty in our measurements and increase your confidence in the information you use to make important decisions in your daily life. And part of the way NIST does that is through Standard Reference Materials (SRMs).

Standard Reference ... what?

The government has acronyms for seemingly everything. At NIST, one even has a registered trademark: SRM® is the "brand name" of our certified reference materials, the generic term for these vital tools. Many other organizations measure and distribute certified reference materials, but only NIST has SRMs. So what exactly is an SRM or certified reference material? It can be difficult to explain, because SRMs are actually a lot of different things. In fact, NIST sells more than 1,000 different types of SRMs, from gold nanoparticles to peanut butter.



NIST researcher John Sieber, concrete SRM development. Credit: Earl Zubkoff

NIST has very carefully studied each of its SRMs, and it's these characterizations, rather than the materials themselves, that customers pay for. SRMs serve a variety of purposes but are mostly used by other labs and members of industry to check their analytical measurements and to perform other kinds of quality-control tests.

Steve Choquette, director of NIST's Office of Reference Materials, says SRMs are like widgets, tools that provide a service or help you complete a task. In this case, SRMs give manufacturers access to a level of measurement accuracy they wouldn't otherwise be able to obtain. "What an SRM really does is give our customers the highest quality measurements in a form they can easily use," Choquette says.

Peanut butter—SRM 2387—is an excellent example. NIST scientists know exactly how much fat, salt, sugar and other nutrients are in the peanut butter, and they've recorded those amounts on a certificate that's sold with the SRM. When an SRM user measures the NIST peanut butter with his or her own instrument, he or she should get amounts that match the certificate. If not, the manufacturer knows the machine must be adjusted.

NIST is a nonregulatory agency, which means it doesn't set the rules for things

like food and water safety. However, manufacturers frequently use NIST standards such as SRMs because they are a reliable, science-based means to demonstrate compliance with the rules set by regulatory agencies.

Does your food measure up?

Like the peanut butter SRM, many NIST SRMs are food products. These SRMs help the food industry comply with various U.S. food regulations such as those requiring nutrition facts labels. Regulators can be sure those labels are accurate when producers use SRMs to ensure their measurement instruments are properly calibrated.

In the lab, Joe Katzenmeyer, senior scientist and strategic analytical manager at Land O'Lakes, uses the SRMs for nonfat milk powder, infant formula and meat homogenate (a canned pork and chicken mix).

"We most often use NIST SRMs when developing a new testing procedure, and we need to know that a result is the 'correct' result," Katzenmeyer said. "NIST values are established through a very thorough process and by labs across the country. This gives a high credibility to their established values."

And that's how you can be confident in the nutrition facts labels, too, so you can make healthy decisions about what to eat. But NIST food SRMs don't just help you accurately count your carbs. Remember the concern about arsenic in apple juice and rice? NIST already had a rice flour SRM, but NIST researchers recently added measurements for different types of arsenic. And, NIST is in the process of making an SRM for apple juice that will include levels for various forms of arsenic as well. Government agencies, like the Food and Drug Administration, can use these SRMs to ensure that arsenic levels in the foods we eat are safe.

NIST SRM 2385, spinach. Credit: K. Irvine/NIST

And both health and safety are driving forces behind another type of NIST SRMs—those for dietary supplements. Marketers can make some pretty strong claims about their products. But do so-called "superfoods" like green tea or blueberries live up to the hype? The first step in finding out is to carefully measure the properties of these foods. That's why NIST makes SRMs for green tea and blueberries, as well as multivitamins, St. John's Wort and Ginkgo biloba, among others.

A medical measurement marvel

Nearly 74 million Americans have high levels of LDL cholesterol—that's the bad kind. Those with high cholesterol have twice the risk of heart disease as those with normal levels. Keeping tabs on your cholesterol can be a matter of life and death. So, when you or your loved one goes to the doctor's office to give a blood sample, how do you know the result you get is right? If you're thinking it's because of NIST SRMs, you'd be right! NIST sells a number of SRMs that lab techs use to calibrate clinical laboratory equipment.

But SRMs don't just help maintain the status quo. They also help drive innovation. A new SRM for monoclonal antibodies—a large class of drugs for treating cancer and autoimmune diseases, among other things—could make these life-saving treatments more widely available. Monoclonal antibodies are large protein molecules designed to bind to disease-causing cells or proteins, triggering a patient's immune system to attack and clear them from the body. Sales of these drugs in the U.S. reached $50 billion in 2015. Manufacturing a monoclonal antibody drug on a large scale is complex and involves the use of genetically engineered cells that churn out large quantities of the molecule. Testing to make sure that the molecules are being made correctly happens at many points in the manufacturing process. The NIST SRM is an important tool for assuring the quality of these test methods and of the final product. And, since patents on many monoclonal antibodies are set to expire in the next several years, many anticipate a growing market for biosimilar—or generic—versions of the drugs. Generics could save patients billions of dollars by 2020. But, this will mean a lot of testing and measurements to determine whether these generic versions are nearly identical to the branded versions. The NIST monoclonal antibody SRM could help with measurement challenges faced by researchers tasked with testing these drugs.

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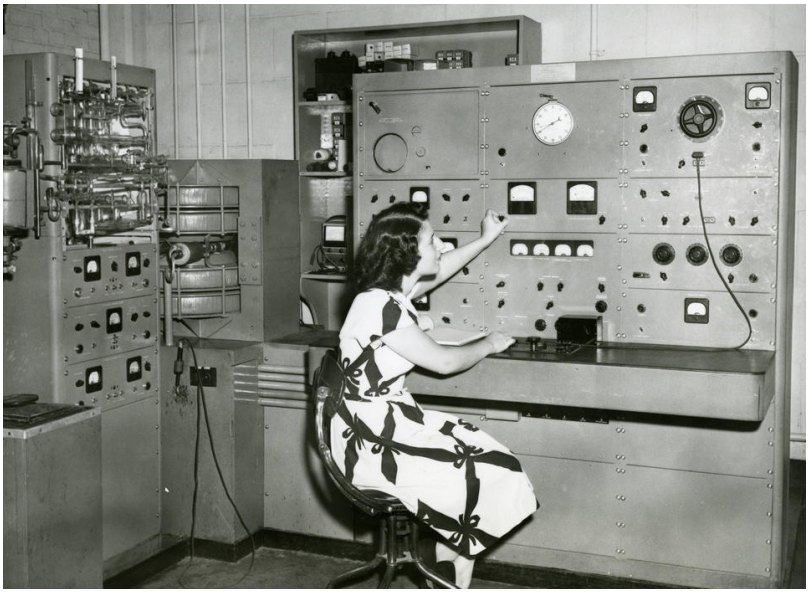
NIST UPGRADES WIDELY USED DATABASE OF MOLECULAR 'FINGERPRINTS'

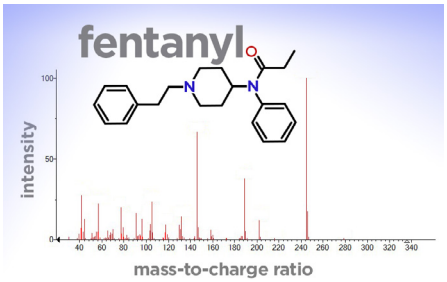
Scientists in almost every major industry rely on the NIST Mass Spectral Library to accurately identify chemical compounds



In this 1948 photo, a NIST staff member operates an early mass spectrometer. Credit: NIST

When scientists need to identify an unknown compound, they do what a police detective might do. They get fingerprints—in this case, the "molecular fingerprints" of the unknown compound—and run them through a database of fingerprints from known suspects to look for a match. One of the world's largest and most widely used databases of molecular fingerprints is the NIST Mass Spectral Library, and that library just got larger still. On June 6, NIST added fingerprints from more than 25,000 compounds to the library, bringing the total number to more than 265,000. This library contains fingerprints of organic compounds—a class of carbon-containing molecules that exist in an endless variety, both natural and man-made.

"This library is used by scientists and engineers in virtually every industry," said Stephen Stein, the NIST chemist who oversees the Mass Spectral Library. He rattled off just a few uses: diagnosing medical conditions, conducting forensic investigations, identifying environmental pollutants and developing new fuels. "And anything having to do with food," he said, since the taste of a food is determined by the complex mixture of organic molecules within it. "The flavor and fragrance industries live and die by this stuff."



