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News Briefs

General Developments

Inquiries about News Briefs, where no contact person is identified, should be referred to the Managing Editor, Journal of Research, National Institute of Standards and Technology, Building 101, Room E215, Gaithersburg, MD 20899-2500; telephone: (301) 975-3577.

INFORMATION ON WELD FERRITE STANDARDS NOW AVAILABLE

Austenitic weld metals usually contain a small but controlled amount of ferrite to reduce the tendency for cracking during solidification. Ferrite is a magnetic component that has an important effect on properties such as weld toughness and corrosion resistance. Stainless steel welds contain a balance of austenitic and ferritic phases to optimize their mechanical properties. Measurement of the ferrite content is an important commercial issue because content ranges are commonly specified in contracts and production standards. In the United States, the amount of ferrite is usually measured magnetically according to the American Welding Society AWS A4.2 standard.

The AWS standard specifies procedures for both primary and secondary calibration of the instruments. Primary calibration is based on reference materials of coating thickness, such as NIST Standard Reference Materials 1361 to 1364. Secondary calibration is based on certified specimens of stainless steel and is the only way of calibrating instruments for which no primary calibration method exists. It is also the most appropriate standard for in-process checks and is much more durable than the primary reference materials.

NIST recently acquired the responsibility for calibrating and distributing secondary standards for both national and international markets, and has just published a guide to these calibrations titled *Secondary Ferrite Number Reference Materials: Gage Calibration and Assignment of Values* (NIST Special Publication 260-141). The publication covers gage calibration, measurement of secondary reference materials, certification of secondary reference materials and discussion of errors, and microstructure. NIST also sells sets of these secondary ferrite standards, known as RM 8480 and RM 8481 (RM stands for reference materials).

Copies of the calibration guide (ask for no. 10-00) are available from Sarabeth Harris, NIST, MC104, Boulder, CO 80303-3337; (303) 497-3237. The SRMs and RMs can be ordered from the Standard Reference Materials Program, NIST, 100 Bureau Dr., Stop 2322, Gaithersburg, MD 20899-2322; (301) 975-6776; fax: (301) 948-3730; srminfo@nist.gov.

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COMMON TIME SCALE ESTABLISHED FOR ALL OF NORTH AMERICA

The official time scales of North America are coordinated through regular comparisons among the Canadian National Research Council (NRC), the Mexican Centro Nacional de Metrología (CENAM), and the U.S. National Institute of Standards and Technology. After several years of international comparisons and negotiations, NRC, CENAM, and NIST recently have declared that their respective versions of Coordinated Universal Time (known as UTC) are equivalent to within 5×10^{-6}s for time measurements and within 1×10^{-12} for frequency measurements.

The common time scale defined by the declaration is known as UTC North America, and within the stated uncertainties, the time supplied by any of the three national laboratories UTC(NRC), UTC(CENAM) or UTC(NIST) can be used as UTC North America without corrections or conversions.

This declaration supports trade and technology across the region, especially through such things as time tags for financial transactions and scientific observations. The three institutions hope that a common time

eventually can be extended to include all members of the Interamerican Metrology System (abbreviated SIM for the Spanish translation, Sistema Interamericano de Metrología), an organization set up to harmonize measurement standards among its members, including nearly all of the nations in North, Central and South America, as well as the Caribbean.

To access the official time in any U.S. time zone, go to www.time.gov on the World Wide Web. For times outside the United States, the site offers links to a UTC display and an international time zone web site (via the "About This Service" page).
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OH, WHAT A TANGLED WEB THESE PARTICLES WEAVE!

Researchers in the Time and Frequency Division of NIST's Boulder, CO, Laboratories have made the first observation of quantum entanglement of four particles. Featured as the cover story in the March 16, 2000, issue of *Nature,* the experiment is considered an essential step toward the future development of a quantum computer a device whose computing capabilities would be defined by the laws of quantum physics, far surpassing any conventional computer in power and efficiency when applied to certain problems.

Entanglement is a form of linking between two or more particles in which some of the quantum properties of those particles become "shared." Subsequently, information about one particle's properties is instantly and "mysteriously" linked to the others, even when the particles become widely separated. Albert Einstein termed this phenomenon "spooky action-at-a-distance," and it remains one of the most puzzling features of quantum mechanics.

To achieve the entanglement, NIST researchers confined four singly ionized beryllium atoms in an electromagnetic trap so that they were spaced along a line. They then used lasers to cool the atoms to near absolute zero and forced them all to be in the same spin state (atoms can be in one of two states: spin-up or spin-down). Suitably tuned laser light then entangled the atoms by exploiting their mutual electrical repulsion, creating a superposition of all four atoms being both spin-up and spin-down simultaneously.

Quantum superpositions are often explained in terms of the famous cat postulated in 1935 by physicist Erwin Schroedinger. Schroedinger considered the possibility that a cat could be made to be both dead and alive at the same time when the rules of quantum mechanics are followed to an extreme. "Schroedinger's cat" soon became a shorthand way to refer to a whole class of superposed quantum states.

Although the NIST result represents the largest entangled superposition ever achieved, four atoms is still far removed from the complexity of a cat. However, as a NIST researcher explains, "Our technique is scalable to a lot more atoms. If we get to that level, we'll not only bring the strangest feature of quantum mechanics closer to the macroscopic world, but we also may have a quantum computer."

Scientists predict that such a computer could store and process superpositions of numbers in parallel, using the extra linkage afforded by entanglement. A quantum computer would quickly solve problems such as the factoring of extremely large numbers and the handling of huge arrays of data tasks requiring so much memory that conventional computers cannot handle them.

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NIST HELPS DEVELOP SOME OF WORLD'S COLDEST REFRIGERATORS

For most people, refrigeration means a large box where milk is kept cool and ice cream is kept frozen. But there are some people for whom refrigeration means cooling things down to just a few degrees above absolute zero. Now, that's *really* cold! NIST has been a pioneer in the development of these extremely low temperature refrigerators, called cryocoolers.

