MATERIAL MEASUREMENT LABORATORY

TURNING IDEAS INTO INNOVATIONS

MEASUREMENT SCIENCE AND TECHNOLOGY FOR THE NATION AND INDUSTRY

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

The Material Measurement Laboratory supports the NIST mission by advancing measurement science, standards and technologies in the biological, chemical and materials sciences that contribute to innovation and help American industries compete globally.

NIST

The NIST mission is to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards and technology in ways that enhance economic security and improve our quality of life. A non-regulatory agency, NIST is an unbiased source of scientific data and metrology practices staffed by people committed to serving the nation by improving efficiency, competitiveness and acceptance in global markets, and contributing to the responsible adoption of technology and science-backed policy development. NIST has a research infrastructure that few members of industry or academia can match, which we apply to respond to national needs to benefit all Americans.

Introduction

Why measure? Nearly every aspect of modern life relies on measurements: They provide us with a way of describing the state of our environment and the objects within as well as a common language on which commodities traders, manufacturers, regulators and consumers agree.

Metrology is the science of measurement. The Material Measurement Laboratory is one of two metrology laboratories at the National Institute of Standards and Technology. We employ metrology to find new ways of measuring known substances with ever more precision and accuracy and ways of measuring and characterizing novel substances for the first time. We also use metrology to develop measurement standards—in the form of documented measurement methods, instrument calibrations or reference materials—that help people generate reliable and reproducible measurements. Metrology helps us have confidence in measurements, which is essential to health care, safety and security, food safety and nutrition, every sector of manufacturing, and scores of other human endeavors.

When clinical labs check the validity of their vitamin D or cholesterol test methods, they are likely to use Standard Reference Materials developed by scientists at the Material Measurement Laboratory. When engineers design new steel bridges and buildings, they are likely to rely on strength tests that have been verified by Standard Reference Materials developed at the Material Measurement Laboratory. When first responders handle suspicious powders, they are likely to use collection protocols developed by staff members of the Material Measurement Laboratory.

We shape our programs based on national needs with input from industry and government. Thanks to the breadth of our research programs and the depth of our metrology expertise, we have the flexibility to respond to national priorities and rapid advances in science and technology.

Manufacturing Measures Up

The Material Measurement Laboratory at NIST supports American manufacturers with measurement solutions that enable:

- Design, optimization, scale-up, monitoring and control of manufacturing processes, including biomanufacturing
- Quality control and assessments of the manufacturability of raw chemicals and materials
- Assessments of the regulatory compliance of production processes
- Assessments of the sustainability of manufacturing enterprises and products

As you'll read in these pages, our support of manufacturing cuts across many technology sectors including advanced materials, automotive, biomanufacturing, chemicals, electronics, energy, and materials for bridges, roadways, pipelines and other engineered structures. We are contributing to an American advanced manufacturing infrastructure that can support the development of new generations of technology-based products, creating jobs and a stronger economy.

Our work addresses measurement-related issues in these areas of national importance:

- Advanced materials
- Biomedical and health
- Electronics
- Energy
- Environment and climate
- Food safety and nutrition
- Manufacturing
- Physical infrastructure
- Safety, security and forensics

Our customers include members of established industrial sectors, emerging industries, government agencies, standards and trade organizations, and the academic and scientific research communities.

When trading partners agree on systems of measurement, technical barriers to international trade are diminished. Members of the Material Measurement Laboratory work with the international community, including our counterparts at other national metrology institutes, to help make systems of measurement and standards compatible worldwide.

Measurement Services

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NIST Standard Reference Material® is a registered trademark for a physical artifact produced and with property values certified by the National Institute of Standards and Technology. NIST Standard Reference Materials are used by manufacturers and test labs to calibrate measurement instruments, verify the accuracy of measurements and develop new measurement methods. Standard Reference Data, also produced by NIST researchers, are collections of critically evaluated qualitative and quantitative information on the composition, structure and state properties of a variety of substances, from refrigerants to DNA markers for human identity tests.

The Material Measurement Laboratory coordinates the NIST-wide Standard Reference Material and Standard Reference Data programs, which include production, documentation, inventory, marketing, distribution and customer service. NIST provides more than 1,300 Standard Reference Materials that ensure the accuracy of millions of measurements made daily in medical clinics, manufacturing plants and industrial labs, and federal and state agencies.

NIST supports U.S. industry by providing traceability to national standards and the International System of Units. Furthermore, NIST interacts with other national metrology institutes to ensure the comparability of measurement standards worldwide. Therefore, industry sectors that use NIST reference materials can develop their own measurement infrastructures knowing that measurement results for their products meet the requirements of foreign markets.

Advanced Materials

Because advanced materials have novel properties, they must be fully characterized so they can be incorporated into products that outperform existing products and create new industries. As such, measuring the properties of advanced materials requires cutting-edge instruments, methods and standards. With unmatched expertise, the scientists at the Material Measurement Laboratory at NIST develop world-class measurement technology—instruments, measurement methods, standards, models and data—based on the most advanced measurement science to accurately determine the composition, structure and properties of advanced materials.

NIST

The NIST spectroscopy beam lines at the National Synchrotron Light Source at Brookhaven National Laboratory, staffed by members of the Material Measurement Laboratory, enable analysis of the structure and chemistry of materials and devices at the nanoscale, thereby assisting industry with advanced materials development and optimization. A quarter of the operating time of the National Synchrotron Light Source is available to members of industry, academia and other government agencies who are investigating and developing new materials.

NATIONAL NEEDS	CORE CAPABILITIES AND EXPERTISE	PRODUCTS AND SERVICES
Metrology and technology to advance: Materials by design Materials discovery Materials identification and optimization Materials substitution Materials sustainability	**Composition and structure determination** Surface analysis and depth profiling at the sub-nanometer scale X-ray, neutron, electron, ion, laser, synchrotron and optical-based methods Electron and scanning probe microscopy Mass spectrometry Synchrotron spectroscopy Nanoparticle measurements	SRMs* and RMs† for: Gold nanoparticles Carbon nanotubes X-ray diffraction Low-temperature thermoelectrics SRD‡ for Phase equilibria diagrams Crystal structure Thermodynamics Nanoparticle measurement protocols
	Mechanical property measurements from the nano- to macro-scale Deformation and fracture Adhesion High-impact testing Sheet metal forming Strain mapping	
	Magnetic property measurements High-resolution transmission electron microscopy Post-CMOS electronics	
	Thermal property measurements Thermophysical and thermoelectric methods Nanocalorimetry	
	Computational modeling methods First principles Atomistic Phase field Finite element Thermodynamically consistent representations Statistical optimization	

* NIST Standard Reference Material®
† Reference material
‡ Standard Reference Data

Nanoparticles one million times smaller than an ant can carry cargoes of cancer-killing drugs directly to tumors, eliminating the need for invasive therapies. Material "cages" neutralize harmful pollutants in air and water, making the environment safer and enhancing our quality of life. Magnetic materials are used to levitate trains, providing smooth, quiet and reliable transportation. These are just a few examples of how advanced materials—materials with novel or improved properties—are likely to contribute to technological innovations in manufacturing, the environment, energy, physical infrastructure and health care.

The Material Measurement Laboratory's capabilities enable innovation and commercialization of advanced material-based products such as cell phones, self-navigating cars and implantable medical sensors. Following are some examples of how our world-class capabilities for measuring advanced materials benefit U.S. industry and other federal agencies.

Lighter, more energy efficient vehicles. To boost fuel efficiency, the U.S. auto industry is striving to manufacture cars from lightweight metals including high-strength steels and aluminum and magnesium alloys, but companies do not have the requisite measurement capabilities to produce vehicle components from these advanced materials. In response, our Automotive Lightweighting Center develops and provides measurement methods, models and data that enable industry to rapidly design manufacturing methods for lightweight alloys at lower cost and to test the crashworthiness of vehicles containing lightweight alloys.

Sustainability through materials substitution. In response to new regulations and to capitalize on the growing market for products that are manufactured sustainably, many industry sectors wish to make products from advanced materials that have lower toxicity, consume less energy to process and incorporate fewer scarce elements, such as those in the rare earth family. The Material Measurement Laboratory is developing measurement methods and data to facilitate industry adoption of such advanced materials substitutions. For example, our researchers are working with industry to enable materials design and processing routes for composite materials, lead-free solders and polymers synthesized from biological rather than petroleum-based sources.

Advanced materials include newly discovered materials and existing materials used in new applications. Use of advanced materials with new or improved properties enhances the performance of products in ways that cannot be achieved through redesign of products containing "mature" materials.

Illuminating the smallest structures. For 30 years, NIST has partnered with the Department of Energy to develop advanced synchrotron measurement methods at the National Synchrotron Light Source at Brookhaven National Laboratory. There, powerful magnets accelerate electrons at high speeds to create intense beams of X-rays that can generate nanoscale, two- and three-dimensional maps of the chemical structures of materials that no other method of analysis can match. Each year, more than 200 researchers, many from industry, use the NIST beam lines to accelerate the development of new materials for new devices and systems for a broad spectrum of industries. The NIST beam lines have been used to characterize a single layer of carbon atoms in graphene, finding that folds and wrinkles in the material negatively affect its otherwise amazingly efficient conductivity, and that contaminants from processing graphene tend to linger among its folds. Basic research such as this helps manufacturers transform graphene and other materials from promising novelties into new or improved products that give us cleaner energy, faster electronics and many other benefits.