The mass spectrum for the synthetic opioid, fentanyl. The mass spectrum is like a molecular fingerprint, and is used to identify unknown compounds. The red lines represent the charged fragments of the molecule created during analysis. The vertical axis shows the relative intensity, or amount, of each fragment, while the horizontal axis shows the mass-to-charge ratio for each fragment. Credit: NIST

To generate the molecular fingerprint of an organic compound, scientists put a sample of the compound into a laboratory instrument called a mass spectrometer. In the most common practice, that instrument heats the sample to vaporize it, then shoots it with a beam of high-energy electrons. That causes the molecules to break into electrically charged fragments, which the instrument separates based on their weight, or mass. When you line up the fragments in order of their mass-to-charge ratio, you get the molecule's distinctive "mass spectra," which looks like a barcode and functions like a fingerprint.

The number of organic compounds in the world is astronomical, and any database can only hope to capture a tiny fraction of them. So Stein and his colleagues have to focus on the compounds they think are most important. Among the important compounds whose fingerprints are included in this upgrade are many dangerous drugs. These include dozens of synthetic cannabinoids—aka "synthetic marijuana"—which can cause psychotic episodes, seizures and death. Also included are more than 30 types of fentanyl, the synthetic opioid that is driving an epidemic of overdoses nationwide. Having the fingerprints of these compounds in the Mass Spectral Library will help law enforcement and public health officials fight the spread of these new and dangerous substances.

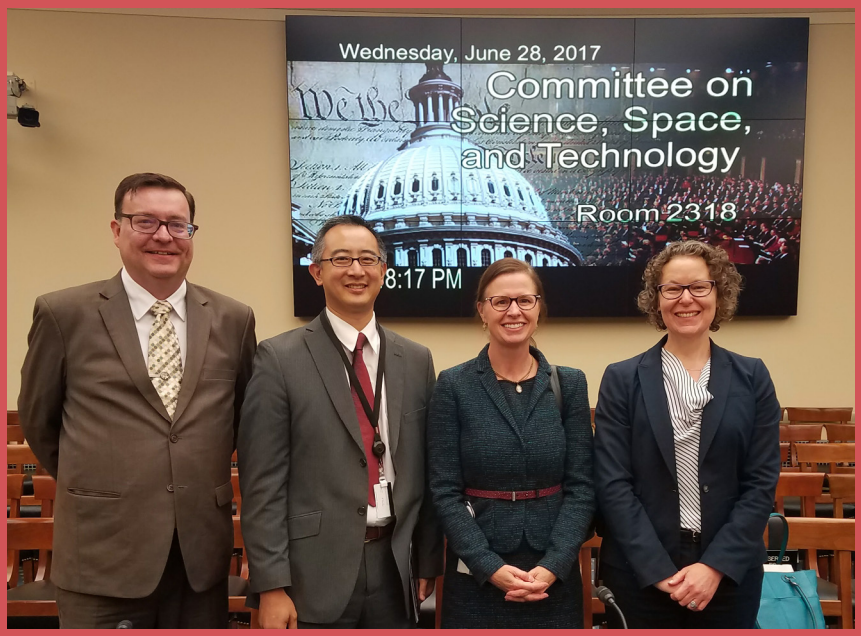
NIST has released the latest version of the Mass Spectral Library, and the software needed to run it, to more than 60 distributors that bundle the data and software into mass spectrometry instruments. Owners of existing instruments can also download the latest version from distributors online.

The NIST Mass Spectral Library is actually several libraries, each covering a variation of the basic analytical method. The library that covers a technique called tandem mass spectrometry has expanded by more than 65 percent the number of compounds covered. For more information on the various libraries and software tools, check out NIST's Mass Spectrometry Data Center.

NIST has been publishing its Mass Spectral Library since 1989. To ensure that the data in that library is accurate, NIST scientists apply a very high level of quality control. "It's a very specialized activity, and nobody else does it at the level and scale we do," Stein said.

LOCASCIO TESTIFIES TO CONGRESS ON ADVANCED MATERIALS

On June 28, 2017, MML director Laurie Locascio testified on "Material Science: Building the Future" before members of the Energy and Research and Technology subcommittees of the House Committee on Science, Space, and Technology. Dr. Locascio talked about NIST's role in meeting measurement science needs to help advance materials-related industries, with emphasis on the Materials Genome Initiative (MGI). The MGI was launched in 2011 to speed adoption of the "materials by design" approach for the more rapid development of materials with novel properties. Materials scientists using this approach use data and modelling to predict the performance of materials before making them, rather than rely on expensive trial-and-error experiments. NIST supports the MGI with a nation-wide infrastructure for materials property data and founded a center of excellence, the Center for Hierarchical Materials Design, to foster and showcase practical applications of the MGI. Other witnesses at the hearing were Matthew Tirrell of Argonne National Laboratory, Ames Laboratory's Adam Schwartz, and Fred Higgs of Rice University. The House Committee on Science, Space, and Technology has responsibility for "government activities involving Federal non-military research and development," which includes, through the Subcommittee on Research and Technology, jurisdiction over NIST. You can view the hearing or read Dr. Locascio's written testimony.



(L-R) MML's Michael Fasolka, Eric Lin, Laurie Locascio, and Leah Kauffman

NIST 2017 MASS SPECTRAL LIBRARY UNVEILED AT ASMS IN INDIANAPOLIS

The NIST Mass Spectrometry Data Center released the 2017 version of the NIST Mass Spectral Library (SRD 1A v17 aka NIST 17) at the American Society for Mass Spectrometry (ASMS) annual meeting, June 4-8, 2017 in Indianapolis, IN. The NIST Mass Spectral Library is the world's most widely used and trusted MS library. NIST 17 contains nearly a million mass spectra and MS search software for compound & fragment identification. For the 2017 release, the library was enhanced with the addition of more than 30,000 electron ionization (EI) spectra, 418,000 MS/MS spectra (including metabolites, peptides, & lipids), and 16,000 additional compounds to the gas chromatography (GC) Retention Index library. In addition, a powerful new spectral search algorithm allows identification of chemical compounds not present in the library. The MS Data Center unveiled NIST 17 at ASMS to distributors, customers, and users through six oral presentations, 13 poster presentations, a distributor informational session, and the NIST MS Library exhibit booth.

SCIENTISTS LAY THE GROUNDWORK FOR A RELIABLE MARIJUANA BREATHALYZER

NIST researchers have measured a fundamental physical property of the primary psychoactive compound in marijuana

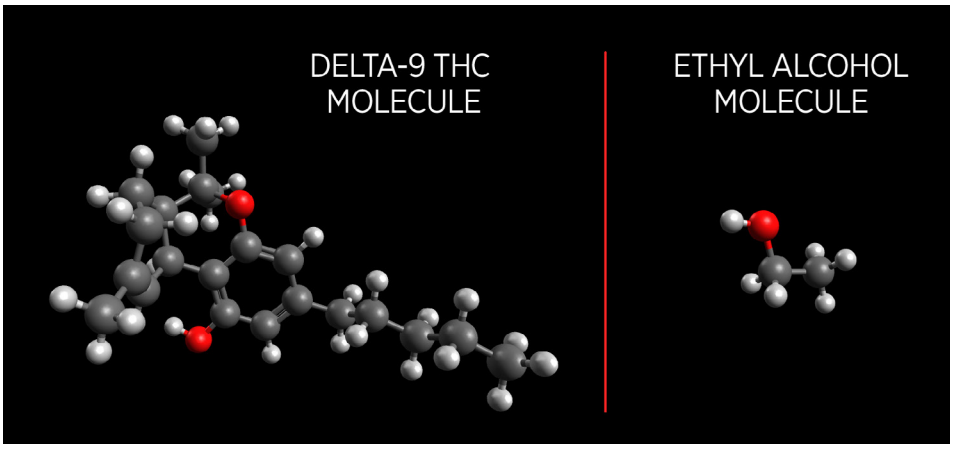
Marijuana is now legal for recreational or medicinal use in at least 28 states and the District of Columbia. But driving under the influence of marijuana is illegal no matter which state you're in. To enforce the law, authorities need a simple, rigorous roadside test for marijuana intoxication.