Since 1950, about 100 000 cryocoolers have been manufactured in the United States for military applications such as cooling infrared sensors in tanks, airplanes and missiles. However, the past decade saw the market for cryocoolers move to the civilian side—a trend that appears to be growing strong. For example, cryopumps for the semiconductor fabrication industry have been the primary application of the technology since 1990, with the devices being produced at a rate of about 20 000 per year. And as semiconductor components continue to shrink, companies will need cryocoolers with less vibration and that can reach temperatures as low as 10 K to 15 K above absolute zero. At the other end of the scale, large cryocoolers are being developed for liquefying natural gas and methane-rich gas emitted from large landfills. Perhaps the application most familiar to the public is the use of cryocoolers in superconducting magnets for magnetic resonance imaging systems where temperatures can get down to 4 K above absolute zero.

A new paper from NIST reviews the history and development of cryocoolers, focusing on one type called a

pulse-tube refrigerator. Because these refrigerators have no moving parts at the cold end, they provide less vibration, higher reliability and lower cost. They also have a longer lifespan from 3 to 10 years—and are desirable for applications in outer space. Other potential uses for pulse-tube refrigerators include industrial gas liquefaction and power applications of superconductors.

For a copy of the paper, "Development of the Pulse Tube Refrigerator as an Efficient and Reliable Cryocooler" (no. 11-00), contact Sarabeth Harris, MC104, NIST, Boulder, CO 80303-3337; (303) 497-3237; sarabeth@boulder.nist.gov.
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FINANCIAL STANDARDS COMMUNITY TO USE NIST CRYPTOGRAPHY GUIDELINE AS A MODEL

At the most recent meeting of ANSI X9F3, a subcommittee of Accredited Standards Committee X9F, which is responsible for developing information security standards and guidelines for the financial community, members expressed significant interest in the new NIST Special Publication (SP) 800-21, *Guideline for Implementing Cryptography in the Federal Government.* Members of the financial community proposed the development of a new ANSI document based heavily on the guideline, which was authored by a NIST staff member. The ANSI document will be written for the financial sector, rather than the federal government, and will guide developers, integrators, managers, technical specialists, procurement specialists, and auditors of financial information security systems. X9F3 will submit a New Work Item proposal for this document to ANSI X9F for balloting this spring.

SP 800-21 provides guidance to federal agencies on how to select cryptographic controls for protecting sensitive unclassified information. It presents a thorough overview of the current suite of federal standards used to provide numerous security services, such as confidentiality, authentication, integrity, etc. Federal employees who are responsible for designing systems and procuring, installing, and operating security products to meet identified security requirements comprise the intended audience of SP 800-21. The document does not provide a technical discussion of the mathematics that underlies cryptographic security. Rather, it provides managers, technical specialists (not necessarily experienced with cryptography), and procurement specialists with sufficient information to select appropriate cryptographic methods to protect sensitive data.

SP 800-21 is available at http://csrc.nist.gov/nistpubs/. For more information on NISTs cryptographic standards, see http://csrc.nist.gov/cryptval.
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COORDINATE MEASURING MACHINE UTILIZED FOR PRECISION MEASUREMENTS

A commercial, state-of-the-art coordinate measuring machine (CMM), which was error mapped at NIST last year to improve its accuracy, is now being utilized by NIST staff for many demanding measurement needs. Most recently, the machine was used to measure a set of ball bars that serve as critical length standards for a new measurement of the universal gravitational constant *G* being carried out by a team of researchers at the University of Washington. Ball bars up to 460 mm in length were measured with uncertainties below 0.5 μm. As a consistency check, the ball bars also were measured on another NIST CMM; these values agreed with the first values at the submicrometer level, which is within the combined uncertainties expected for the two machines. CONTACT: Dennis Everett, (301) 975-5272; dennis.everett@nist.gov.

TRANSMITTAL PAGE OF U.S. CONSTITUTION SEALED IN NEW ENCASEMENT

Resulting from the outstanding effort by a large number of NIST staff, the transmittal page of the U.S. Constitution has been sealed in the first of the new encasements for the Charters of Freedom documents (i.e., Constitution, Declaration of Independence, and Bill of Rights). Several NIST staff members were present on Feb. 23 to close the valves to complete the gas filling and sealing of the first encasement. The encasement is filled with humidified argon (40 % relative humidity at the display temperature) with very low levels of residual oxygen. This accomplishment represents the end of the beginning for the project team. Next, the project team must build the second prototype (of a smaller size) and then complete the production run of seven more encasements. The ability to draw on the diverse expertise of so many NIST staff has enabled this project to meet the extremely challenging performance and schedules demanded by the National Archives and Records Administration.
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METROLOGY FOR DEVELOPMENT OF EMBEDDED CAPACITANCE TECHNOLOGY FOR HIGH-SPEED ELECTRONICS

NIST scientists, in collaboration with industry and academia, are developing test methodology for embedded capacitance technology. There is a widespread need for power-ground decoupling in todays electronic circuits to assure signal integrity and to reduce electromagnetic noise. Currently used discrete capacitors pose several drawbacks, such as the significant manufacturing costs and the amount of surface area they occupy on the electronic assembly. In addition, discrete capacitors do not perform adequately at frequencies above 1 GHz, the frequency regime for todays wireless communication and other high-speed electronics. In looking for a technical solution the National Center for Manufacturing Science, NIST, and more than a dozen industry partners formed a consortium to develop and advance embedded-decoupling-capacitance (EDC) technology. The embedded-decoupling capacitance appears to be the most efficient way to achieve low noise in the voltage driving device, and thus, the highest possible data-speed that otherwise is unobtainable by any other known packaging solution.

Through this multidisciplinary effort over the past 2 years, the EDC Consortium has identified polymer-ferroelectric-composite materials as one of the primary candidates for this new technology need. The NIST effort focused on design of test vehicles and procedures for dielectric testing these polymer composite films. Progress on this effort was reviewed at a recent workshop organized by the EDC Consortium that attracted over 100 researchers from materials suppliers, circuit manufacturers, original equipment manufacturers, and universities. During the workshop, experts from the consortium members, including NIST, discussed new design guidelines and measurement aspects of the EDC test methodology that led to agreement on further actions towards developing a new standard test procedure for EDC technology.