MANUFACTURING HIGHLIGHT

X-Ray Standards for Materials Innovation

The structures of a wide range of materials, from ceramics to metals and polymers, can be analyzed from the atomic to microscopic scales using X-ray diffraction techniques. Developers of advanced materials use X-ray diffraction for materials identification in process development and optimization, while manufacturers rely on these techniques for quality control.

The Material Measurement Laboratory provides a suite of X-ray Standard Reference Materials and is the world's only source of such physical artifacts for the calibration of diffraction equipment and measurements that are traceable to the International System of Units. Our X-ray reference materials enable such accurate analyses that the resulting measurements are often used in the validation of patent applications for advanced materials. In addition, our extensive crystallographic Standard Reference Databases provide accurate descriptions of the arrangements of atoms in over 140,000 solid materials, contributing to the development and optimization of industrial materials. Finally, NIST X-ray reflectometry methods can measure layer thickness and roughness of interfaces and surfaces of multilayer films sometimes just a few atoms thick, enabling the billion-dollar microelectronics industry to incorporate advanced materials into devices with greater performance, utility and reliability. (For more on our program in electronics, see page 12.)

We also collaborate with major equipment manufacturers to enhance measurement methods. Several of the leading vendors of X-ray diffractometers rely on NIST Standard Reference Materials to improve the performance of their equipment and include our standards with every instrument they sell.

Biomedical and Health

Health care spending in the United States accounts for over 15 percent of the gross domestic product. In addition to services for patients, health care spending includes everything from basic research to the manufacture of therapeutics, biological and chemical reagents, instruments, and other materials. This enterprise of goods and services depends on measurements that are accurate and comparable. The Material Measurement Laboratory develops and disseminates standards (reference methods, materials and data) to support the accuracy of those measurements, which are used to help doctors, patients and researchers make critical decisions about diagnoses and treatment of disease and what avenues of new therapies to pursue. Our products and services support laboratory medicine, diagnostics and molecular pathology, basic medical research, the medical device industry, and the discovery, development, and manufacture of new therapeutics.

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In the field of regenerative medicine, the Material Measurement Laboratory conducts research to develop new measurement methods and standards for the reliability of laboratory-grown cells and tissues and study the interactions between implantable materials and the body.

NATIONAL NEEDS		CORE CAPABILITIES AND EXPERTISE	PRODUCTS AND SERVICES
Metrology and technology to advance: Bioengineering Bioinformatics Biotherapeutic manufacturing Cell and tissue measurements Cell-based therapeutics Clinical chemistry Dental materials Forensic science Gene expression Genetic testing Immunology Laboratory medicine Medical and biological imaging Medical devices Metabolomics Molecular pathology Proteomics Regenerative medicine Toxicology and nanotoxicology	MOLECULAR	Identity, composition, concentration and biological activity of metabolites, sugars and lipids	Databases: HIV protease and Chem-BLAST gateway for Protein Data Bank ligands Reference materials
		Protein identity, structure, dynamics, function, interactions and concentration, and supporting database tools	Reference material for peptide molecular mass and purity Human mitochondrial protein database Biomolecular crystallization database
		Gene and genome-scale sequence analysis, amount (microbial and mammalian) and measurement assurance (DNA and RNA); DNA and RNA structure, dynamics and interactions; DNA damage, repair and lesions	Reference materials for amount of DNA, human identification (short tandem repeats), DNA sequencing, clinical genetics, DNA damage and repair Short Tandem Repeat DNA database Clinical DNA information resource database Clinical diagnostics quality assurance
	SYSTEMS	Structure, dynamics and interactions between biological and bioactive molecules including proteins and nucleic acids	Thermodynamics of enzyme-catalyzed reactions database Flow cytometry calibration
		Metabolic and molecular phenotype and complex responses of mammalian and microbial cells and populations, and supporting database tools	Cell image reference data Cell image analysis methods: live and static Reference materials for fluorescence microscopy Semantics for biological data database Extracellular matrix for controlled cellular response Cell line identification method Flow cytometry standards Best practices for characterization and measurement of biothreats
		Materials structure, dynamics and properties that directly affect their interactions with biological systems (cells and tissues)	Tissue scaffold reference materials Dental tissue reference materials
		Particle and protein characterization, process sensors, cell expression, biochemical-surface interactions	Standards for informing regulatory decisions on the safety and efficacy of biologics

In the 1980s, a national need prompted NIST to begin development of reference standards to improve the accuracy of clinical chemistry tests, which include the commonly performed serum cholesterol and electrolyte tests. In just one example of the impact of this program, the nation realizes savings of more than $100 million per year from improved cholesterol measurements that inspire people to change their lifestyles and enable doctors to make more informed life-saving treatment decisions for patients with cardiovascular diseases.

Today, the Material Measurement Laboratory maintains reference materials for over 30 analytes measured by chemistry-based clinical tests. The laboratory also maintains robust programs to develop standards for other areas of laboratory medicine and molecular pathology including genetic testing, DNA sequencing, clinical proteomics, toxicology, immunology and tests for serum protein disease markers such as prostate-specific antigen.

Investigators working on new therapeutics and diagnostics need accurate measurements to have confidence in results and compare them to understand if their attempts at making new drugs are successful. Messenger RNA, for example, carries the instructions for the production of proteins, which are essential to physiologic function—and dysfunction. Measuring which messenger RNAs for disease-related genes are at work is useful for discovering disease mechanisms and the effects of engineered bioactive molecules. Through its gene expression measurement efforts, the Material Measurement Laboratory developed the world's first reference standard to enable quantitative measurement of the amount of messenger RNA transcribed from genes, whether the measurements are made using gene chips, quantitative polymerase chain reaction or other techniques. In another first, we developed a Standard Reference Material for 50 metabolites in human plasma, in conjunction with the National Institutes of Health's Metabolomics Technology Development Initiative.

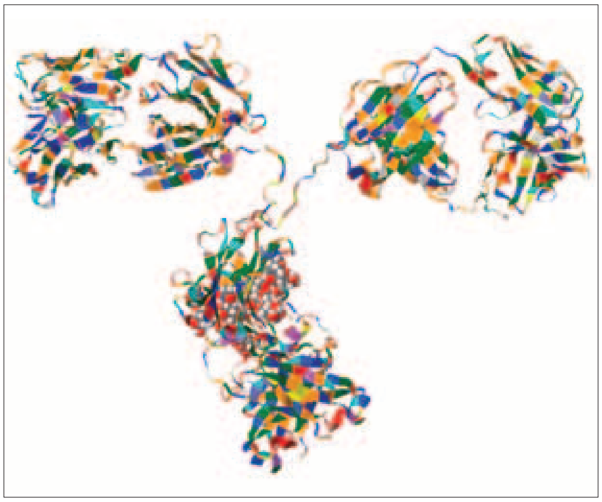
The Material Measurement Laboratory also supports measurements of proteins for cancer biomarker discovery: Through an ongoing collaboration with the National Cancer Institute's Clinical Proteomic Technology Assessment for Cancer program, we developed a set of necessary reference materials for mass-spectrometry measurement of proteins. In fact, the laboratory maintains the database of peptides and synthetic polymer reference spectra used in spectrometers throughout the world. We support cell- and tissue-based measurements as well, in part by providing the reference methods and materials that researchers require to determine the biomarkers present in and on cells. The laboratory also develops and maintains bioinformatics resources for researchers; our database of proteins from human immunodeficiency virus is just one example.

Pacemakers, cardiac stents, prosthetics and other implantable medical devices are made of metals and plastics. The emerging field of regenerative medicine also relies on implantable materials, many of which have novel and complex compositions. The companies that develop and market these devices require accurate measurements of their properties and how cells and tissues interact with these products so they can understand and prevent device failure from rejection or infection. Our core capabilities in chemistry, biology and materials science enable us to develop the measurement science and reference materials needed for these critical studies. We also enjoy long collaborations with the American Dental Association and the National Institutes of Health to develop the standards and measurements that accelerate the improvement of dental polymers.

MANUFACTURING HIGHLIGHT

Biomanufacturing

Biologic drugs, the fastest growing class of therapeutics, offer new life-saving options for patients with cancers and inflammatory diseases. Unlike traditional chemical pharmaceuticals, most biologic drugs are complex mixtures of large protein molecules that are not easily identified or characterized. They are made by living cells in a manufacturing process that is difficult to control and subject to variability. They also can induce immune responses that harm patients and reduce their efficacy. Their complexity means that biologic drugs cannot be exactly copied as generics after patent expirations; they can only be made to exhibit similar physical, chemical and clinical properties—hence copies are called "biosimilars." Because of the challenges inherent in biologic drugs, thousands of critical measurements are performed in their development and manufacturing. The Material Measurement Laboratory develops standards and methods for improved measurements of the structure of biologics, their immunogenic properties, and better understanding of the cells used in their manufacture. Our programs help improve the development and manufacturing process of biologic drugs, inform regulatory decisions for both new and biosimilar products, and improve their safety and efficacy for patients.