Although several companies are working to develop marijuana breathalyzers, testing a person's breath for marijuana-derived compounds is far more complicated than testing for alcohol.

But scientists at NIST have taken an important step toward that goal by measuring a fundamental physical property of the main psychoactive compound in marijuana, delta-9 tetrahydrocannabinol (THC). Specifically, they measured the vapor pressure of this compound—a measurement that, due to the compound's chemical structure, is very difficult and has not been accomplished before. The results were published in *Forensic Chemistry*.

"Vapor pressure describes how a compound behaves when it transitions from a liquid to a gas," said Tara Lovestead, a NIST chemical engineer and the lead author of the study. "That's what happens in your lungs when a molecule leaves the blood to be exhaled in your breath. So if you want to accurately measure blood levels based on breath, you need to know the vapor pressure."

Law enforcement agencies are interested in a breathalyzer because roadside collection of blood or urine would be impractical and invasive. Lovestead is not designing a breathalyzer herself. Rather, by measuring this fundamental physical property, she and her colleagues are laying the technical groundwork for manufacturers to develop accurate devices. While this research is an important step forward, more research will still be needed to understand how breath levels of THC correlate with blood levels, and what blood levels of THC indicate that a person is too impaired to drive.



One reason it is difficult to design a reliable marijuana breathalyzer is that delta-9 tetrahydrocannabinol (THC), the primary psychoactive compound in marijuana, is a large molecule with a complex structure. Ethyl alcohol is more easily measured with a breathalyzer. In these images, carbon atoms are dark gray, hydrogen atoms are light gray, and oxygen atoms are red. 3D model based on computer rendering, not experimental data. Credit: Kelly Irvine/NIST

What is Vapor Pressure?

Vapor pressure tells you how adventurous a molecule is. Even when they are in solid or liquid form, molecules are in a constant state of jiggly motion, and some will escape as a gas. Molecules with a high vapor pressure, such as ethyl alcohol, are constantly escaping. That's why when you open a bottle of whiskey, you can instantly smell the alcohol molecules that have collected in the air space beneath the cap.

Ethyl alcohol escapes so easily because it is a small molecule with a simple shape. But THC molecules are large and complex, with loops and spurs that cause them to stick together. This results in a very low vapor pressure—so low that you can't measure it the usual way, which would involve putting THC in a closed container and waiting for the pressure to equalize.

"You'd be waiting a very long time," Lovestead said.

A New Technique

The researchers overcame that obstacle by using a technology called PLOT-cryo—short for porous layer open tubular cryogenic adsorption. "PLOT-cryo is an extremely sensitive technique for capturing and analyzing things in the vapor phase," said Tom Bruno, a NIST research chemist and co-author of the study. "It was a natural candidate for this type of problem."

Bruno invented PLOT-cryo in 2009 for use with airport puffer machines that blow air onto passengers or luggage, then sniff the air for traces of explosives. At the time, existing technology could detect the explosive traces in the air, but could not precisely identify which compounds were present. PLOT-cryo solved that problem. The technology has since been used to sniff fire debris for evidence of arson and to find clandestine graves by following the faintest scent of decomposition.

PLOT-cryo is so sensitive that it can capture and analyze even the relatively

few molecules of THC that escape into the vapor phase. In this experiment, the researchers used pure THC, purchased in compliance with a DEA research license. They swept an inert gas across the sample to capture escaping molecules, then chilled the gas to collect them (that's where the "cryo" part of the name comes from). By measuring the mass of the recovered molecules in a known volume and temperature of sweep gas, the researchers calculated the vapor pressure.

The researchers also calculated the vapor pressure of a second compound, cannabidiol, which is considered less psychoactive than THC.

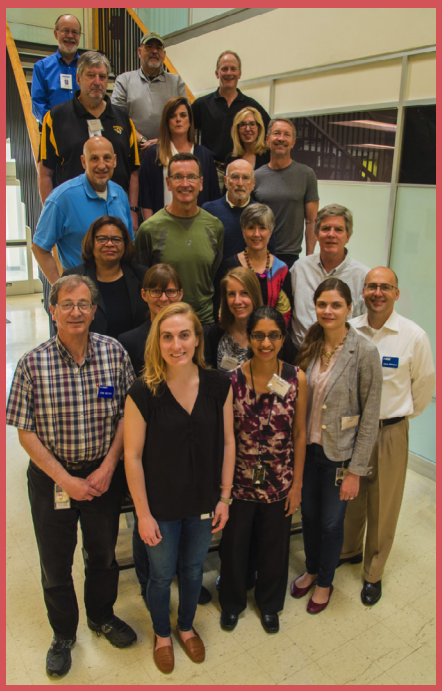
Measurements are Fundamental

When it comes to alcohol breathalyzers, NIST helps ensure accurate results by manufacturing ampules of ethyl alcohol mixed to extremely precise concentrations. Police agencies use these as reference standards to calibrate their breathalyzers. This ensures that different devices used in different jurisdictions produce consistent results—something that's particularly important when guilt or innocence hangs in the balance. Similarly, accurate vapor pressure measurements for THC will help ensure that marijuana breathalyzers are calibrated to a consistent standard.

T.M. Lovestead and T.J. Bruno, Determination of Cannabinoid Vapor Pressures to Aid in Vapor Phase Detection of Intoxication, *Forensic Chemistry*, Published online 27 June 2017, http://dx.doi.org/10.1016/j.forc.2017.06.003

JUDGES EXCHANGE BLACK ROBES FOR NIST LAB COATS

MML's Applied Chemicals and Materials Division recently provided a short course on Vapor Sampling and Characterization for 13 members of the judiciary on June 8 and 9, 2017, under the auspices of the National Courts and Science Institute (NCSI). NCSI is a nonprofit foundation that provides scientific training to the judiciary, enabling judges to better handle scientific evidence. Judges who complete training are designated Resource Judges, or upon completion of multiple training modules, Fellows of the Institute. These specially trained judges then mentor other judges throughout the judiciary on specific scientific topics. Two state supreme court justices, five state appellate judges and six trial judges participated in the course at NIST-Boulder. The main topic was the NIST-developed technology called PLOT-cryoadsorption, which has both a laboratory and a field portable version. The example application of the technology was vapor characterization for arson fire debris. The judges heard lectures on vapor characterization, chemical analysis, mixture behavior, and measurement uncertainty. Five laboratory sessions featured experiments on all the techniques, in which the judges exchanged their black robes for white lab coats. The capstone lab was called the six-pack: six samples of fire debris (made by burning gasoline, diesel fuel, or no accelerant) were chosen by a dice throw, and the judges had to figure out what, if any, ignitable liquid was used in the fire. Finally, the judges participated in the mock *voir dire* hearing of an expert witness. Boulder District Attorney Stan Garnett was a special guest playing his usual role of prosecuting counsel, and prominent Boulder environmental lawyer Marcus Martin served as defense counsel. The judges had a great time and came away better equipped to handle scientific evidence. One appellate jurist expressed that he wished he had taken the course before he presided over an arson appeal a few months ago. There are currently 60 more judges on the waiting list for two offerings of the course next May.



NIST-NCSI Vapor Characterization class of 2017. NCSI Science Director and NIST Group Leader Tom Bruno (front, left) and his staff are in the front two rows. Credit: NIST

The judges enjoyed temporarily trading their black robes for lab coats. Credit: NIST

FENTANYL CAN SICKEN FIRST RESPONDERS. HERE'S A POSSIBLE SOLUTION.

NIST researchers demonstrate screening techniques that can help prevent accidental exposure to synthetic opioids

A lethal dose of heroin compared to a lethal dose of fentanyl. This is just an illustration—the substance actually shown in this photo is an artificial sweetener. Credit: Bruce A. Taylor/NH State Police Forensic Lab

Dan Kallen, a detective in southern New Jersey, was searching a home with fellow officers in August 2015, when they found a bag of white powder. Kallen removed a scoop of powder for testing. When he was done, he closed the bag, and a bit of air escaped, carrying a puff of powder with it. It was enough to send Kallen and a fellow officer to the emergency room.