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COMPUTATIONAL STUDIES ADVANCE ATOMISTIC UNDERSTANDING OF ELECTRONIC CERAMICS

Recent computational studies by NIST researchers have made significant advances in elucidating the microscopic origins of the behaviors of two types of electronic ceramics. The first type, lead-containing perovskite ceramics, $PbB_{1/3}B'_{2/3}O_3$ (B and B′ are metal ions such as Mg^{2+}, Ti^{4+}, and Nb^{5+}), are currently used in actuators and sonar/medical imaging transducers. The electrical properties of these materials are sensitive functions of the precise arrangements of the metal ions in the crystal structure; hence, carefully controlled processing is required to achieve optimized properties. First-principles total energy calculations have revealed a complex many-body interaction between lead and certain oxygens that explains atomistically why the B cations disorder at much lower temperatures when the ceramics contain Pb instead of Ba. Typically, Pb–O bonds are stronger and more covalent than Ba–O bonds because Pb has a lone-pair of 6 *sp* electrons—this type of interaction results in technically important properties such as ferroelectricity in $PbTiO_3$. The computational results showed that this Pb–O interaction is further enhanced when the oxygen is "underbonded"; i.e., when the other cations bonded to that oxygen are relatively low in charge. For example, the oxygen in a Mg^{2+}–O–Mg^{2+} environment is underbonded and reacts more strongly with Pb than an oxygen in a Ti^{4+}–O–Ti^{4+} environment. These results explain why, how, and under what conditions metal ions order and/or disorder, and are immediately useful for property optimization.

The second electronic ceramic, $CaTiO_3$, is used in base station filters and resonators for wireless communications. The dielectric constant of $CaTiO_3$ is nearly 200, which is unusually high for a non-ferroelectric material. First-principles calculations reveal the microscopic origin of these unusual electrical properties. Computed phonon spectra and dielectric constant indicated that interatomic forces in $CaTiO_3$ are characterized by a delicate balance between electrostatic attraction and short-range repulsion, which results in a set of low-frequency phonons that have large amplitudes in an applied electric fieldthese phonons are the direct cause of the high dielectric constant. The results also revealed the nature of these critical phonons as modes in which the Ca^{2+} and Ti^{4+} cations move together in a direction opposite that of the negatively charged oxygens—this explains chemically why the polarization associated with these modes is maximized, and the very high dielectric constant is observed. These results provide fundamental knowledge useful for the rational design and prediction of materials with controlled properties.

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THERMODYNAMIC DATA PREDICTS CONDITIONS FOR ALLOY ELECTRODEPOSITION

The electrodeposition of metallic alloys has been central to the growth of the electronics and magnetic recording industries. This is largely due to the exceptional properties exhibited by electrodeposited material as well as

the favorable economy of scale associated with electrodeposition processes. Most often, alloy deposition proceeds at potentials well below the reversible potentials of the alloy constituents. Composition and microstructure are generally controlled by electrolyte composition, solution hydrodynamics and electrode potential. In some cases, alloys can be formed at potentials that are positive of the reversible potential of the less noble species (underpotential deposition, UPD) due to the favorable free energy associated with alloy formation.

A technology important to electronics manufacturing in which UPD plays a vital role in determining deposit properties is the electrodeposition of gold. For gold thin film growth, electrodeposition proceeds in the UPD region of an impurity metal which promotes nucleation and grain refinement. The impurity metal is incorporated only at trace levels in the deposit. It is likely that UPD alloy deposition will be seriously examined for copper metallization for future generations of on-chip interconnects requiring copper alloys. NISTs research objective is to develop the underlying theory and metrology necessary to gain a better understanding of UPD as it relates to the bulk formation of alloys. In collaboration with a University of Mississippi scientist, NIST researchers have examined the electrodeposition of aluminum-transition metal alloys from an aluminum chloride/1-methyl-3-ethylimidazolium chloride ambient temperature molten salt. This non-aqueous electrolyte was chosen so that surface oxides and hydrogen evolution could be avoided. Using the alloy free energy data that appear in the phase diagram literature, the researchers have accurately predicted that Cu-Al, Ni-Al, Co-Al, and Fe-Al alloys can be electro-deposited at potentials positive of the aluminum reversible potential; i.e., these alloys co-deposit by a UPD mechanism. Further, the researchers can predict the potential at which alloy deposition is initiated. The alloy free energy treatment also accurately predicts that Zn-Al and Sb-Al alloys will not form by UPD. Future work will focus on the development of electrode potential—alloy composition relationships based on alloy free energy.

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CROSSLINKED MICELLAR GEL FOR ENVIRONMENTAL CLEANUP

Surfactants are commonly used in detergency applications where several hundred surfactant molecules aggregate to form a micelle consisting of a hydrophobic core that is shielded from its aqueous environment. Unwanted (often oily) solutes are spontaneously solubilized in the hydrophobic cores of the micelles, providing a homo-geneous dispersion of oil in water where the oil is effectively concentrated inside the micelle. Unfortunately, the oil-containing micelles are typically too small (ca. 5 nm) to be removed from the water by conventional methods such as filtration or centrifugation. Stabilized "macro-micelles" would provide a method for not only concentrating contaminants, but also removing them from solution.

Recently, a NIST chemical engineer in the NIST Center for Neutron Research (NCNR), succeeded in synthesizing a surfactant-based material that retains features and functionality of surfactant micelles and benefits from the structural stability of a crosslinked polymer matrix. The material, a crosslinked micellar gel, is prepared by a simple one-step aqueous polymerization of the surfactant cetyltrimethylammonium 4-vinylbenzoate to which a small quantity of a crosslinker, divinyl benzene, has been added. As prepared, the surfactant mass fraction of the gel is 1 % and its water mass fraction is 99 %, but it can easily be handled and cut to a desired shape.