RCSB PDB, LJ Harris et al. Biochemistry 36: 1581 (1997)

The stability of protein molecules that constitute biologic drugs depends on the presence of sugar groups (or glycans) that are added to the protein molecules. To analyze the glycan content (shown here in red and white buried in the bottom center region of the protein) for quality control, drug makers often rely on traditional chromatography or mass spectrometry analysis methods, which can be time consuming, expensive and require expert data interpretation. As alternatives, researchers at the Material Measurement Laboratory are developing measurement techniques for rapid glycan analysis using lectins, proteins that bind to particular sugars. One such method for rapid glycan analysis can be read without instruments in about 10 minutes or with common laboratory tools in about one minute.

Electronics

NIST has contributed to the microelectronics industry since its beginnings, pioneering nondestructive measurements of the silicon in semiconductors. The Material Measurement Laboratory continues to provide critical support to semiconductor manufacturers, using our metrology expertise to help them incorporate new materials into integrated circuits and produce reliable, ever-smaller structures.

Copyright Robert Rathe

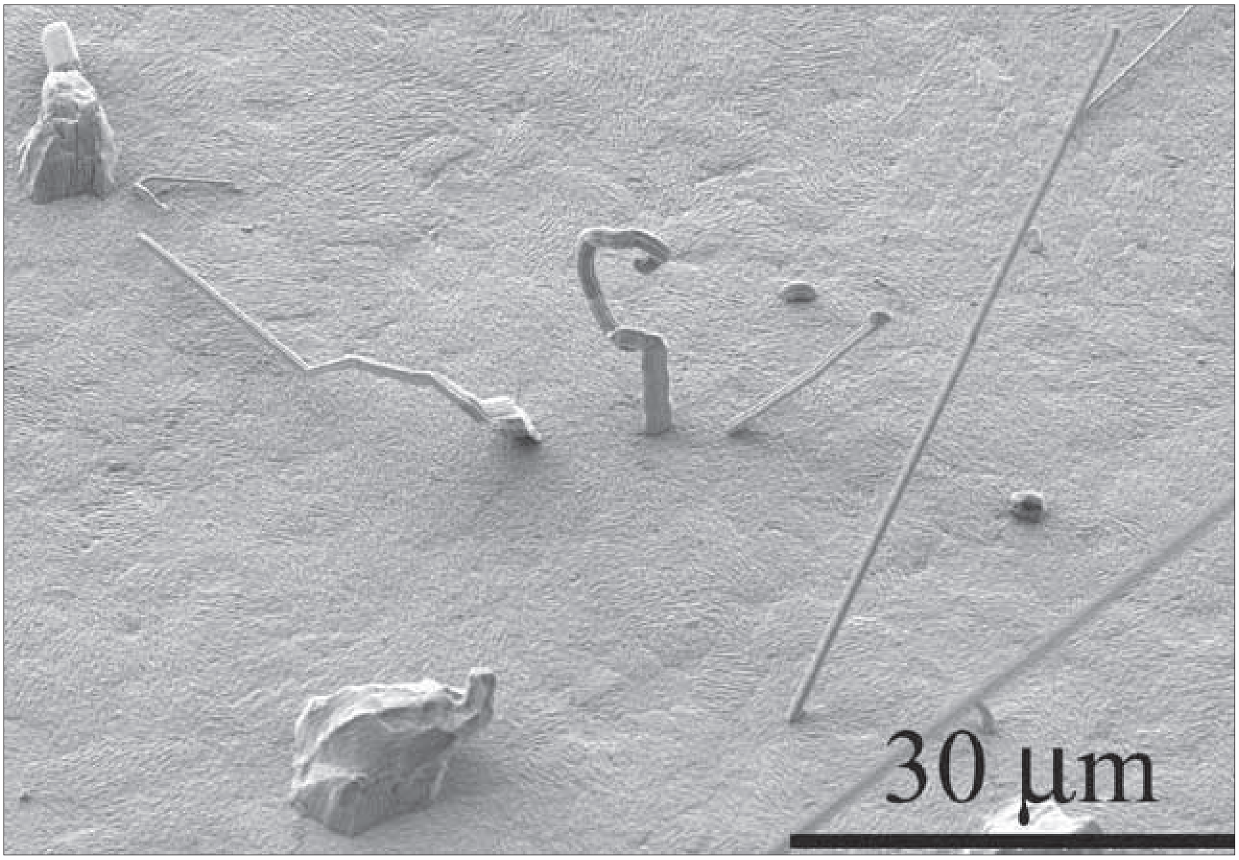
Researchers at the Material Measurement Laboratory make frequent use of the NanoFab, part of NIST's Center for Nanoscale Science and Technology. The NanoFab includes tools for lithography, metrology, dry etching, metal deposition, imaging, wet chemistry, and chemical vapor, ion beam and atomic layer deposition.

NATIONAL NEEDS	CORE CAPABILITIES AND EXPERTISE	PRODUCTS AND SERVICES
Metrology and technology to advance: Failure analysis Nanomaterial characterization Post-CMOS microelectronic device design and performance assessement Semiconductor design and manufacturing support	**Emerging materials** Magnetics, spin and tunneling behavior for memory and logic Semiconductor nanowires Organic electronics Local structure determination Local (atomic scale) composition	Mechanical property measurements and standards at the μm to nm scale SRMs* for semiconductor dopants Atomic scale, 3-D mapping of composition and structure
Critical dimension metrology Development of next-generation integrated circuits and high-performance stacked chips	**Lithography and interconnects** Dimensional metrology Through-silicon via (TSV), chip stacking—measurements and reliability	Predictive models Simple measurement methods to predict complex behavior for TSV
Electronic materials and device performance prediction	**Modeling and simulation** First principles calculations, molecular dynamics, potential function-based calculations Computational property prediction and simulation	Modeling of microstructure changes due to phase transformations Models and standards to support computational design of materials
Assessment of: Advanced performance electronic devices Advanced sensing Solar thin films High-reliability electronics Nanoelectromechanical devices Thin film reliability	**Emerging electronics/Mixed performance systems** Nanomechanics Miniature systems (cryocoolers) Flexible electronic technologies (displays, sensors, batteries, bio implants and photovoltaics) Lead-free solder/Tin whiskers	Interface reliability and characterization SRMs and critical data for lead-free solders

* NIST Standard Reference Material

Makers of computer chips have regularly met or exceeded Moore's Law, which states that the number of transistors placed on integrated circuits will double about every two years; this has been achieved largely by shrinking the dimensions of a circuit's structures. As the semiconductor industry makes smaller and smaller devices, however, any imperfections in the processes by which they are produced are magnified, raising concerns that new chip designs can't be scaled up to mass production. Further, new materials and processes are needed to fabricate these smaller structures, from the substances used for the lithography that initiates production to methods to assemble nanoscale components without hands-on manipulation. To continue to progress, the computer chip industry needs new ways to measure new nanometer-sized structures. Scientists in the Material Measurement Laboratory developed a new, nondestructive way to measure the shapes of semiconductor patterns in three dimensions. Beyond measuring shapes, the CD-SAXS (critical dimension small angle X-ray scattering) method even reveals sub-nanometer surface features that can affect performance. The CD-SAXS method helps computer chip manufacturers determine if their new chip designs can be manufactured on a large scale.

Computers drive our critical technological infrastructure, therefore computer chips must work reliably. Lead has been phased out of the solder used to assemble microelectronics because of environmental concerns, but solders made of lead-free tin alloys tend to grow microscopic whiskers that can cause electrical shortages in sensitive components. When connections fail in a new talking toy, consumers are disappointed. When connections fail in a satellite or jet fighter, it's a very expensive, potentially deadly matter.



Maureen Williams NIST

Tin solders without lead are prone to spontaneously sprout whiskers, which can short circuit sensitive electronics. The Material Measurement Laboratory provides measurements and data necessary for industry to change their production methods to prevent the formation of tin whiskers.

Our scientists are responding to an urgent national need, conducting measurements that help determine why whiskers grow and how to prevent them. In addition, the Material Measurement Laboratory has issued a series of Standard Reference Materials to help the manufacturers who supply NASA and the military, who are allowed some lead in their solders, to validate the test methods they use to determine how much lead their solders contain.

Our experts also contribute to the semiconductor industry's quality control efforts by conducting measurements of the stress and strain exerted on the microelectronic elements that connect a chip to the components it commands. Another effort uses mass spectrometry to detect trace elements and contaminants in dopants, the substances used to change the electrical properties of semiconductor materials. The series of reference materials that resulted from this work help manufacturers calibrate their measurements of dopants to be sure that their mass manufacturing methods produce identical, high-performance computer chips.

MANUFACTURING HIGHLIGHT

Semiconductors

NIST helps the computer chip industry identify and overcome the limits of conventional materials. As computer chips shrank, manufacturers realized that the on-chip "wiring" in an integrated circuit, made of aluminum and aluminum-copper alloys, wouldn't work on such a small scale: there wasn't enough aluminum to function as a conductor. The industry then successfully moved from aluminum to copper, a better conductor of electricity. However, chip designers had trouble finding a chemical additive that would enable copper to be reliably deposited into the deeper and narrower trenches—less than a micron wide—that connect circuits on next-generation silicon chips.