The drugs in the bag had been spiked with fentanyl, a synthetic drug that, like heroin, is an opioid. But it is 50 times more potent than heroin, and accidentally inhaling even a tiny amount can be extremely dangerous. Kallen described his experience in a Drug Enforcement Agency video that warns first responders of the dangers of handling unknown powders.

Scientists from NIST are working to address this hazard. In a paper published in ***Forensic Chemistry***, they report that two technologies, Ion Mobility Spectrometry (IMS) and Direct Analysis in Real Time Mass Spectrometry (DART-MS), can detect trace amounts of fentanyl even when mixed with heroin and other substances. This research is the first to identify the lowest concentrations at which fentanyl mixtures can be detected using these techniques, and it suggests new ways to protect law enforcement officers, evidence examiners, and drug-sniffing dogs.

IMS instruments are commonly used at airports. In that setting, a security officer might swab a piece of luggage or a passenger's hands, then insert the swab into the instrument to check for traces of explosive residue. Similarly, a police officer might test a bag of powder for fentanyl before opening it. "Currently, police officers have to handle drugs to test them," said Ed Sisco, a research chemist at NIST and the lead author of the study. "But with these technologies, they can just swab the outside of a bag to test for fentanyl." If the test comes back positive, they can take extra precautions.

Amber Burns, chief of the Controlled and Dangerous Substances Unit at the Maryland State Police Crime lab, agreed that screening with IMS or DART-MS would be useful. "Several law enforcement agencies have reached out to us about how to better handle suspected drugs," Burns said. "Because IMS is portable, it would be pretty user friendly for them to bring to a scene and screen a sample quickly."

IMS instruments cost around $35,000 and are the size of a microwave oven. Burns said the DART-MS instruments, which are more sensitive but larger and more expensive, might be ideal for screening incoming material at a forensic lab before it's handled by evidence examiners.

In addition, these technologies might be used to screen packages at the border or at postal service inspection facilities.

The authors have also reached out to medical researchers about investigating whether fentanyl screening might be useful when treating overdose victims. Because fentanyl is so potent, reviving an individual after a fentanyl-related overdose often requires multiple doses of the opioid antidote naloxone. Swabbing the victim's hands might reveal if fentanyl is involved, and that information might be useful in determining a course of treatment.

An Epidemic of Drug Overdoses

According to a recent report from the Centers for Disease Control and Prevention, more than 52,000 people died of drug overdoses in the United States in 2015, more than triple the number from 1999. That rapid increase is being driven by heroin and synthetic opioids, mainly fentanyl. In just a single year, from 2014 to 2015, the death rate from synthetic opioids (excluding methadone) increased by 72 percent.

Pharmaceutical fentanyl is used as a painkiller. But according to the Drug Enforcement Agency, most illicit fentanyl is smuggled into the United States. The manufacturers constantly create new forms of fentanyl, each with a slightly different chemical structure. They do this to stay one step ahead of the authorities, who must individually ban each new fentanyl analog as it emerges. Drug dealers often lace their supply with fentanyl or an analog to boost its potency. Users may not know the strength of the drugs they're buying, or how the different substances in it interact. A particularly dangerous fentanyl analog, carfentanil, is increasingly turning up in the U.S. drug supply. Carfentanil is used as a large animal tranquilizer, and it is 100 times more potent than fentanyl—5,000 times more potent than heroin. "A small amount, just the size of a poppy seed, can kill you," Burns said.

Research Based on a Realistic Scenario

For their research, Sisco and colleagues used IMS and DART-MS instruments to detect 16 different fentanyl analogs, including carfentanil. Both technologies work by ionizing the molecules in question, which gives them an electric charge. An electrical field then draws the ions toward a detector, and you can measure how long it takes for them to arrive. That time delay is like a signature that identifies the molecule.

Detecting the synthetic drugs in their pure form is easy. In this case, the researchers mixed small amounts of fentanyl and fentanyl analogs with heroin and with common cutting agents such as caffeine.

"We wanted to mimic what first responders and evidence examiners are likely to see in the field," said Sisco. "Would the large amounts of cutting agents mask the fentanyl signatures? That's what we wanted to find out."

They found that, using IMS, they could detect fentanyl in mixtures that contain as little as 0.2 percent fentanyl. With DART-MS, they could easily detect mixtures down to 0.1 percent. Both types of instruments were able to detect traces of the compounds that inevitably land on the outside of plastic bags through handling. In addition, both techniques distinguished between most of the different analogs of fentanyl. This is important because some analogs are far more potent than others. In addition, identifying specific analogs will help law enforcement and public health officials keep track of new analogs as they emerge.

This research paper is the first to publish the IMS and DART-MS signatures for the 16 fentanyl analogs tested. Sisco and his co-authors are speaking with IMS manufacturers about adding the newly identified signatures to their product software. That way, agencies that already own the instruments would be able to identify the fentanyl analogs after their next software update. NIST publishes a widely-used DART-MS library, and the authors are working on getting the signatures added to that library as well.

"We hope this makes a real difference to the safety of people who come into contact with synthetic opioids," Sisco said. "The opioid epidemic is a huge problem. This might be one small way to try to get a handle on it."

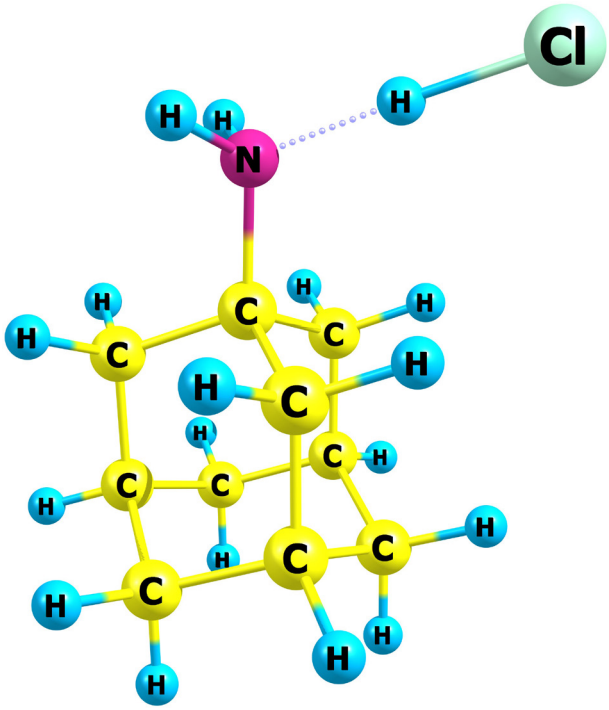
E. Sisco, J. Verkouteren, J. Staymates, J. Lawrence, Rapid Detection of Fentanyl, Fentanyl Analogues, and Opioids for on-Site or Laboratory Based Drug Seizure Screening using Thermal Desorption DART-MS and Ion Mobility Spectrometry, *Forensic Chemistry*, Published online 27 April 2017, http://dx.doi.org/10.1016/j.forc.2017.04.001

NEW NIST DATA TO AID PRODUCTION AND STORAGE OF 'FASCINATING' MEDICATION

Amantadine hydrochloride may be the most common medication you've never heard of. This compound has been around for decades as the basis for antiviral and other medications, from flu therapy to treatments for brain disorders such as Parkinson's disease and the fatigue associated with multiple sclerosis. And yet, this compound has long been a bit of an enigma because of missing information on its properties. Now, chemists at NIST and collaborators have published the very first data on this important chemical's thermodynamic properties, including data on how it responds to heat and changes from a solid into a gas. Such data are valuable to the chemical and pharmaceutical industries for getting the highest production yields and shelf life for the medication.

"Our research results are not directly related to the medical application of this multifunctional drug, although I am really fascinated by the range of its pharmacological activity," NIST research chemist Ala Bazyleva said. "We studied its thermodynamic properties and decomposition," Bazyleva said. "It is surprising, given the long history of amantadine-based drugs, that there is almost no information like this in the literature for many of them. Chemical engineers often have to rely on estimates and predictions based on similar compounds. Collating this information and developing these types of recommendations is at the core of what our group at NIST does."