Physical characterization of the micellar gel at the NCNR by small-angle neutron scattering has confirmed that the structure of the gel is that of cylindrical micelles between crosslinks. The micelles have a circular cross-section of 4 nm, and an average pore size of 40 nm. The pore size is adjustable by controlling the initial surfactant concentration. The micellar gel is capable of solubilizing common hydrocarbons and other hydrophobic solutes. The most significant advantage of the micellar gel is that once oily material has been solubilized and concentrated in the gel, the gel (and the contaminant) can simply be lifted from the solution. This material clearly has promise in use for wastewater cleanup (gasoline, for example). Other possible applications include a controlled release matrix for drug delivery, a porous matrix for gel electrophoresis, or a selective filter membrane. A patent is pending on the material and work is continuing toward defining a class of crosslinkable micellar materials.

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QUANTUM ENTANGLEMENT OF FOUR PARTICLES FEATURED IN *NATURE*

In the cover story of the March 16, 2000, issue of *Nature,* NIST staff members describe the first successful quantum entanglement of four particles. This breakthrough represents an important step in demonstrating a quantum-logic system that possesses the requisite characteristics for scaling to larger computing systems.

Such entangled states explicitly demonstrate the nonlocal character of quantum theory, and have been suggested for use in quantum communication, cryptography, computation, and high-resolution spectroscopy.

The entanglement used a recently proposed technique applicable to trapped ions. Coupling between the ions is provided by the Coulomb interaction through their collective motional degrees of freedom, but actual motional excitation is minimized. Entanglement was achieved using a single laser pulse, and this same one-step method can in principle be applied to any number of ions.

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SCATMECH C++ LIBRARY MAKES POLARIZATION CALCULATIONS AVAILABLE TO EVERYONE

NIST Scientists perform measurements of the angular distribution and polarization of laser light that has been scattered elastically from smooth surfaces possessing various types of defects. They have found that scattering from each type of defect or particulate contamination on the surface exhibits a characteristic scattering pattern, and the experimental results are in excellent agreement with theoretical predictions. Hence, by comparing observed and theoretical scattering patterns, researchers can identify the particular defects present in a sample. These results are being used by the semiconductor industry to improve its ability to locate and identify contamination on silicon wafers. Other industries, such as the display, storage, and optical industries, which also require high-quality surfaces, are expected to follow.

Calculations of scattered light intensity and the analysis of its polarization, however, are not typically within the capabilities of any but the leading specialists. Accordingly, NIST has developed an object-oriented software library, the SCATMECH Polarized Light Scattering C++ Object Class Library, which implements various models and allows researchers to analyze polarizations readily. The SCATMECH library contains object classes that allow researchers to manipulate objects describing the polarization state of light, to predict the intensity and polarization of light scattered using various approximations, and to readily add new models to the library. The library enables researchers to try models for their own applications, allows software developers to expand ray-tracing programs, and acts as a platform to allow other researchers to expand the library. Anticipated users include wafer inspection toolmakers, optics companies, manufacturers of data storage media and devices, com-panies interested in the appearance and surface finish of products, and academic researchers. The SCATMECH Library is being distributed on the World Wide Web at http://physics.nist.gov/scatmech.

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A NEW THEORY FOR TRANSVERSE COOLING IN FOUNTAIN FREQUENCY STANDARDS REDUCES UNCERTAINTIES

In a collaborative effort with Russian scientists, a NIST researcher has developed a new concept for two-dimensional sideband Raman cooling and Zeeman state preparation in an optical lattice. The development of this concept was driven by the need to reduce transverse velocities of laser-cooled atoms in primary cesium-fountain frequency standards, and will provide for significant reduction in the uncertainty of NIST-F1, NIST's new primary frequency standard.

This new approach for transverse cooling appears to be both simpler and more effective than previously proposed methods and has two significant advantages: the method only requires laser beams transverse to that atomic fountain direction, and the cooling process simultaneously pumps atoms into the desired ground-state energy level. An experimental apparatus designed to test the effectiveness of this cooling method is now under development at NIST.

The largest uncertainty in cesium-fountain frequency standards is the so-called spin-exchange frequency shift, the magnitude of which depends on the density of atoms averaged over the fountain trajectory. In NIST-F1, the magnitude of the transverse velocities of the launched atoms (cooled to about 1.5 μK) results in a loss of approximately 90 % of the atoms before they reach the detection region. This means that most of the atoms contribute to an increased spin-exchange frequency shift without contributing to the output signal. With better transverse cooling, a larger fraction of the atoms will reach the detection region and the launch density can be decreased leading to a lower spin-exchange shift while retaining a good signal-to-noise ratio. The new theory predicts that 95 % of the atoms can be cooled to transverse temperatures of about 100 nK.

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METALLIC XENON OBSERVED

A NIST scientist, in collaboration with workers at the Carnegie Institution of Washington, has investigated the electrical conductivity of Xenon at high pressures.

Rare gases such as Xe are expected to metallize only at very high pressures because the atoms have completely filled electronic energy shells. Xe has been predicted to have the lowest metallization pressure. Various optical measurements have suggested a transition to metallic-like behavior between 135 GPa and 150 GPa.

In this work, direct measurements of the temperature dependence of the conductivity from 0.03 K to 90 K, at a variety of pressures between 121 GPa and 155 GPa, have clearly shown a transition from semiconducting to metallic conductivity for pressures above 121 GPa. A search for pressure-induced superconductivity (which some theoretical work has predicted) yielded a null result, even at the highest pressure and lowest temperatures. This search will be continued when a new pressure cell capable of reaching higher pressures is finished.

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SUPPORT PROVIDED FOR NEW OSCILLOSCOPE CALIBRATORS

As the frequency response rolloff performance (or 3 dB bandwidth) of newer real-time analog and digital oscilloscopes has increased, verifying the specification for this important performance parameter has become increasingly difficult. Recent offerings of popular brands of real-time sampling scopes offer 3 dB bandwidth specifications as high as 3 GHz.

The capability at NIST of measuring the parameters of fast pulse sources has continued to improve. Equivalent-time sampling oscilloscopes having effective 3 dB bandwidths of 50 GHz are now used at NIST to support calibrating the parameters of fast pulse generators (edge rise times as short as 15 ps). Also, a precision waveform sampling system based on a custom-made, strobed analog comparator integrated circuit has been developed having an effective 3 dB bandwidth of 2.5 GHz.