NIST, including experts at the Material Measurement Laboratory, tackled this formidable technical challenge. Our metallurgists developed new measurement methods that chip developers can perform quickly and inexpensively to tell if their solutions of additives and copper will properly fill complex patterns of trenches. This advance has lowered the cost of research and development and reduced the time from research to production. An economic impact report calculated that NIST's efforts resulted in a nearly 80 percent rate of return on the original investment, helping industry bring improved semiconductors to the market faster and with less cost to develop.

Similarly, as chip manufacturers pack ever-increasing numbers of transistors onto a single chip, the smaller distances between them make it ever more important to insulate their electrical connections. The semiconductor industry needed reliable measurements of various candidate insulating materials. SEMATECH, an industry consortium, called on experts at the Material Measurement Laboratory, citing their technical and broad research capabilities and their objectivity. In addition to analyzing about 180 candidate materials, our scientists developed new techniques for characterizing advanced nanoporous materials and at a cost savings compared to farming the tasks out to multiple research groups. These contributions are estimated to have saved the semiconductor industry more than $10 million in research and development costs, freeing up resources for other innovations.

Energy

The Material Measurement Laboratory works to establish the measurement tools and standards necessary for developing a cleaner energy infrastructure and improving energy efficiency, contributing to the energy security of the United States. Our products and services, provided in cooperation with federal, state, academic and international partners, are providing the research basis and outputs necessary to make energy systems powered by renewable sources such as biomass, hydrogen and the sun a reality, and contribute to the safe and effective use of traditional energy sources, including petroleum, natural gas and coal.

Copyright Geoffrey Wheeler

Researchers at the Material Measurement Laboratory analyze complex fuel mixtures, including new formulations containing biofuels. The data is used by industries across the life cycle of an engine, from choosing feed stocks for fuel mixtures to designing engines.

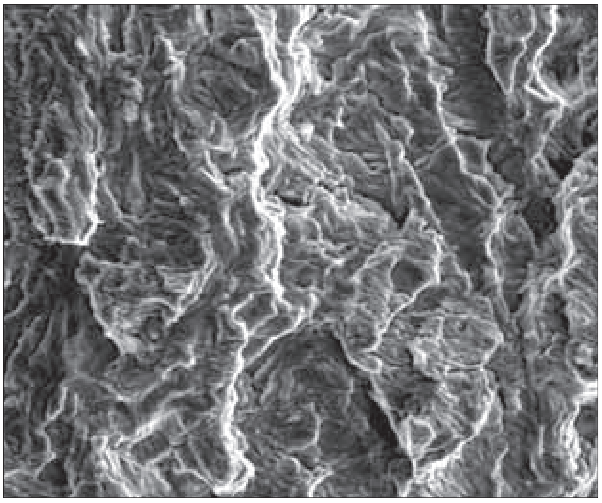
NATIONAL NEEDS	CORE CAPABILITIES AND EXPERTISE	PRODUCTS AND SERVICES
Metrology and technology to advance: Sustainable fuels, biofuels and hydrogen fuel for: Transportation sector and international trade therein Aviation fuels Engine design Fuel distribution infrastructure Biobased product industry	Experimental measurements, computational fluid dynamics, theory, and data for kinetics and property studies of fuels Materials compatibility: tensile strength testing Magnetic technology analysis Chemical analysis: trace chemical determination Advanced photolithography Cryogenic technology analysis Combustion science and simulation Aerosol generation and analysis Calorimetry Separation and surface science Materials interface analysis Scientific database management	Standard reference materials, critically evaluated standard reference data and documentary standards International and consensus property standards
Advanced power generation for: Electric utilities Thermoelectronics		
Carbon capture and sequestration for environmental quality		
Solar photovoltaics		
Energy efficiency for Automotive industry Chemical and petrochemical industries Heating, refrigeration and air conditioning Transportation		
Fossil fuel distribution infrastructure efficiency/safety Pipeline safety and reliability		
Fuel cells/Batteries (energy storage)		
Support for nuclear technology		

In 2008, 52 percent of all renewable energy consumed in the United States was based on biomass. Although these fuels may help improve our air quality and support rural economies, many properties of biofuels differ from those of conventional fuels, requiring considerations of engine performance, distribution systems, additive packages and environmental effects. Because there is presently no comprehensive source of reliable biofuels property data, the Material Measurement Laboratory is developing methods for the determination of biofuel composition and properties and disseminating related measurements, models, reference materials and property databases. Our work supports the wide-spread adoption of biofuels and future alternative fuels, including new formulations for defense and aviation applications.

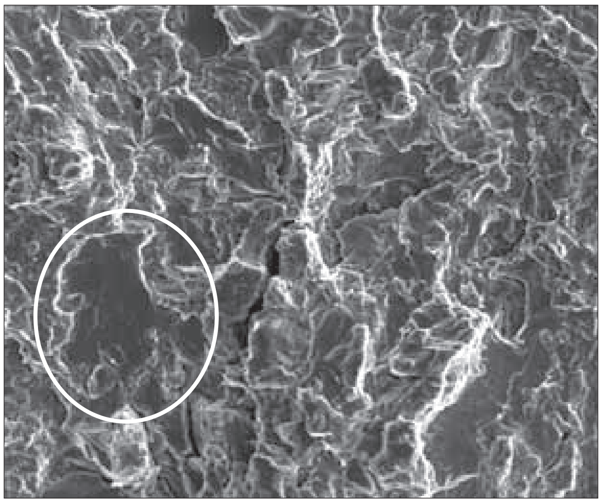
Hydrogen fuel has the potential to revolutionize transportation and perhaps our entire energy system. Hydrogen, the most abundant element in the universe, can be produced from water, with the primary energy coming from solar, fossil fuels, biomass, and even wind or nuclear sources. Producing hydrogen with renewable energy such as biofuels and using it in fuel cell vehicles holds the promise of virtually pollution-free transportation and complete independence from fossil fuels. Realizing this vision requires purity and flow specifications to ensure fair trade, high storage capacity to support a competitive market, and a safe and efficient distribution system to ensure consumer confidence and fuel availability. The Material Measurement Laboratory is engaged in research that can help the country move closer to a hydrogen-powered grid.

Hydrogen burns without carbon emissions and can be produced domestically. To become a widely used energy source, however, hydrogen, a potentially corrosive gas, will need a safe and reliable distribution system. We recently launched the country's largest facility for evaluating how parts of a hydrogen pipeline infrastructure will react to exposure to hydrogen. Standard test components—chunks of pipeline, a piece of a valve—are exposed to pressurized hydrogen, mimicking pipeline conditions. This data will lead to the development of standards for building safe, reliable systems for future hydrogen fuel storage, delivery and dispensing.

Working with partners in Europe and South America, we provide certified soy and animal fat reference materials that are well characterized for the properties that are important to the international sale, distribution and use of biodiesel fuel.



Robert Amaro NIST



Robert Amaro NIST

The hydrogen pipeline test facility at the Material Measurement Laboratory can test the durability of high-strength steels under the high-pressure conditions in which hydrogen is transported in the real world. At left, a microscopic image of X52 steel that cracked under stress while exposed to air: The consistent texture is characteristic of a ductile metal that has cleaved both through grains and along grain boundaries. At right is X52 steel that cracked under stress while exposed to hydrogen at 5.5 MPa, showing signs of embrittlement: Crack propagation occurred primarily along grain boundaries, yielding flat surfaces like the one circled here.

MANUFACTURING HIGHLIGHT

Organic Solar Cells

Dave White 2008

Solar energy is a potentially limitless source of clean energy. Compared to traditional inorganic solar cells made of silicon, organic electronics technology permits the fabrication of solar cells using printing techniques borrowed from the graphic arts. A consequence of printing electronic components from inks is that their structural details are set "as the ink dries." This can result in variability and unpredictability.

The use of organic chemistry to make new solar cells has vast potential, but research has not unraveled the full story of how performance correlates with the way the material is processed. Consequently, the industry is locked into an expensive, iterative development cycle where huge numbers of new materials have to be made to discover a few good candidates. The Material Measurement Laboratory provides measurement tools that reveal how processing and performance are linked, making research and development targeted and faster.

Our measurements help manufacturers print solar cells with the same reliability that Polaroid once printed photographic film. Old chemical film factories have been repurposed to print photovoltaics, using much of the same equipment.

Environment and Climate

The Material Measurement Laboratory develops and disseminates critical measurements, standards and reference data to assist in the conservation, protection and restoration of our nation's natural resources. Our measurement protocols, data and models facilitate sound environmental decision-making and help industries comply with existing and new regulations in both U.S. and foreign markets. These activities promote effective and improved pollution prevention, control and mitigation, helping industries minimize their environmental impact and meet the requirements of overseas markets. Our work improves environmental quality and health and enables better assessment of pollution and climate change.

T. Moore NOAA

Since 2001, the NIST Marine Environmental Specimen Bank at the Hollings Marine Laboratory in Charleston, SC, has held biological and environmental specimens for future retrospective measurements of newly discovered contaminants, verification of chemical measurements, and re-analysis using new analytical techniques as these become available for existing or new chemicals of concern. Specimens include marine mammal and sea turtle tissues and fluids, mussels and oysters, bird eggs and feathers, marine sediments, and a variety of fish tissues.