Amantadine hydrochloride belongs to a diamondoid class, a family of compounds whose structure is based on a cage of carbon atoms similar to diamond. Amantadine has a single carbon cage with a nitrogen atom attached on one side. Nonmedical studies have focused on the solid form of amantadine hydrochloride because it was expected to form disordered, or plastic, crystals, as many diamondoids do. Turns out, amantadine hydrochloride does not.



NIST chemists have published the first data on the thermodynamic properties of amantadine hydrochloride, used for many years as the active pharmaceutical ingredient for antiviral and anti-parkinsonian medications. The new information can help optimize production and storage conditions of this important compound. Its structure in the gas phase was obtained by quantum chemistry methods. In the molecular structure, C is carbon, H is hydrogen, N is nitrogen, and Cl is chlorine. Credit: Bazyleva/NIST

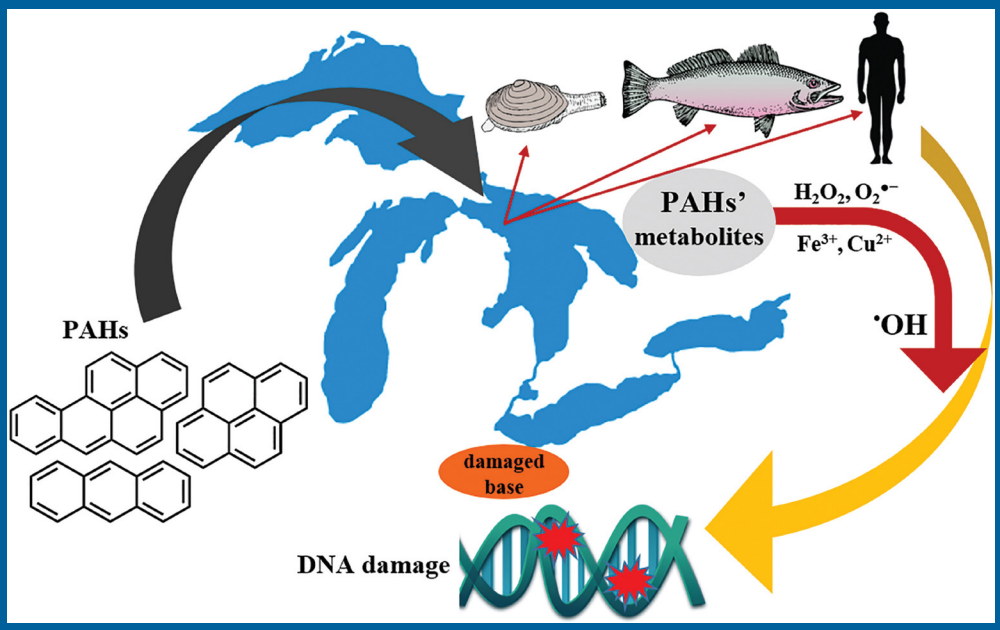
Bazyleva began studying amantadine hydrochloride years ago while in Belarus working on her doctoral dissertation, and continued the effort during her postdoctoral studies in Germany and Canada. But progress was slow, partly because adamantine hydrochloride changes from a solid directly into a gas (a process called sublimation) and simultaneously falls apart, or decomposes. She needed a model explaining this complex process, one that incorporates detailed, high-level calculations of quantum chemistry. She finally got access to this computational capability after she began working with the Thermodynamics Research Center (TRC) Group at NIST in Boulder several years ago.

"NIST was fundamental in facilitating the modeling component," Bazyleva said. "In particular, the unique combination of facilities, software and expertise in quantum chemical computations allowed us to apply high-level calculations to get insight into the structure and stability of the drug in the gas phase."

While the compound behaves like it is ionic (composed of positively and negatively charged pieces, though neutral overall) in the solid crystal form and when dissolved in a liquid, quantum chemistry calculations revealed that it decomposes into two neutral compounds in the gas phase. The data were generated by NIST's TRC, which for more than 70 years has been producing chemical data for scientific research and industrial process design. Co-authors are from the Belarusian State University in Belarus; the University of Rostock in Germany; and the University of Alberta in Canada.

Bazyleva, A.V. Blokhin, D.H. Zaitsau, G.J. Kabo, E. Paulechka, A.F. Kazakov and J.M. Shaw, Thermodynamics of the antiviral and antiparkinsonian drug amantadine hydrochloride: condensed state properties and decomposition, *Journal of Chemical and Engineering Data*, Published online May 1, http://dx.doi.org/10.1021/acs.jced.7b00107

NIST RESEARCHERS DEVELOP A GENOTOXICITY ASSESSMENT TOOL FOR THE GREAT LAKES



Researchers in MML's Biomolecular Measurement Division, in collaboration with researchers at the National Ocean and Atmospheric Administration (NOAA; Mussel Watch Program), have recently reported in the journal *Environmental Toxicology*, a method for evaluating genotoxicity effects, DNA damage, in the soft tissues of zebra mussels found in the Great Lakes. The mussels were obtained from archived samples collected from the harbor of the Ashtabula River in Ohio, where 500,000 cubic yards of sediment contaminated with 25,000 pounds of PCBs, uranium, radium & thorium were removed between 2006 and 2007 as part of the Great Lakes Legacy Act of 2002. NIST researchers measured DNA damage in mussels collected in 2014 from the Ashtabula harbor, where NOAA has confirmed measurement of elevated concentrations of polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs), versus mussels collected from a reference area away from the harbor on the shores of Lake Erie. From this sampling, the extent of DNA damage appeared to be correlated with exposure to pollutants. The reported genotoxicity assessment uses NIST Standard Reference Material 2396 Oxidative DNA Damage Mass Spectrometry Standards. Publication of the assessment protocol, combined with the availability of SRM 2396, enables widespread measurement of genotoxicity effects in species, such as the zebra mussels, to determine the extent of pollutant bioeffects on organisms as well as success of remediation efforts.

P. Jaruga, E. Coskun, K. Kimbrough, A. Jacob, W.E. Johnson, M. Dizdaroglu, Biomarkers of oxidatively induced DNA damage in dreissenid mussels: A genotoxicity assessment tool for the Laurentian Great Lakes, *Environmental Toxicology*, 2017, https://doi.org/10.1002/tox.22427

X-RAYS FROM COPPER SOURCE SET NEW GOLD STANDARD FOR MEASURING INDUSTRIAL MATERIALS

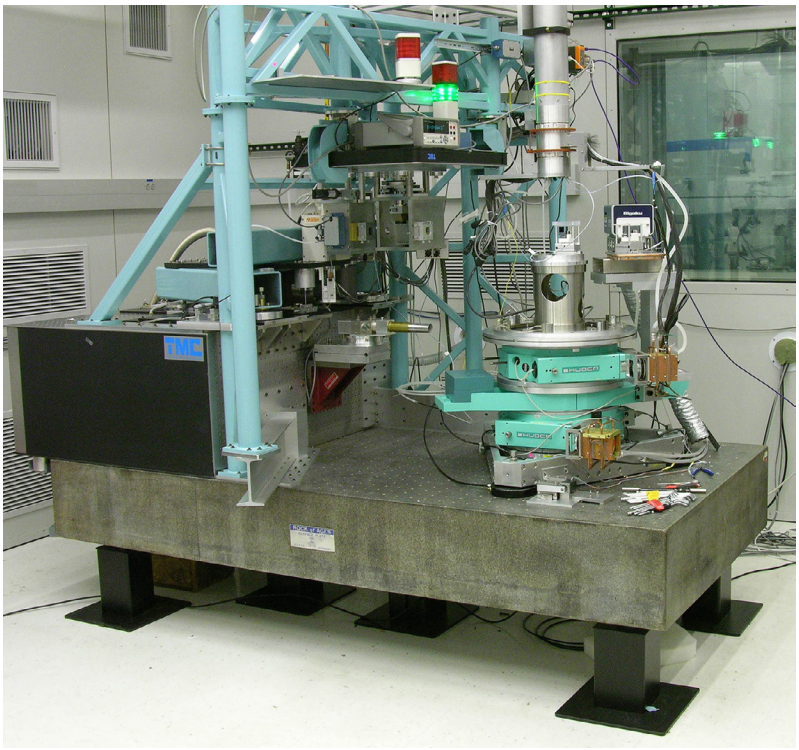
World's most accurate measurements of important X-ray spectrum could advance applications from infrastructure to drugs

Researchers at NIST have produced and precisely measured a spectrum of X-rays using a new, state-of-the-art machine. The instrument they used to measure the X-rays took 20 years to develop, and will help scientists working at the agency make some of the world's most accurate measurements of materials for use in everything from bridges to pharmaceuticals. It will also ensure that the measurements of materials from other labs around the world are as reliable as possible.