Therefore, when two U.S. instrument manufacturers decided to develop new oscilloscope calibrators having fast edge pulse generators for 3 dB bandwidth testing, NIST was prepared to characterize the prototype units that both companies sent in for special calibration (formal NIST reports issued). Besides testing for the edge rise time (or transition duration), the NIST pulse testing systems were able to make accurate determinations of the waveform aberrations (deviations from flatness in settling) that were desired by the two companies. New product catalog entries and marketing literature by both companies describe the specifications and features that are now offered in the new calibrators, related to the unique measurement support capabilities provided by NIST.

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QUANTUM MECHANICAL SIMULATORS EVALUATED TO EXPEDITE DESIGN OF DEEP SUBMICROMETER TRANSISTORS

Researchers at NIST initiated a study to compare, for the first time, quantum mechanical simulators and analysis software suites that are critical to the continued shrinking of silicon complementary metal oxide semiconductor (CMOS) transistor structures. The significance and industry need for this study is accentuated by a private company's recent announcement of the production of a 2 nm gate oxide film, which is equivalent to about 6 atoms stacked end-to-end. At this thickness, reliability of the transistor becomes a serious issue, because atomic-scale defects can result in charge leakage and lead to device failures. Even for a defect-free oxide, quantum mechanical tunneling leads to predictable, but unwanted currents.

Today, industrial determinations of gate oxide thickness are based on consistency between electrical measurements (capacitance-voltage, or *C-V* curves) and quantum mechanical simulations. The simulations take into account electron tunneling, quantization of states in the gate channel, and depletion of charge in the polysilicon gate electrode, all with different levels of sophistication. In spite of the importance of the models, there have been no reported comparative investigations of differences resulting from the different simulations until now.

In addressing this need with a first-ever benchmarking study, NIST researchers acquired and installed the simulators and analysis software suites that are available from university, corporate, and commercial research groups. A capacitor test structure was designed, representing different levels of electrode doping, and oxide thickness ranging from 1 nm to 10 nm. Qualitative trends of the *C-V* curves were found to be similar for all simulators; however, quantitative analysis revealed both depletion and accumulation capacitance differences, which become larger as the film thickness approaches 2 nm.

NIST researchers presented invited summaries of these findings to the SEMATECH Gate Stack Engineering Working Group and the International Metrology Council.

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COAXIAL NOISE-TEMPERATURE MEASUREMENT SERVICE REOPENED WITH NEW, FASTER RADIOMETERS

NIST staff have completed construction and testing of two new radiometers for measuring coaxial noise sources. The two new radiometers cover the frequencies 4 GHz to 8 GHz and 8 GHz to 12 GHz, respectively. Their completion has permitted the reopening of the 4 GHz to 12 GHz coaxial noise-temperature measurement service, which had been suspended due to water damage to the previous radiometers. Careful mechanical, thermal, and electronic design and construction have resulted in major improvements in stability, repeatability, and speed over the previous generation of NIST radiometers. These improvements are all required for a measurement service for noise parameters of amplifiers, which is currently under development. The new radiometers also pay an immediate dividend in greatly increased speed of traditional noise-temperature calibrations. On the new system, it is possible to calibrate a noise source at 10 or more frequencies in the time required for one frequency on the old system. This greatly increased speed has permitted a corresponding reduction in the fee charged to customers for the measurement service. The cost for each additional frequency point (after the first) has been reduced by a factor of 10, i.e., to $210 per point. The new system is documented in a NIST Technical Note and a paper presented at the 55th Conference of the Automated Radio Frequency Techniques Group (ARFTG) held in Boston in June 2000.

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NEW EFFICIENT APPROACH TO BLIND DECONVOLUTION OF IMAGES DISCOVERED

A NISTmathematician has developed a powerful new technique for blind deconvolution of images. Blind deconvolution seeks to deblur an image without knowing the cause of the blur. This is of considerable interest in numerous medical, industrial, scientific, and military applications. The mathematical problem is very difficult and not fully understood. So far, most approaches to blind deconvolution have been iterative in nature. However, the iterative approach is generally ill behaved, often developing stagnation points or diverging altogether. When the iterative process is stable, a large number of iterations and several hours of computation may be necessary to resolve fine detail.

In a recently completed research paper, the mathematician has developed a novel approach to the problem that is non-iterative in nature. The method does not attempt to solve the blind deconvolution problem in full generality. Instead, attention is focused on a wide class of blurs that includes and generalizes Gaussian and Lorentzian distributions, and has significant applications. This is the class **G**. Likewise, a large class of sharp images is exhibited and characterized in terms of its behavior in the Fourier domain. This is the class **W**. It is shown how 1-D Fourier analysis of blurred image data can be used to detect class **G** point spread functions acting on class **W** images. This approach is based on empirical observations about the class **W** that have not previously been exploited in the literature. A separate image deblurring technique uses this detected point spread function to deblur the image. Each of these steps uses direct (non-iterative) methods. Although the new technique does require interactive adjustment of parameters, it still enables blind deblurring of 512×512 images in only minutes of CPU time on current desktop workstations.

Analysis of the blind deconvolution problem within the class **G** already has produced a number of interesting and unexpected results. Current research seeks to extend this approach to a wider class of blurs, in particular, out-of-focus blurs.

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THE EFFECTS OF GAS SPECIE ON METERING PERFORMANCE OF CRITICAL FLOW VENTURIS

NIST researchers have identified a new mechanism that affects the mass flow of certain gases (e.g., CO_2) flowing through small-scale critical flow venturis (CFVs). In small-scale CFVs, rapid flow acceleration processes occur over small distances (i.e., 1 mm) leading to short residence times (about 10^{-6} s). This leaves insufficient time for the vibrational energy of the flowing gas molecules to equilibrate with the changing thermodynamic environment. For gases that relax slowly and have sufficient levels of vibrational energy, vibrational relaxation phenomena has been shown to increase the discharge coefficient by as much as 2 % relative to gases unaffected by this mechanism.