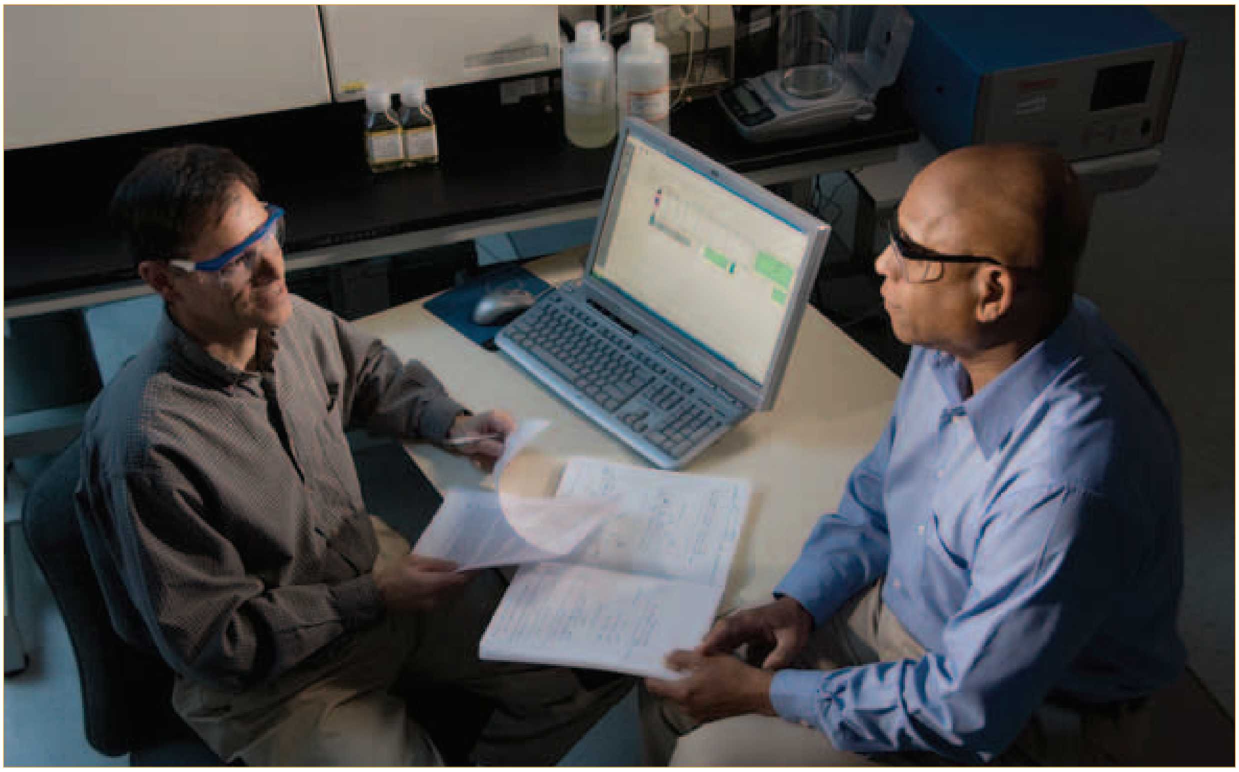
NATIONAL NEEDS	CORE CAPABILITIES AND EXPERTISE	PRODUCTS AND SERVICES	IMPACT AREAS
Metrology and technology to advance: Assessment of climate change	Greenhouse gases measurements Aerosols characterization Field-deployable detection technologies Stationary and mobile source emission monitoring Combustion metrology and modeling Theory and chemoinformatics Thermophysical property measurement and modeling	Aerosol analysis: black and brown carbon Atmospheric lifetime reference data Greenhouse gas warming potential data Gas concentration standards Standard reference materials for fossil fuels and environmental monitoring	Carbon cap-and-trade Air quality and health assessments Environmental regulations Weather/climate satellite calibration Alternative fuels Climate change policy
Environmental monitoring, quality and health	Aquaculture Separation science, spectroscopy Preparation of marine reference materials Chemoinformatics and metabolomics Nanoparticle measurements Water pipe material structure, monitoring and use	Measurement traceability frameworks Reference methods and materials for environmental contaminants Standardized protocols for measuring contaminant exposure NIST/EPA/NIH Mass Spectral Library Environmental monitoring technologies including infrastructure inspection	Environmental research, including remediation, and regulations National needs responses including Gulf oil spill damage assessment and restoration Seafood safety Quality assurance
Green sustainable manufacturing and industrial processes	Mechanistic studies, materials property measurement and modeling Automotive lightweighting Reduction of toxic metals in the environment including mercury, lead and cadmium Alternative fuel pollution potentials	Standards and measurements to support sustainability including NIST WebBook, ThermoData-Engine and REFPROP Reaction and properties data for renewable polymer and sustainable composites Data and models for fire retardant and fluorinated refrigerants incineration	Fuel economy Plastics, polymers and electronics industries Air and water quality Waste management industry

The Material Measurement Laboratory has a long history of helping to establish the scientific basis for measurement and monitoring of substances that may negatively impact our environment, climate and health. For more than 40 years, we have developed Standard Reference Materials to support the determination of inorganic and organic contaminants in sediments and soils, marine and animal tissues, air particulate, and botanical materials. Many of these reference materials were developed specifically to address the regulations and needs of the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration, including meeting the needs of those assessing the Deep Water Horizon oil spill in the Gulf of Mexico in 2010 (see page 24).

While NIST is not a regulatory agency, the laws that ensure acceptable levels of contaminants in food, water, air, building materials and consumer products require materials and measurement procedures that analytical scientists can rely upon to calibrate instruments and obtain data that can be confidently compared from lab to lab.

As examples, we work with the EPA to develop mercury gas standards so that fossil fuel power plants and other sources can accurately measure their emissions to comply with EPA mercury reduction initiatives and monitoring requirements, and with the Consumer Product Safety Commission to develop tools for the validation of test methods for lead paint in children's toys and other products.

The climate is changing. Determining how fast the climate is changing and elucidating the complex relationships among the different factors affecting these changes are critical objectives for the U.S. government. The Material Measurement Laboratory seeks to improve measurements and standards for determining the identity and concentrations of greenhouse gases, as well as the type and amount of aerosols—mixtures of gases and particles—in the atmosphere. Our measurements provide the critical information that scientists need to fully integrate the effects of greenhouse gases and aerosols, like so-called black and brown carbon species, into reliable and accurate climate models.



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With funding from the EPA, scientists at the Material Measurement Laboratory developed a new system for measuring trace levels of mercury in air samples. The system is being used to provide instrument calibrations for fossil fuel power plant emissions monitoring down to 0.2 micrograms per cubic meter. Reducing these emissions should lower mercury contamination in fish, which is a health risk for certain segments of the U.S. population.

MANUFACTURING HIGHLIGHT

Fossil Fuel Reference Materials and Data

As long as carbon-burning fuels continue to be the predominant source of energy, the Material Measurement Laboratory will continue to support the fossil fuel Standard Reference Material program, active since the 1970s. The current inventory of fossil fuel reference materials includes coals, cokes, residual fuel oils, distillates and gasolines to support the needs of the energy, electric utility and transportation fuel sectors as they strive to meet environmental regulations.

Because fossil fuels are major sources of carbon dioxide emissions to the atmosphere, the Material Measurement Laboratory is generating structural, thermodynamic and kinetics data essential for the design of coal-fired power plants with reduced carbon dioxide emissions. This work, along with developments of accurate and effective statistical mechanics model for the simulation of the geological sequestration of carbon dioxide and other greenhouse gases, will help solve many of the technological obstacles to effectively reduce, capture and store carbon dioxide emissions.

Determining Nanoparticle Safety

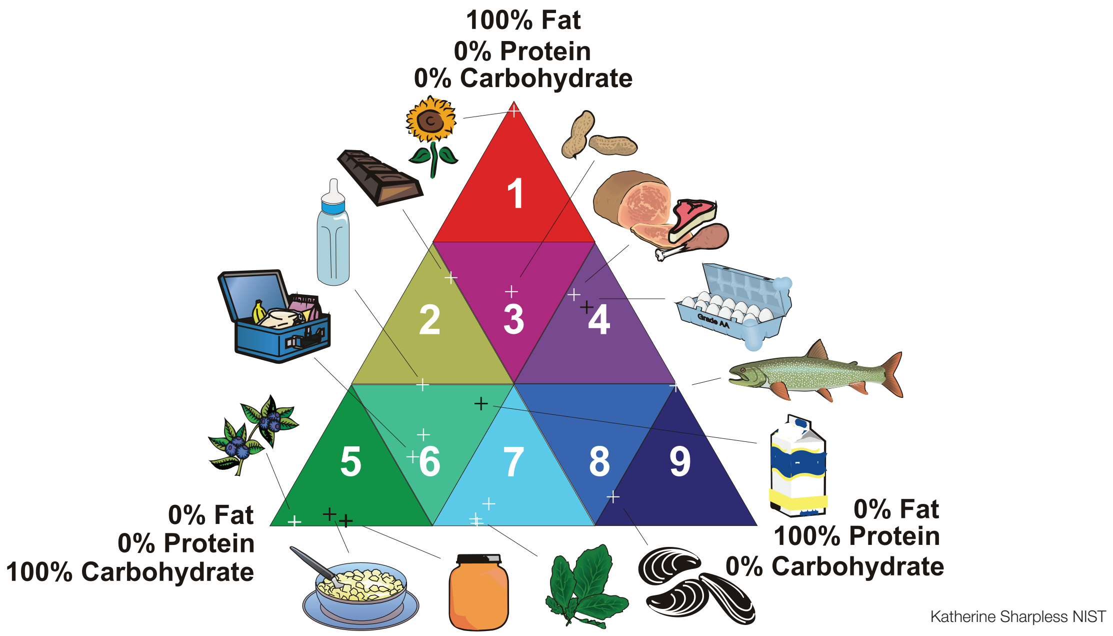
Engineered nanomaterials are intentionally produced to have unique properties resulting from their extremely small size. Currently, these materials are used in more than 1,000 consumer products such as strong-yet-lightweight tennis rackets and stain-resistant clothing. Future nanomaterial products are expected to provide cleaner sources of energy, stronger buildings and bridges, and faster communication systems. The full benefits of products that incorporate engineered nanomaterials may never be realized, however, due to growing concerns about their potential hazards to humans and the environment. Assessing the potential hazards to workers, consumers and the general public from exposure to engineered nanomaterials requires knowledge of their physical and chemical properties, such as size and surface composition.