The process of building the instrument for making the new measurements was painstaking. "This new specialized precision instrument required both a tremendous amount of mechanical innovation and theoretical modeling," said James Cline, project leader of the NIST team that built the machine. "That we were able to dedicate so many years and such high-level scientific expertise to this project is reflective of NIST's role in the world of science."

"The wavelength of an X-ray is a ruler by which we can measure spacings of atoms in crystals," said Marcus Mendenhall, lead author of a new paper in the *Journal of Physics B: Atomic, Molecular and Optical Physics* that applies the new instrument to the measurement of the copper X-ray emission spectrum. "We now know the length of our ruler better, and all kinds of materials can now be measured with improved accuracy."

The new machine will allow researchers to link measurements of the lattice spacings with greater confidence to the definition of the meter in the International System of Units (SI). It is the comparisons to the SI meter that allow for quality assurance at the smallest and most precise levels. The researchers' measurements were consistent with results from the past 40 years and captured new details of the X-ray spectrum. In addition to the lattice spacings, all of the elements that went into making measurements were fully traceable to the SI, assuring the accuracy and reliability of the measurements.



NIST's new X-ray machine for high-precision measurement of the Copper Alpha spectrum, shown here in its 0.01 degree Celsius temperature-regulated space. Credit: James Cline/NIST

X-ray work is often associated with medical care, but X-ray instruments are also widely used in commerce, as they can help to identify and characterize a broad range of common substances, including cement, metals, ceramics, electronics and medicines. In both medical and industrial applications, X-rays provide scientists with a way to see inside matter. In the case of injured humans, that might mean looking inside a body to see problems such as broken bones. X-rays are also used, however, to view the atomic structure of substances via a method known as diffraction.

Powder diffraction—which involves grinding a substance and placing it into a precision X-ray machine for analysis—has become a ubiquitous analytical technique in science. There are now more than 30,000 laboratory diffractometers being used to view crystals using X-rays with powder diffraction methods around the world. In addition, there are several hundred powder diffractometers worldwide that utilize nonconventional types of radiation such as those from synchrotron and neutron sources.

NIST produces Standard Reference Materials (SRMs) for industry and academic research, and they are essential for quality assurance programs and to verify the accuracy of specific measurements. The agency also produces reference values needed for calibrating laboratory X-ray instruments worldwide. This new, high-precision machine will play a large role in the future of both enterprises.

The X-rays the new instrument produces, the K-alpha lines of copper, are no different from those produced by countless other X-ray machines. They are produced by firing electrons at a copper target. What is different, however, is that years of engineering and calculation have brought forth an instrument that can scan a full circle around the sample with extraordinary accuracy. Additionally, it is equipped with an X-ray camera that gives much richer information than traditional detectors, and provides self-consistency checks for alignment of the sample and reduces systemic uncertainties. The instrument was constructed in a subterranean laboratory featuring a closely controlled temperature, which allows for extremely accurate measurements.

One of the team's proudest accomplishments was the instrument's well-characterized goniometer, which is the part used for the measurement of the angles between the faces of crystals that make up typical samples of solid materials. The machine is calibrated using the circle closure method, a technique that uses multiple comparisons of the differences between two or more angular scales, repeatedly rotated with respect to each other to determine the measurement uncertainties in each scale. This, in conjunction with wide scan range, allows accurate measurement of the angle between the crystals and, therefore, the X-ray spectrum, without disturbing crystal alignment.

Mendenhall and Cline are now planning to update the measurements of many SRMs as well as other important X-ray lines (from materials other than copper) in the NIST catalog using their new machine. That process will take time, since this kind of X-ray measurement can take weeks or even months. Fortunately, most of the task only involves a small amount of human interaction, since the machine is automated once a measurement has begun, allowing the scientists to continue researching other topics while the machine does its job.

"The goal was not to make a machine that the rest of the world and commercial entities can imitate and make themselves, but rather, to make a machine that can give everyone the best answer to measurement questions," said Mendenhall.

M. Mendenhall, A Henins, L. Hudson, C. Szabo, D. Windover and J. Cline, High Precision measurement of the X-ray Cu Kα spectrum, *Journal of Physics B*: *Atomic, Molecular and Optical Physics*, Published online May 12, 2017, http://dx.doi.org/10.1088/1361-6455/aa6c4a

OUTREACH AND PARTNERING

NEW TRC CONSORTIUM MEMBER

The TRC Consortium is excited to announce the newest member of our long-running industrial consortium, D. E. Shaw Research (DESRES). The NIST Thermodynamics Research Center (TRC) Group, within the MML Applied Chemicals and Materials Division, provides industry with high quality thermophysical and thermochemical data for improved design, operation, and innovation in the chemical manufacturing and related industries. DESRES is a privately held biochemistry research company based in New York City that develops technologies for molecular dynamics simulations and applies such simulations to basic scientific research in structural biology and biochemistry, and to the process of computer-aided drug design. By leveraging the unique data resources the TRC Group provides through ThermoData Engine, DESRES will be able to develop and validate the next generation of molecular force fields, making *in-silico* prediction of drug-biomolecule interactions fast and reliable.

NIST EXPANDS DISTRIBUTION CHANNELS FOR THERMOPHYSICAL PROPERTY DATA

Knovel Data Analytics has just released a new way for the chemical science community to access the property recommendations of the NIST Thermodynamics Research Center (TRC) Group of MML's Applied Chemicals and Materials Division. Under a licensing deal between Knovel and NIST, Knovel has just released for limited Beta distribution their visualization technology as applied to the NIST ThermoData Engine (TDE). TDE represents the first implementation of an expert system for thermophysical and thermochemical property data, combining a database of experimental data, the latest property prediction schemes, and expert heuristics to dynamically provide up-to-date recommendations for the properties of well-defined compounds. Through this agreement, Knovel plans to distribute these NIST data resources to its network of subscribers including academic and industrial libraries. This distribution channel is in addition to others already in place, and strengthens the penetration of NIST data to its broad community of users.

GENOME EDITING CONSORTIUM

Targeted genome editing tools can be used to generate changes at specific sites of the DNA code in living cells. These technologies are being actively pursued by industry, academic, government, and non-profit sectors to advance medicine and bioscience in areas such as regenerative medicine, synthetic biology, novel antimicrobials and antivirals, protein therapeutic biomanufacturing, agriculture, and global food production. Utilizing these technologies for manufacturing and to generate therapies to treat patients will first require robust quantitative assays and measurements to enable high confidence characterization of DNA alterations resulting from genome editing. MML's Biosystems and Biomaterials Division, with the input of other government, academic, and industry stakeholders, is developing a NIST-led Genome Editing Consortium to assist with meeting these needs. The pressing need for norms and standards in this field was highlighted and summarized in a June 2017 *Nature Methods* editorial where the journal endorsed the value of NIST assisting the genome editing community and encouraged readers to engage with NIST. (http://www.nature.com/nmeth/journal/v14/n6/full/nmeth.4328.html)

OUTREACH AND PARTNERING

HARNESSING BIG MATERIALS DATA THROUGH THE MATERIALS DATA FACILITY

In 2015 the Center for Hierarchical Materials Design (CHiMaD), a NIST Center of Excellence, collaborated with NIST staff to establish the Materials Data Facility (MDF). The MDF accelerates, streamlines, and automates data-driven discovery. The MDF is a suite of cloud-based data services and tools that makes materials data more easily publishable and discoverable, and decreases the barriers inherent to sharing and describing complex and often large materials science datasets. The MDF allows researchers to self-publish datasets while also providing flexible data sharing and search capabilities for these published datasets. In addition to facilitating materials discovery more broadly, these capabilities will specifically help NIST Materials Genome Initiative goals by making datasets generated via CHiMaD, select NIST resources, and other community datasets more discoverable, easier to share, and more accessible. Progress on the MDF was recently presented at the CHiMaD 2017 Annual Review Meeting. To date, the MDF has taken in large data sets with more than 1.5M files and 1.5 terabytes. By volume, MDF has 7.2 terabytes of materials data, across 31 total datasets (with more than 30 more in the pipeline), and has provided data publishing solutions to 94 authors from 14 institutions. MDF has shared 5.3 terabytes of data, facilitating materials data research for thousands of end users. In addition to indexing individual data sets, 16 large data sources have been fully indexed, further facilitating data discovery, and six additional data repositories have been harvested, including around 200 datasets, with more than 1M individual records, and 260 TB of now discoverable data. More information is available in the CHiMaD 2017 Annual Report.