A first principle mathematical model has been developed that predicts mass flow for gases affected by non-equilibrium states (e.g., CO_2) as well as gases unaffected by non-equilibrium states (e.g., N_2, H_2, O_2, Ar). The model uses molecular theory to determine the rate of relaxation of vibrational energy modes due to non-equilibrium processes. The solution of the non-equilibrium flow field is obtained by globally iterating between the gas dynamic equations and the vibrational energy rate equation so that both are simultaneously satisfied. This model yields a reduction in uncertainty

by a factor of 5 compared to existing models for CO_2 gas flow, and predicts the discharge coefficient for all gases to within 0.4 % of experimental data. The good agreement between the model and experiment could help alleviate the need for experimental calibration in many applications and even enable the use of these sensors as primary standards at mid-range uncertainties.
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NIST HELPS ASME PRODUCE NEW STEAM TABLES BOOK

The American Society of Mechanical Engineers (ASME), through its Research and Technology Committee on Water and Steam in Thermal Systems, Subcommittee on Properties of Steam, has issued a new reference book: *ASME International Steam Tables for Industrial Use* (ASME Press, New York, 2000). The authors include two NIST staff members and NIST personnel produced several chapters and all of the tables.

Water and steam are important in many fields of engineering, notably the power industry where the thermodynamic properties are central to the design and evaluation of steam power generation equipment. Standardized properties are essential to provide a level playing field for all parties in the industry. Standard property formulations are set by the International Association for the Properties of Water and Steam (IAPWS). The book is based on the standard for industrial use adopted by IAPWS in 1997. The previous standard, adopted in 1967, was the basis for the widely used ASME Steam Tables book. The new formulation is a significant improvement in accuracy, internal consistency, and computational speed. The book was redesigned and rewritten to reflect the needs of current engineers. Tables and charts are given in both SI and U.S. customary units, and are less extensive than in the 1967 book in recognition that they are now mainly a tool for rough estimates, with computers being used for most design calculations.

This book is based on the IAPWS standard "for industrial use," which is tailored to the needs of the steam power industry. This should not be confused with the separate standard IAPWS maintains "for general and scientific use," which is a more precise and comprehensive (but also more complex) formulation. Software implementing this latter standard is distributed by NISTs Standard Reference Data office. Software implementing the standard for industrial use, and therefore
consistent with the new book, is available from ASME.

Copies of the steam tables handbook may be obtained by contacting the American Society of Machanical Engineers, Customer Service, 22 Law Dr., P.O. Box 2900, Fairfield, NJ 07007-2900; (800) 843-2763; www.asme.org. The cost is $60 for ASME members and $75 for non-members.
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NVLAP OFFERS NEW ACCREDITATION PROGRAMS

The National Voluntary Laboratory Accreditation Program (NVLAP) is now offering accreditation for certifiers of spectrophotomet-ric filter NIST Traceable Reference Materials (NTRMs) in the chemical calibration field of its Calibration Laboratories Accreditation Program. NIST Special Publication SP 260-140: *Technical Specifications for Certification of Spectrophotometric NTRMs,* describes an NTRM as "a commercially produced reference material with a well defined traceability linkage to existing NIST chemical measurement standards."

In addition, under the terms of an agreement between NIST and the U.S. Environmental Protection Agency (EPA), NVLAP now accredits laboratories that are competent to characterize samples and to conduct proficiency test programs to support EPA requirements for environmental laboratories. Technical oversight of the program and the evaluation process is provided by NIST.

NVLAP accreditation is offered in areas necessary to support environmental laboratory testing of drinking water and waste water. Testing is currently divided into three major areas: inorganic chemical analysis; organic chemical analysis; and biological and microbiological testing. A fourth group, radiological testing and analysis, will be added in the near future. To date, 11 providers have been accredited for various program codes within the three groups. *The Directory of Accreditation Laboratories* on the NVLAP web site at http://ts.nist.gov/nvlap provides details.
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NIST VALIDATES PREDICTIONS OF AIR CLEANER PERFORMANCE

NIST has completed the first phase of an experimental evaluation of the ability of the CONTAM program to predict the impact of residential indoor air quality control technologies. CONTAM is a multizone airflow and pollutant transport model developed at NIST. In this first phase of testing, the air cleaning ability of several mechanical air filters and electronic air cleaners was determined in a single-zone test house. Measurements

were made of other airflow and particle transport parameters such as the envelope airtightness, particle deposition rates, and particle penetration factors. These parameters then were used as input data to a CONTAM model of the test house. CONTAM predictions of building air change rates and particle concentrations were compared to measurements for two different air cleaners to assess the ability of CONTAM to predict the impact of these devices. For both tests, CONTAM was able to predict air change rates within 5 % of measured values and average particle concentrations within 30 % of measurements for particle sizes between 0.3 μm and 5 μm. The results are described in detail in the final report (NISTIR 6461). This work is continuing with a second phase being conducted in an occupied townhouse.

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FIRE DYNAMICS SIMULATOR (FDS) RELEASED BY NIST

NIST publicly released its fire model, Fire Dynamics Simulator (FDS), plus the companion visualization program, Smokeview.

The model has previously been called LES3D (Large Eddy Simulation) and IFS (Industrial Fire Simulator). The new name was chosen to distinguish the released version from internal research versions. An article in *The New York Times* Science section (March 7, 2000) highlighted the capabilities and past applications of the model. The software and references can be downloaded from http://fire.nist.gov.

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NIST CO-HOSTS WORKSHOP ON OPEN ARCHITECTURE CONTROL FOR ROBOTICS

NIST and the Robotic Industries Association (RIA) hosted a workshop on Open Architecture Control for the Robotics Industry, in February 2000, in Orlando, FL. The workshop included presentations from end users, vendors, and systems integrators, followed by three parallel breakout sessions in which the attendees discussed key items of interest that could form the basis of ongoing work. Key topics covered include the use of existing standards to reduce system integration costs that can reach six times the purchase cost of the robot itself. Over 50 participants attended the workshop, and proceedings are available.

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NEW NIST PROGRAM THE "SHOP FLOOR AS NATIONAL MEASUREMENT INSTITUTE" INTRODUCED AT CONFERENCE

The new NIST program, "The Shop Floor as National Measurement Institute," has been introduced publicly at a corporate conference on Large Scale Optical Metrology in an invited presentation by a NIST staff member.