Working with the National Cancer Institute, the Food and Drug Administration, and the Environmental Protection Agency, among others, researchers at the Material Measurement Laboratory are developing measurement methods and standards to determine the physical and chemical properties of the most industrially relevant nanoparticles including gold, silver, titania and silica. Our scientists developed gold nanoparticle Standard Reference Materials with values for diameter—the first reference nanomaterials available for biomedical and environmental studies. These are broadly used by industry to develop safe and effective nanomaterial-based products. We also conduct studies to detect and measure nanoparticles in biological and environmental matrices.

Food brings friends and families together and helps us share our cultures and mark our milestones. We need to know that the food we buy won't compromise our health and is safe to eat. The Material Measurement Laboratory provides reference materials and data and other products that help the food industry perform measurements to detect contaminants and spoilage from farm to fork and provide nutrition information to consumers.

Chemical contaminants in food are a critical public health concern. For example, following the 2010 oil spill in the Gulf of Mexico, the Material Measurement Laboratory's environmental Standard Reference Materials, including SRM 1974b Organics in Mussel Tissue (*Mytilus edulis*), supported efforts to analyze seafood for polycyclic aromatic hydrocarbons, indicators of exposure to oil. In fact, use of our mussel tissue Standard Reference Material is required by the government agencies that conducted the analyses of oyster, crab, shrimp, and finfish samples to determine if the seafood was safe and fishing areas could be reopened. We also produce Standard Reference Materials that are characterized for other contaminants, including pesticide residues, toxic elements like arsenic and lead, and methylmercury.

The Material Measurement Laboratory supports the measurements required for nutrition labeling by producing a variety of Standard Reference Materials for quality assurance in food analysis. Whether it's egg or milk powder, baking chocolate or peanut butter, a food manufacturer's lab chooses a Standard Reference Material of similar composition to the food they want to analyze. For example, SRM 1549 Non-Fat Milk Powder is certified to contain a known amount of calcium. In industry, the Standard



The food triangle, developed by AOAC International, groups foods into nine sectors based on their relative levels of fat, protein and carbohydrate because foods within each of the nine sectors offer similar analytical challenges. The corners of the overall triangle each represent 100 percent fat, protein and carbohydrate. NIST reference materials of various foods, many of which were developed at the request of the food industry, are characterized for their nutrient concentrations and populate most of the food triangle.

NATIONAL NEEDS	CORE CAPABILITIES AND EXPERTISE	PRODUCTS AND SERVICES
Metrology and technology to advance: Allergen testing Basic nutrition research Food safety and quality Heavy metals testing Nutrition labeling Organic contaminants testing	Analytical mass spectrometry Analytical separation science Atomic and X-ray fluorescence spectrometry Nuclear analytical methods Nuclear magnetic resonance spectrometry NIST Center for Neutron Research	Marine Environmental Specimen Bank (includes food species) Quality assurance programs SRMs* support food safety including food allergens, protein toxins and synthetic materials SRMs for food and dietary supplements

* NIST Standard Reference Material®

Reference Material is likely to be used so an analyst can determine the accuracy of her measurements: She measures the calcium in both our Standard Reference Material and her company's milk powder. When she gets the same result that NIST certified for the Standard Reference Material, she can have confidence in her analysis of her company's product. Because the Standard Reference Materials we produce can be used to demonstrate the accuracy of measurements, they also help ensure that U.S. food exports meet foreign regulations and can be sold in overseas markets.

The Material Measurement Laboratory also produces Standard Reference Materials for the fast-growing dietary supplement industry. In the United States, where dietary supplements are regulated as foods, manufacturers are required to verify that their products contain what the package says they do, that they don't contain anything that they shouldn't, and that their analytical methods are working properly. The Material Measurement Laboratory provides several suites of botanical dietary supplement products to facilitate this, including reference materials for ginkgo, green tea and saw palmetto. We measure active and other compounds as well as toxic elements (arsenic, cadmium, lead and mercury) in supplements. In cases where botanicals used as dietary supplements are also eaten as traditional foods, as are cranberries and soy, the materials are characterized for their nutrient content as well.

MANUFACTURING HIGHLIGHT

Accurate Nutrition Labels

Soon after implementation of the 1990 Nutrition Labeling and Education Act, which requires nutrition information labels on all packaged food, the U.S. Food and Drug Administration tested the accuracy of labels on 300 randomly sampled products. While most of the nutrients were adequately reflected by labeling, about 30 percent of samples misstated the amount of iron that foods contained; the amount of vitamin A was misstated on nearly 50 percent of labels. Our analytical chemists determined that a lack of standardized testing methods and controls were to blame. In response, NIST (which already had programs for measuring minerals and elements in food) expanded the development of Standard Reference Materials for nutrient concentrations.

The Material Measurement Laboratory continues to develop reference materials, working with the Grocery Manufacturers Association and other groups, to respond to the needs of the packaged food industry. As a result, manufacturers can comply with the regulations of the Food and Drug Administration and the Department of Agriculture, and consumers can confidently make informed food choices.

Physical Infrastructure

The American Society of Civil Engineers reports that one in four bridges in the United States is "either structurally deficient or functionally obsolete," and in 2009 gave the nation's transportation infrastructure a grade of "D." The Material Measurement Laboratory is a source of objective standards and validated measurement methods for assessing the health of aging physical infrastructure components. Testing and inspection can help prevent failures of aging public works projects and—because aging infrastructure components can't be tackled all at once—provide data to inform which projects are deemed most critical. We develop methods to test and predict the health of critical connections in bridges and buildings and nondestructive evaluation techniques for structures such as in-service bridges that can't be dismantled for examination.

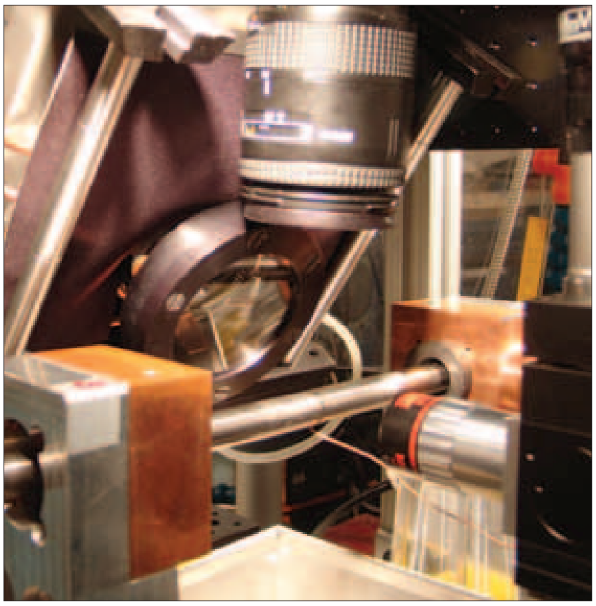
J Burrus NIST

The Material Measurement Laboratory has a variety of hydraulic test machines that can apply loads ranging from just a few pounds to one million pounds at temperatures ranging from -269 °C to 1000 °C and with additional conditions applied, such as pressure. Located on our campus in Boulder, Colo., the "million pound machine," shown here at left, is the largest west of the Mississippi that can apply both compression and tension. It is used to test structural steel for pipelines, bridges and buildings.

NATIONAL NEEDS	CORE CAPABILITIES AND EXPERTISE	PRODUCTS AND SERVICES	IMPACT AREAS
Metrology and technology to advance assessment of: Structural properties *Materials:* Steel, composites, polymers, concrete *Joint performance:* Welding, brazing, bonding, curing, mechanical joining (bolts, pins, etc.)	Mechanical testing Fracture, fatigue, deformation Charpy impact testing Elevated temperatures High strain rates Dynamic fracture Microstructural analysis Optical, SEM, TEM Fracture mechanics	SRMs* for indirect verification of Charpy machines SRMs and documentary standards for hardness testing Standard test methods and data for fracture prediction in fuel pipelines Standards for fire-resistant steel	Design properties for bridges, buildings, ships, wind turbines and other objects of structural metal Nuclear materials reliability
Environmental interactions	Materials testing in pressurized hydrogen Corrosion fatigue and microbially enhanced fatigue testing in alternative fuels Microscale mechanical testing	Data and models to update codes and standards for materials in hydrogen service Testing of materials in, or exposed to, harsh environments	Hydrogen storage and distribution for transportation Nuclear materials reliability Storage and distribution of other alternative fuels
Condition	Non-destructive evaluation Large-scale digital image correlation	Calibration of acoustic emission sensors SRMs for calibration of ultrasonic crack detection instruments Failure analysis Deformation in large-scale structures under abnormal loads	Condition assessment of existing pipelines and tanks for storage and distribution of conventional fuels

* NIST Standard Reference Materials

After the collapse of the I-35W bridge in Minneapolis, Minn., in 2007, the Federal Highway Administration asked NIST to collaborate on their tests of the safety of gusset plates, which had been implicated in the failure because they were undersized. We have been applying our expertise in digital imaging methods to measure the strain in gusset plates under many different loading scenarios, which has uncovered new information about conditions that affect their strength. In addition, we are the only source in the country that can provide calibrations traceable to international standards for acoustic emissions sensors, which are used extensively to "listen" to the vibrations of a structure to detect abnormalities that might signal fatigue cracking or the onset of failure.