MEASURING THE IMPROVEMENT OF NOVEL ELECTRONIC DEVICES

Researchers in MML and NIST's Physical Measurement Laboratory, in collaboration with Wake Forest and Georgetown Universities, have performed an in-depth study to help elucidate the effect of structural disorder on the evolution of transistor performance. Recent efforts toward developing materials for new types of flexible and biocompatible electronic devices, such as durable displays and implantable bioelectronics, rely on novel materials in which the physical mechanisms are not well understood. In a recent article, the NIST-led team describes an experimental study of incrementally ordered polymers that provides a clear connection between energetic ordering and device ideality by showing the progression from energetically disordered to ideal devices. The science behind formation of ideal devices in these platforms is essential to predicting and creating usable electronics.

E. G. Bittle et al., Dependence of electrical performance on structural organization in polymer field effect transistors, *J. Polym. Sci. Part B Polym. Phys.*, 2017, http://dx.doi.org/10.1002/polb.24358

NIST-FDA WORKSHOP SERIES

NIST and FDA are actively collaborating on projects that address regulatory and measurement challenges for cell therapies and regenerative medicine products. As a part of this joint effort, NIST and FDA held a highly successful workshop on Sharing Practices in Cell Counting Measurements on April 10, 2017. Workshop presentation slides can be found at https://www.nist.gov/news-events/events/2017/04/nist-fda-cell-counting-workshop-sharing-practices-cell-counting. Building on the success of the Cell Counting Workshop, NIST and FDA are planning a workshop to examine measurement challenges associated with flow cytometry: https://www.nist.gov/news-events/events/2017/10/nist-fda-flow-cytometry-workshop-building-measurement-assurance-flow

AWARDS

REFRIGERANTS RESEARCH HONORED WITH ROCKY MOUNTAIN EAGLE AWARD

On July 20, Mark McLinden (left) and Andrei Kazakov (right) of MML's Applied Chemicals and Materials Division were awarded the Colorado Federal Executive Board's Rocky Mountain Eagle Award for Scientific Achievement. Kazakov and McLinden worked as part of a team from 2011 to 2017 to provide industry with feasible refrigerant options to transition to the next generation of refrigerants. At present, the most common refrigerants are hydrofluorocarbons. Because of their high global warming potential, hydrofluorocarbons are being phased out per the Montreal Protocol, an international treaty which mandates an 85% reduction of HFCs by 2036 which translates to $45B- $99B cost to the U.S. economy. Using artificial intelligence methods, the team identified the performance characteristics of 'ideal' refrigerants and carried out a systematic and exhaustive screening of a comprehensive database of molecules — 60 million in total - then winnowed this database down to a set of 27 'best' candidates. The study demonstrated inevitable tradeoffs between efficiency, global warming potential, flammability and toxicity, and presented an optimal set of potential refrigerants, which are critical in facilitating the transition facing the industry.

CICERONE RECEIVES FLEMMING AWARD

Marcus Cicerone was recently recognized for outstanding federal service through seminal contributions to the field of label-free chemical imaging, by introducing broadband coherent anti-Stokes Raman scattering (BCARS) microscopy, and to the field of biological therapeutics by introducing the practice of using nanosecond and picosecond dynamics to rapidly and accurately predict long term stability of freeze-dried therapeutic proteins. Cicerone has followed these landmark accomplishments with simplifying adaptations that allow the associated technologies to be used in practical applications; BCARS for label-free chemical mapping of diseased tissues with unprecedented speed, and a bench-top fluorescence method for rapidly evaluating freeze-dried formulations.

KILPATRICK RECEIVES AACC AWARD

On August 1, 2017, MML staff scientist Eric Kilpatrick was honored with the Outstanding Abstract Award in the Division of Mass Spectrometry and Separation Sciences at the 2017 American Association for Clinical Chemistry Conference in San Diego, CA. Kilpatrick's abstract was entitled "Characterization of Standard Reference Material 2924 C-reactive Protein Solution."

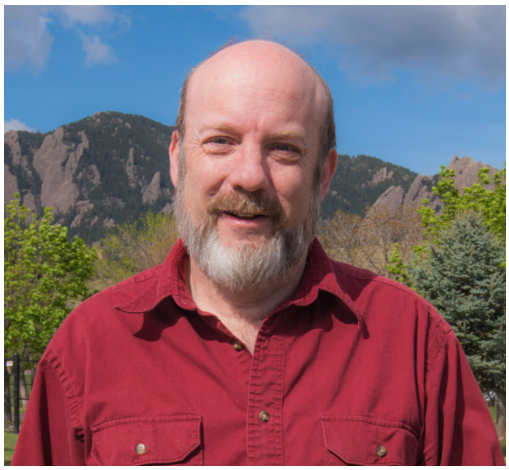
AWARDS

GAYLE AND COOK RECEIVE 2016 JMR PAPER OF THE YEAR AWARD

Andrew Gayle (left) and Robert Cook (right) were selected by the *Journal of Material Research*, a publication of the Materials Research Society, for the 2016 *JMR* Paper of the Year Award. The paper is entitled "Mapping viscoelastic and plastic properties of polymers and polymer-nanotube composites using instrumented indentation." The *JMR* Paper of the Year Award recognizes excellence in advancing materials knowledge through written scholarship. The announcement took place at the 2017 MRS Spring Meeting in Phoenix, Arizona.

MIGLER RECEIVES WASHINGTON ACADEMY OF SCIENCES AWARD

On May 11, 2017, the Washington Academy of Sciences presented an award to MML staff scientist Kalman Migler (left) at their annual awards banquet. Migler was recognized for the design and application of innovative optical and rheological experimental techniques to definitively measure and affirm key physical phenomena of polymer fluid flow. The Washington Academy of Sciences (http://www.washacadsci.org) was incorporated in 1898 as an affiliation of Washington D.C. area scientific societies.



LEMMON HONORED WITH AGA ACHIEVEMENT AWARD

On May 1, 2017, Eric Lemmon of MML's Applied Chemicals and Materials Division was presented with the Achievement Award at the American Gas Association (AGA) conference and exhibition in Orlando. The AGA represents more than 200 local energy companies committed to the safe and reliable delivery of clean natural gas to more than 69 million customers throughout the nation. In early 2000, AGA approached NIST to help AGA revise AGA Report No. 8 which pertains to the thermodynamic properties of natural gas. NIST's willingness to help set the course for a unique and exemplary partnership between government and the private sector for the benefit of the natural gas industry. It included over 10 years of research and working with national and international experts, such as researchers at the Ruhr University in Germany, the International Standards Organization, AGA's Transmission Measurement Committee, and various stakeholders associated with the American Petroleum Institute and GPA Midstream Association. The revised AGA 8, which is now two parts, is the result of this extensive effort and hard work. The AGA Achievement Award recognizes an individual whose dedication, significant efforts, and contributions have led to the advancement of the natural gas industry and those that work for this industry.

AWARDS

WONG-NG NAMED ICDD FELLOW

MML research chemist Winnie Wong-Ng has been named the 2017 Distinguished Fellow for the International Centre for Diffraction (ICDD). ICDD is a non-profit scientific organization as well as a publishing house for the Powder Diffraction File (PDF). The PDF is a versatile database and tool that is used worldwide for materials characterization. This award is for her sustained outstanding contributions to ICDD, to the growth of the PDF, and to the powder diffraction community.