The conference, held in Long Beach, CA, in February 2000, was an ideal venue for this introduction because the audience was composed of metrology managers and practitioners. The presentation described how U.S. manufacturers could meet the requirements of the "new traceability" defined in an emerging suite of international standards. These ISO standards, called the "Global Product Specification," deal with measurements made to determine whether part dimensions conform to the tolerances specified by a customer.

A primary concern of these standards is that measurements be linked to the Systeme Internationale dUnites (SI) unit of length and described by a statement of uncertainty. The uncertainty is to conform to the ISO Guide to the Expression of Uncertainty in Measurements (GUM). A combination of GUM and shop floor interferometers will allow industry to assert such traceability without use of national measurement institute (NMI)-calibrated dimensional standards. However, new methods, procedures, instruments, and standards will need to be developed. Therefore, a primary goal of this new program is to aid U.S. manufacturers to realize the "new traceability" on the shop floor through development of these needed measurements and standards.

The program will focus on three areas:

- compensating for the effect of shop-floor atmosphere on interferometric measurements;
- compensating for the effect of non-standard temperatures on parts, gages, and measuring machines; and
- establishing an uncertainty statement for measurements made on the shop floor.

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NIST STAGES AN ACROSS-THE-OCEAN ISO PROJECT TEAM MEETING

In February 2000, NIST staff held a Tele-Conference/NetMeeting of the ISO Project Team developing Application Protocol (AP) 219 on Dimensional Inspection Information Exchange. This specification is currently a Preliminary Work Item of Subcommittee 4 (SC4) on Industrial Data under ISO Technical Committee 184, Industrial Automation Systems and Integration. SC4

has the main responsibility for the development of the set of industrial information standards known as STEP, the Standard for the Exchange of Product Data.

The special Tele-Conference/NetMeeting was held during the February SC4 Meeting in Melbourne, Australia. Together, the group discussed the harmonization of the dimensional measurement concepts in the developing AP219 with similar information concepts in existing Application Protocols, AP214 for automotive manufacturing and AP224 for machining features. The teleconference setup included voice communications by telephone and interactive editing of the EXPRESS schema for AP219. The meeting format enabled a good deal of technical work to be accomplished without the need for all participants to travel to the Melbourne venue.

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FOUR INVITED PAPERS PUBLISHED IN *METROLOGIA*

Four invited papers by NIST authors have been published in *Metrologia,* the international journal of pure and applied metrology (Vol. 36, No. 4, 1999). This volume consists of a special issue to commemorate the formation of the Consultative Committee for Acoustics, Ultrasound, and Vibration (CCAUV) by the International Committee of Weights and Measures (CIPM). Articles in this issue recognize the substantial worldwide effort in the fields of acoustics, ultrasound, and vibration. The CCAUV is actively coordinating international key comparisons that will be essential to the success of the Mutual Recognition Arrangement signed last year by over 30 national metrology institute directors. The titles of the papers are:

- Brief review of primary methods applicable to key comparisons in acoustics;
- Ultrasonic continuous-wave beam-power measurements: 1978-1980 international comparison;
- Ultrasound power measurement by pulsed radiation pressure; and
- Comparison of results of calibrating the magnitude of the sensitivity of accelerometers by laser interferometry and reciprocity.

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NIST HOLDS FIRST JOINT INDUSTRY MEETING ON QUANTUM INFORMATION TECHNOLOGY

NIST scientists recently held a meeting with industrial representatives from leading communication and computer companies interested in quantum information. The meeting was held in March 2000. NIST has established worldwide leadership in the implementation of quantum information using trapped ions. NIST has recently embarked on a larger, coordinated effort to pursue experimental approaches using ultracold neutral atoms, and to evaluate other implementation schemes. A NIST scientist described the potential use of entangled quantum-bits (or qubits) to improve time and frequency standards as one important near-term application.

Industry representatives described their current efforts and interests in this potentially revolutionary technology, and commented on NIST's planned activities. The industry representatives are especially interested in identifying "killer apps" involving a few qubits with an emphasis on applications that can not be done classically. These companies sense that quantum information technology may have enormous economic benefit, but have adopted a wait and see approach pending the discovery of appropriate applications.

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NIST CO-SPONSORS ELECTRONIC DOCUMENTS CONFERENCE

In March 2000, NIST and the Federal CIO Council's Interoperability Committee co-sponsored the Electronic Documents Conference for e-gov designers and implementers throughout the federal government and industry.

The objective of the conference was to get a broad cross-industry/cross-applications look at where we are, where were going, what we want, and how to try to get it, for electronic document interoperability over the next several years. Software product vendors, document user enterprises, government agencies, and standards organizations shared their views and interacted on the issues.

Presentations were given by various standards organizations, including the Association for Information and Image Management, the World Wide Web Consortium Document Object Model Working Group, and the Document Management Platform Special Interest Group of the Object Management Group. The federal government was represented through presentations given by representatives from the U.S. Courts, the Patent and Trademark Office, the Department of Defense, and NASA.

The conference established six working groups to discuss and report back on the following topic areas: multimedia documents in which text/data is secondary; revisable documents-in-progress; business transaction documents of record; engineering and scientific/laboratory documents; negotiable bearer instruments; and general "knowledge" documents. Conference presentations and working-group results are available at www.nist.gov/e-docs/conf.
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NIST HOSTS SECURITY EDUCATORS CONFERENCE

NIST hosted the 13th annual Federal Information Systems Security Educators Association (FISSEA) Conference in March 2000. Nearly 120 information systems security practitioners and managers attended, primarily from federal agencies, college and university faculty and staff, and industry representatives from firms that support federal information systems and security programs.

Presentations during the three-day conference covered the spectrum of information systems security awareness, training, and education. Several panel discussions addressed federal agency use of Computer Security Day and other techniques to "reach the masses." Numerous presenters discussed existing training courses and techniques, from classroom settings to CD-ROM-based material, Web-based courses, and other distance-learning programs.