NIST

Our facilities include a state-of-the-art Kolsky bar, an apparatus that measures stress and strain in materials under extreme rates of deformation. The Material Measurement Laboratory's Kolsky bar can also heat a sample to high temperatures under controlled conditions to measure how materials and combinations of materials are deformed under both extreme loads and heat, making it unique outside of defense research. Further, while most Kolsky bars produce data based on pulses of energy returned by a deforming object, our Kolsky bar is outfitted with a customized high-speed digital imaging system that allows us to directly measure strain, which is especially useful for objects with complicated shapes.

The Material Measurement Laboratory also provides reference materials for the calibration and validation of equipment for testing new materials. We provide reference materials and standards for assessing impact toughness and hardness (see Manufacturing Highlight: Standard Reference Materials for Metals), standards for fuel pipeline performance, and methods to assess the performance of plastic pipes for water and gas. We are currently working on the development of reference standards for the calibration and verification of nondestructive evaluation equipment used by the inspection industry.

Although structural engineers can predict how materials will perform under usual conditions, the performance of structures when subject to fire, explosion, impacts and natural disasters is less well understood. The Material Measurement Laboratory has evaluated the mechanical performance of structural steel at the high temperatures generated by fires and high rates of strain produced by blasts or impacts, most notably contributing to the investigation of the World Trade Center collapse, which has resulted in improved building codes. We contribute to the work of NIST's National Fire Research Laboratory, a new facility that will make it possible to subject full-sized structures to the combined effects of fire and loading. Our work helps to establish standards for evaluating new grades of fire-resistant construction steel that retain their strength at high temperatures, thereby allowing occupants extra time to leave a building in an emergency.

Fuel pipelines crisscross all 50 American states, often in highly populated areas. The first decade of the 21st century has seen more than 2,500 pipeline accidents resulting in several hundred fatalities and injuries and billions of dollars in lost revenue and repair costs. As the industry adopts new design methods and higher strength materials, the Material Measurement Laboratory provides new measurement methods that help to ensure the reliability of the resulting pipelines. Our test facilities also measure the effects of the alternative fuels ethanol and hydrogen, which can accelerate the degradation of pipeline materials. The Material Measurement Laboratory is one of only three facilities in the country that can conduct mechanical tests in high-pressure hydrogen gas (see page 18), and the only one in the world capable of testing multiple samples at the same time, increasing the speed of data collection.

MANUFACTURING HIGHLIGHT

Standard Reference Materials for Metals

In a rush to build ships during World War II, ship yards used high-strength steels and the faster construction method of welds instead of traditional rivets. When a number of these so-called Liberty ships suffered catastrophic failure, NIST was asked to participate in the investigation. Application of the Charpy impact test, which measures the amount of energy it takes to fracture a sample of notched metal, was especially illuminating, revealing the characteristics that made the Liberty ships particularly vulnerable in cold water, and ultimately setting a common requirement for the minimum toughness of steel for cold-weather service.

Today, the structural steel industry, which produces $10 billion dollars-worth of product a year, relies on accurate Charpy impact tests to determine the fracture resistance of steels used in pipelines, bridges, nuclear facilities and ships and assure builders that they are suitable for use. All of those Charpy impact tests rely on the Material Measurement Laboratory's Standard Reference Materials for Charpy impact test equipment, which ensure the calibration of more than 1,500 test machines worldwide at academic and commercial test labs.

Similarly, tests for hardness are the most common methods industries use to assess the strength of materials. Differences in test results can lead manufacturers to reject materials that are in fact suitable or, even worse, accept materials that are deficient. The Material Measurement Laboratory provides a variety of Standard Reference Materials for calibrating hardness testing machines and has led the development of documentary standards for test methods with ASTM International and the International Organization for Standardization.

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The Charpy impact test uses a swinging pendulum to assess the resistance of a material to fracture.

Safety, Security and Forensics

NIST, which once served as the principal crime lab in the United States, has a long history of contributions to forensic science, performing scientific analysis in high-profile cases like the kidnapping of the Lindbergh baby. Today, the Material Measurement Laboratory contributes measurement science that underpins a broad range of forensic activities, from accurately identifying humans to detecting explosives, as well as to public safety and national security efforts. The results of our work are shared with the nation's criminal justice, public safety, emergency responder and homeland security agencies through the Law Enforcement Standards Office, located on NIST's Gaithersburg, Md., campus.

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In 2011, ScienceWatch.com named NIST one of the world's most influential institutions in forensic science, based on journal citations. John Butler, right, a chemist and DNA forensics scientist in the Material Measurement Laboratory, was ranked as the number one "high-impact author in legal medicine and forensic science, 2001 to 2011."

NATIONAL NEEDS	CORE CAPABILITIES AND EXPERTISE	PRODUCTS AND SERVICES
Metrology and technology to advance: Identification of human biological evidence and remains	Gel and capillary electrophoresis for characterization of DNA size and sequence polymorphisms Multiplex, real-time and digital PCR	Short tandem repeat database for recovering information from degraded DNA SRMs* for DNA Training for forensic laboratory staff
Identification of chemical weapons, measurements of toxic industrial chemicals	Raman spectroscopy Mass spectrometry	SRMs for Raman-based detection Standards for verifying field detectors ASTM performance standards for measurement of toxic industrial chemicals ASTM reference methods and analysis tools for toxic industrial chemicals Standard reference data
Collection and identification of biothreats	Evaluation of collection methods and materials	Documentary standards (ASTM), reference materials and training to enable biothreat sample collection and detection by first responders
Field-portable methods for analysis of chemical and biochemical agents	Design of "lab on a chip" measurement devices	Microfluidic technologies for field-portable chemical and biochemical analysis
Trace explosive detection	Analysis of vapor pressure, headspace, polymeric permeation, enthalpy of adsorption, etc. Evaluation of vapor sampling methods Mass spectrometry, inkjet printing, electron microscopy	SRMs for calibration of trace explosives detectors ASTM standards to improve sampling for detectors Thermophysical and property data for explosive materials Test bed for trace explosives detection SRMs for canine olfactory detection of explosives
Determining reliability of soft body armor used by law enforcement	Modeling and measurements of high performance fibers used in armor	Identification of chemical and mechanical degradation routes that threaten body armor materials

* NIST Standard Reference Materials

As criminal cases came to increasingly rely upon the results of DNA testing, the United States Department of Justice asked NIST to develop standards to help the country's crime labs produce accurate data and evaluate new technologies in the rapidly developing field of genetic analysis. Today, DNA testing labs use Standard Reference Materials developed by experts at the Material Measurement Laboratory for quality assurance, validating and calibrating their test methods. These reference materials are specified by the FBI DNA Quality Assurance Standard stating that labs will check their procedures each year or when protocols are changed. The Material Measurement Laboratory's scientists also contribute methods, test protocols, data and training to the continuing professional development of personnel at DNA testing laboratories across the country.

Robert Ausura

To help first responders deal safely and more effectively with suspected biothreat agents, members of the Material Measurement Laboratory led an effort to update existing standards for sample collection and develop overall guidance for when to collect a sample and how to coordinate with other agencies and organizations.

Our expertise in measurement is especially well suited to meeting the critical national need for improved methods to detect and remediate chemical, biological, radiological, nuclear and explosive materials that might be used as weapons. In 2006, at the request of the U.S. Department of Homeland Security, the Material Measurement Laboratory helped to coordinate the development of the first international standards guide to collecting samples of suspicious powders and continues to contribute updates. Members of law enforcement can rely upon NIST standards along the whole timeline of response to a variety of substances, from first detection, to obtaining and preserving samples so that they can be correctly identified, to rapid and accurate analysis of materials in the field or lab, to control of infectious agents, both naturally occurring and terrorism related.

In addition to providing measurement expertise and standards, the Material Measurement Laboratory has built and maintains databases for measurement technologies including mass, X-ray, infrared and X-ray photoelectron spectroscopies, and a short tandem repeat DNA database, all used routinely by forensic laboratories to address a broad range of analytical challenges, from examining chemicals and other substances intended for harm, to identifying degraded human remains. In addition, the NIST ThermoData Engine Standard Reference Database of chemical properties includes thermophysical and other property data for 105 explosive materials.