DOE SUPERCOMPUTING AWARD

The U.S. Department of Energy (DOE) Advanced Manufacturing Office has awarded a supercomputing allocation of approximately 150 million CPU-hours to a team of chemists and chemical engineers from the American Chemical Society Green Chemistry Institute Chemical Manufacturers Roundtable and MML's Chemical Informatics Research Group for a proposal titled, "Accelerating the Industrial Application of Energy-Efficient Chemical Separations." The award was granted through the DOE's High-Performance Computing for Manufacturing program, which seeks to apply high-performance computing resources within the DOE to specific, high-priority problems identified by American manufacturing companies. In broad terms, these problems include the advancement of innovative clean energy technologies and the reduction of energy and resource consumption. The team's proposal is based on the chemical manufacturing industry's reliance on distillation for separating fluids. By itself, distillation accounts for 90% of all separations in the chemical manufacturing industry, and more than 50% of a plant's energy consumption and capital costs. More significantly, chemical distillation represents approximately 10% of the world's energy consumption. Although separation processes based upon porous materials (e.g., adsorbents and membranes), collectively referred to as mass separating agents (MSAs), are expected to operate at a small fraction of the energy cost of conventional distillation, a major technical roadblock preventing the widespread adoption of these energy-efficient alternatives is the lack of thermodynamic data. The team's idea is to fill this fundamental knowledge gap by using state-of-the-art molecular simulation methods and statistical mechanical analysis techniques developed in the Chemical Informatics group and some of the fastest supercomputers in the world. This wealth of data will be made publicly available to scientists and engineers to analyze and hopefully develop new theories of adsorption, which currently remains at an ideal-gas-level of sophistication.

HOW NIST REFERENCE MATERIALS AFFECT YOU (CONT.)

Taking measurements to court

In 1978, Michael Hanline was found guilty of murder in California. But Hanline always said he was innocent. Eventually, the California Innocence Project at California Western School of Law took up his case, and through DNA analysis, showed that Hanline was not the source of DNA found on key evidence. Hanline spent 36 years in prison. He is the longest-serving wrongfully convicted person in California history. When Hanline was convicted, the ability to evaluate DNA evidence didn't yet exist. But today, it's not uncommon to hear of cases where DNA evidence makes or breaks the case. And not just to exonerate the innocent. Far more often, DNA evidence helps law enforcement put away the right people the first time.

NIST forensic DNA SRMs are crucial to this process. They help make sure that labs conducting forensic DNA analysis obtain accurate results. The Federal Bureau of Investigation requires that forensic DNA testing laboratories meet certain quality assurance standards. Labs must check their processes with a NIST SRM (or a reference material that traces back to NIST) every year or anytime they make substantial changes to their protocol.

"The NIST DNA SRM we use in our lab is essential to ensure our analyses are reliable," said Todd Bille, DNA technical leader at the Bureau of Alcohol, Tobacco, Firearms and Explosives. "With all the advances in the forensic community, NIST SRM 2391c is the only set of DNA samples that has what we need to make sure the analyses function properly in our hands. Our lab is also constantly evaluating new methods to handle DNA. Having this set of standard DNA samples allows us to be sure new methods don't adversely affect the results."

Cementing quality control

First of all, John Sieber wants you to know: There's a difference between cement and concrete.

"People get the two mixed up," says Sieber, a NIST research chemist. "Cement is what you have before, and then you mix it with water and sand and gravel—aggregate, they call it—and you pour it into your sidewalk and it hardens through a chemical reaction and becomes concrete."

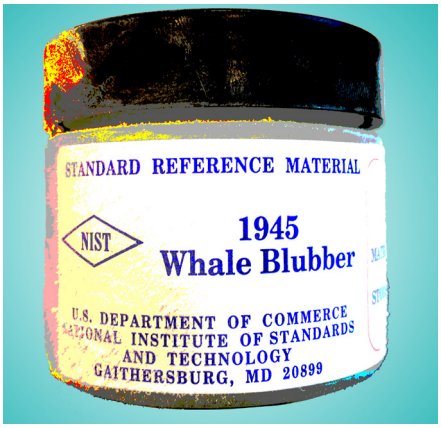
Though you may have never given it a second thought, you no doubt interact with concrete on a daily basis as you drive to work, park your car in a garage, walk across the sidewalk to your office and sit at your desk in a high-rise building.

"The human race is trying to cover the planet in concrete," Sieber jokes.

To make sure their product can withstand the tests of time, wear and weather, cement makers conform to certain quality standards. During the manufacturing process, cement makers test their products hourly. NIST SRMs are crucial to letting manufacturers know the results of their tests are accurate—and that they're creating a high-quality product. NIST sells 15 cement—not concrete—SRMs that help manufacturers ensure their products meet certain quality standards and help buyers know they're getting what they paid for.

Standards of excellence

To tell the story of SRMs is to tell the story of industry in America—its breakthroughs and its setbacks. From the turn of the 20th century onward, NIST stood with American makers as they erected skyscrapers, laid railways and took to the skies in airplanes. NIST helped manufacturers overcome technical challenges they faced in bringing innovative technology to the American people. In 1905, NIST—then known as the National Bureau of Standards—began preparing and distributing the first SRMs, standardized samples of iron, which manufacturers used as a check on their lab analyses. From those early standard samples, the program grew.



NIST SRM 1945: Whale Blubber (posterized)
Credit: R. Pugh and K. Irvine/NIST

Today, NIST still sells versions of these original SRMs, but it has come a long way. The diverse array of SRMs currently available reflect the complexity and technological advancement of a 21st-century society—and the new challenges it faces. NIST constantly works to improve its existing SRMs to adapt to changing needs—such as the arsenic levels added to the rice flour SRM, or the blueberry SRM, to which NIST is in the process of adding measurements for anthocyanins, a type of flavonoid, or pigment, in the blueberries that contributes to its antioxidant properties. And, NIST is always looking for opportunities to create new SRMs to drive innovation in emerging markets, like the monoclonal antibody SRM for biopharmaceutical manufacturers.

"Good science is our carrot," Choquette says. Speaking of carrots, we've got an SRM for that.

MML MEASURES UP

A NIST-developed benign microbe stands in for the bacteria that causes bubonic plague in an exercise in which first responders participate to test their ability to detect biothreats.

UNUSUAL SUSPECTS

Microbial metrology for national security

NIST contributes to public safety with materials that increase the confidence of first responders to detect biothreats in the field.

NIST's Material Measurement Lab developed a microbe that members of law enforcement, the military, and public health labs can use to test their equipment and protocols for detecting biological weapons. Federal law enforcement officers have responded to more than 40,000 reports of suspicious powders–nearly one per day—since 2001. Tests on suspect powders can take hours or weeks, sometimes shutting down public services or requiring evacuations until results are confirmed. To avoid unnecessary disruptions and keep people safe from genuine threats, first responders need to rapidly detect suspicious powders in the field, but a lack of consistent protocols and variations in test results have dissuaded the community from relying on field testing to make decisions.

The yeast could "serve as a viable resource for the first phase of training programs" and "be used periodically as a 'confidence checker' to allow first responders, under controlled conditions, to review or practice their skills."

—Association of Public Health Laboratories Preparedness and Response Committee

The NIST team created a candidate reference material based on genetically engineered yeast that is both appropriately challenging to detection equipment and safe. (Training is often conducted with real biothreats that have been inactivated. In 2015, the Department of Defense mistakenly shipped live anthrax spores to multiple labs.) The yeast material was used in a successful training exercise where nearly a dozen local, state, and federal teams demonstrated their ability to correctly sample and assess biological material in the field. As further proof of concept, the team conducted an interlaboratory comparison study with five public health laboratories, one mobile laboratory, and one in-house laboratory, all of which detected the yeast.

The yeast was modified to contain a genetic sequence from a microbe that lives only on deep sea vents, giving responders a unique DNA signature to look for as they train and challenge their detection technologies. Because it is so unlike any real biothreat, any residue of the yeast stand-in doesn't convey a risk of causing false positive tests during a response to a genuine suspicious powder. It can also be used to assess any process that detects DNA, such as those used in food safety and environmental monitoring. In addition to the development of this candidate reference material, the team contributes to protocols for collecting powder samples and, working with ASTM, standards for biothreat field response.

100% of participants in a simulated suspected biothreat exercise detected the yeast material

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