MANUFACTURING HIGHLIGHT

Trace Explosives Detectors

NIST

Machines that can detect trace amounts of explosives stand guard at airports, shipping depots and other points of entry around the world. To help customers of these machines—including the U.S. Transportation Security Agency, Department of Homeland Security and State Department—evaluate their performance and reliability, the Material Measurement Laboratory developed Standard Reference Materials containing known amounts of trace explosives. The test materials we fabricate can be used to calibrate trace explosives detection equipment once deployed and benchmark the performance of systems so that detector lifetime, response and need for service can be critically evaluated. We also help manufacturers design even more advanced detection technologies by providing them with measurements and standards to evaluate the performance of new detection methods.

Our concerns with detection of explosives go beyond reference materials. The NIST campus functions as a test bed where processes from sampling suspicious materials to the use of trace-explosive detectors are evaluated in and optimized for real-world conditions. We communicate these improvements to manufacturers and users of trace explosives detectors so they might modify their protocols, as well as integrate them into prototype test materials and training we provide to NIST security personnel. As a further result, staff members of the Material Measurement Laboratory have written practice guides for first responders for the standards organization ASTM International.

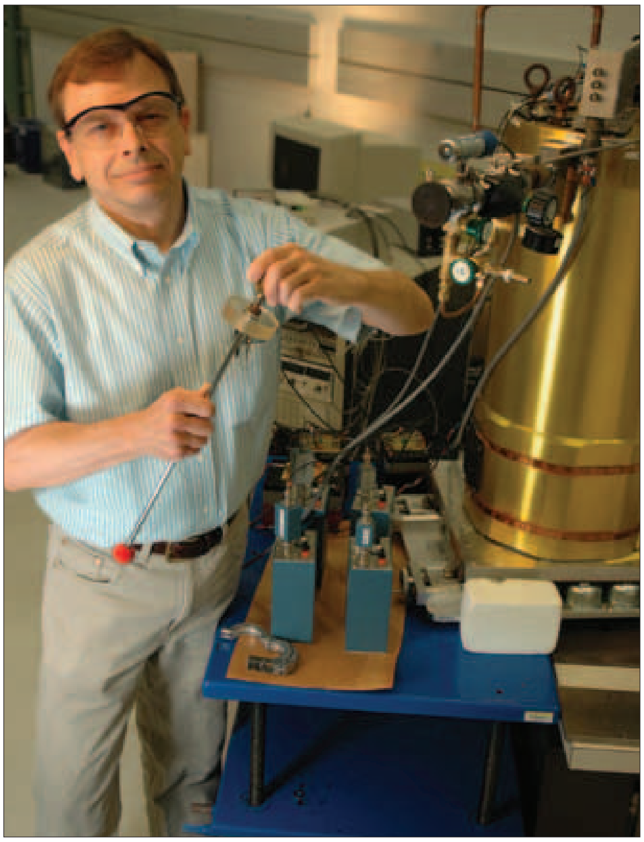
Protecting the Protectors

Bullet-resistant body armor has saved the lives of many who work in harm's way, but there's no easy way to tell if the fibers in a vest have broken down from wear, leaving a first responder unprotected. Our experts have developed a measurement method for determining the effects of repeated folding, finding that the antiballistic properties of the fibers in bullet-resistant vests are reduced by as much as 40 percent. The Department of Justice has revised the standards for antiballistic fibers accordingly, calling for improved durability from body armor designers and manufacturers.

People and Facilities

The Material Measurement Laboratory is home to more than 900 staff members and visiting scientists at five locations:

- NIST main campus in Gaithersburg, Md.
- NIST Boulder Laboratories in Boulder, Colo.
- Hollings Marine Laboratory in Charleston, S.C., where NIST staff work side-by-side with scientists from the National Oceanic and Atmospheric Administration, the South Carolina Department of Natural Resources, the College of Charleston, and the Medical University of South Carolina to provide the science, biotechnology and standards needed to understand links between environmental conditions and the health of marine organisms and humans
- Institute for Bioscience and Biotechnology Research in Rockville, Md., where scientists from NIST, the University of Maryland College Park and the University of Maryland School of Medicine conduct research on measurement science and standards issues associated with advanced therapeutics
- Brookhaven National Laboratory in Upton, N.Y., where, in partnership with the Department of Energy, the Material Measurement Laboratory has a user facility that enables researchers from industry, academia and other government agencies to apply synchrotron-based X-ray spectroscopy techniques to the development of products like oil additives and next-generation electronics (see page 7)



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Working With Us

The Material Measurement Laboratory forms partnerships that advance issues in measurement science and technology that are important to our stakeholders in industry, other agencies and the public sector and foster the transfer of research products to those stakeholders. Our staff members also serve on committees formed to develop new standards that address the needs of industry.

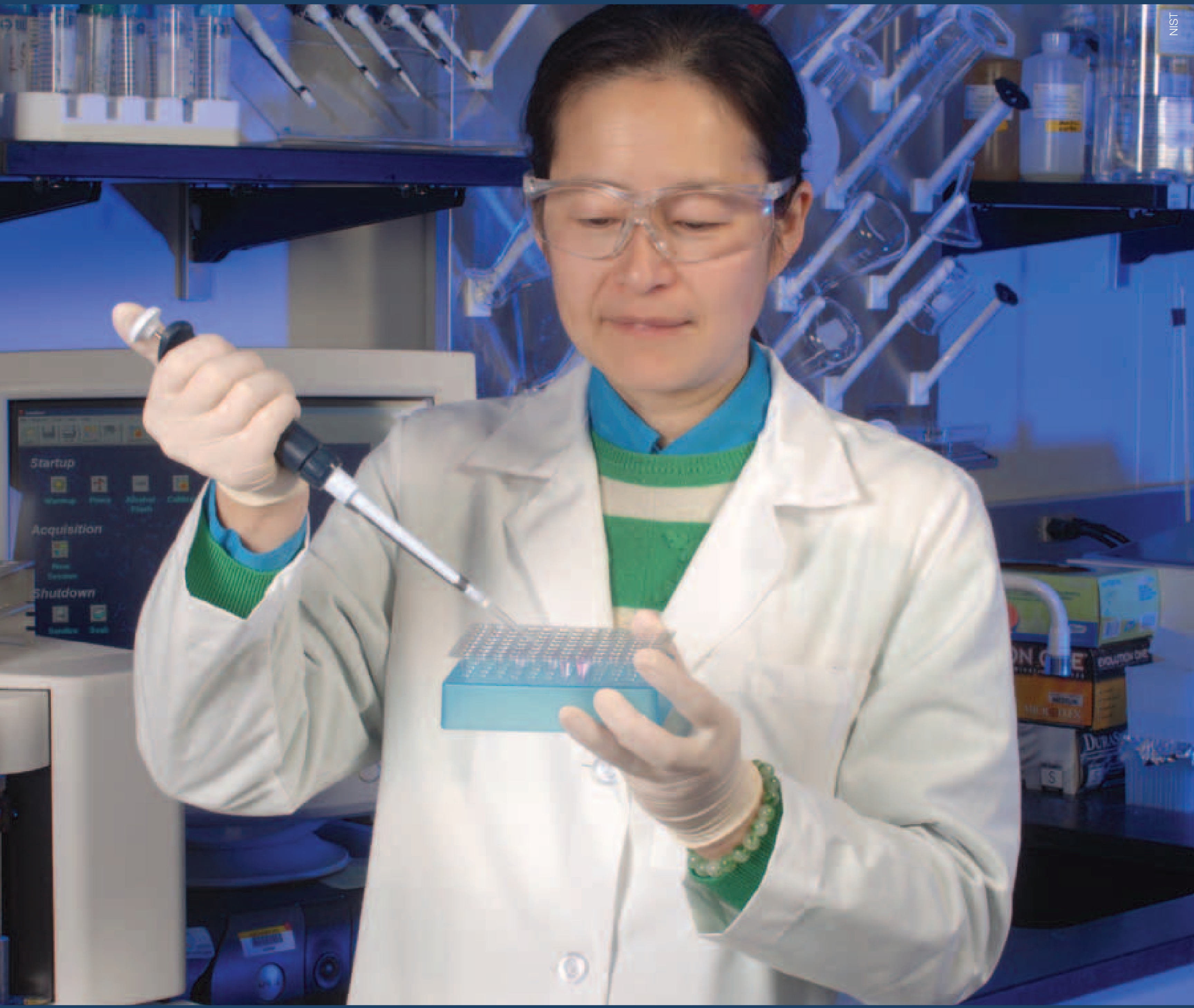
We have many mechanisms for undertaking cooperative relationships. These include formal and informal means, some of which can accommodate legal issues such as intellectual property generation and protection. For both formal and informal relationships, the Material Measurement Laboratory establishes partnerships that advance our research priorities, including:

- Relevance to the missions and priority areas of NIST and the Material Measurement Laboratory
- Synergy with current or emerging programs
- Potential impact on national needs and critical measurement science

To learn more about the Material Measurement Laboratory's priorities and technical programs, and some of the arrangements for collaboration including consortia, cooperative research and development agreements, guest researcher arrangements, the Small Business Innovation Research program, and user facilities, visit http://www.nist.gov/mml/working_with_mml.cfm.

The Material Measurement Laboratory, in partnership with the National Research Council, offers postdoctoral research fellowships. For more information, visit http://www.nist.gov/mml/postdoc.cfm.

NIST



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