The annual conference continues to be a valued forum in which federal information systems security professionals can learn of ongoing and planned training and education programs and initiatives. It provides NIST the opportunity to provide assistance to agencies as directed by the Computer Security Act of 1987.
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1998 NTTAA ANNUAL REPORT NOW ON WEB SITE

NIST is required to collect data on standards and conformity assessment activities from federal agencies and submit an annual report to Congress through the Office of Management and Budget. The 1998 Annual Report on fulfillment of responsibilities under OMB Circular A-119 and the National Technology Transfer and Advancement Act (Public Law 104-113) is now available on the TS Office of Standards Services web site at http//ts.nist.gov/icsp. The report includes information on the progress that federal agencies have made toward using voluntary standards instead of agency-unique standards. It also discusses NIST efforts to coordinate agencie's use of voluntary standards and their participation in voluntary standards activities. This report shows a continuing decline in the number of agency personnel participating in standards activities. Several possible explanations for the decline include retirements of key technical staff, increased strategic planning and management of standards activities, and improved reporting accuracy.
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U.S.-CHINA AUTOMOTIVE STANDARDS WORKSHOP

In March 2000, NIST sponsored a 3 day workshop for representatives of the Chinese automotive sector. The NIST workshop was a component of a 2 week program organized by the Society of Automotive Engineers International. The purpose of the program was to enhance opportunities for harmonized standards and promote Chinas recognition of U.S. standards and conformity assessment practices.

The 27 workshop participants from the Chinese government and private sector were introduced to the U.S. agencies and organizations involved in automotive standards development and conformity assessment. They heard about the public and private-sector responsibilities regarding automobile quality and safety, as well as various aspects of the U.S. system, including a description of the U.S. automotive industry and regulatory approach. Participants also toured several NIST laboratories where they were exposed to the research being done at NIST related to the automotive sector. The NIST visit concluded with a lively discussion among U.S. industry representatives and the members of the Chinese delegation about future trends in the automotive industry.
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BROCHURE CAN GET YOUR QUALITY JOURNEY ON THE ROAD

Thousands of organizations use the *Baldrige Criteria for Performance Excellence* to help assess and improve their organization. Vicki Spagnol, principal, Management Insights, New York, N.Y., says, "The Baldrige criteria provide a proven road map for performance improvement—one that will enable your organization to be more successful than you ever imagined."

But, say you've looked at the criteria and are still uncertain about how to begin. To help you get started,

NIST's Baldrige National Quality Program has developed a new brochure, Getting Started-A Guide to Self-Assessment and Action. The guide will walk you through a 10-step approach to assessing your organization's strengths and developing and implementing a plan for improvement.

For a free copy of the new brochure and the *Baldrige Criteria for Performance Excellence,* contact the Baldrige National Quality Program, (301) 975-2036; fax, (301) 948-3716; nqp@nist.gov. Both publications also are available on the Baldrige web site at www.quality.nist.gov.

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NEW VIDEO, CD SPOTLIGHT STRATEGIES OF 1999 BALDRIGE RECIPIENTS

NIST has released a new set of audiovisual materials showcasing the 1999 recipients of the Malcolm Baldrige National Quality Award and the Baldrige National Quality Program. A VHS videocassette contains two versions of a program (short at 11:45 minutes and long at 47:50 minutes) that features the successful strategies of the award's 1999 recipients: STMicroelectronics Inc.-Region Americas; BI; The Ritz-Carlton Hotel Company L.L.C.; and Sunny Fresh Foods. Also included on the videocassette are "A Journey Worth Beginning," encouraging organizations to apply for the Baldrige Award, and "A Uniquely Rewarding Experience," explaining the role of the examiners who evaluate award applications. A CD-ROM package includes all four video programs, as well as the *Baldrige Performance Excellence Criteria* for 2000, presentations given by the 1999 award recipients at the Quest for Excellence XII conference in March 2000, and other information.

The audiovisual materials are available from the American Society for Quality, 611 E. Wisconsin Ave., Milwaukee, Wis. 53202-4606, (800) 248-1946. Item T1089 is the VHS videocassette and CD-ROM for $49.95. Item T1087 is the CD ROM alone for $35.00. Item T1086 is the videocassette alone for $20.00.

For more information on the Baldrige National Quality Program or the Baldrige Award recipients, contact the Baldrige National Quality Program, (301) 975-2036, nqp@nist.gov, or see the BNQP web site at www.quality.nist.gov.

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CONFERENCE OPENS NATIONAL DIALOGUE ON COMBINATORIAL METHODS

Research scientists, process engineers, R&D managers, representatives from federal funding agencies, and academics participated in a broad, open dialogue on their roles in forging the future of chemical and materials sciences through combinatorial methods. A wide variety of exciting technology platforms were discussed, and opportunities for networking with technologists and business people were available. The workshop was held at NIST in Gaithersburg, MD, May 31 to June 1, 2000.

Combinatorial methodology is a set of tools and techniques the chemical and materials science communities will use in the future to accelerate discovery and development of new materials to meet 21st century needs. Combinatorial methods, which use a large number of carefully designed, multi-dimensional experiments that may be performed rapidly or in parallel on a miniaturized scale with automated instrumentation, have revolutionized the R&D process in drug development. Most major chemical manufacturers and several start-up companies have initiated programs within the past two years to exploit combinatorial methods and accelerate the discovery of advanced materials (catalysts, electronic and optical materials, polymers, metal alloys and ceramics) and process optimization.

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WEIGHTS AND MEASURES DOCUMENTS NOW AVAILABLE ON THE INTERNET

The codes and specifications that form the basis of the U.S. system of weights and measures are now available from NIST on the Internet. Manufacturers, as well as international weights and measures organizations, can now easily access accepted specifications and tolerances for scales and other measuring devices in NIST Handbook 44. They also can view model weights and measures laws and regulations, which have been adopted by most states, in NIST Handbook 130. NIST's Office of Weights and Measures posted these documents to increase their dissemination and availability, thereby promoting uniformity of weights and measures in the marketplace. Uniformity protects consumers and benefits businesses by ensuring fair competition.

Handbook 44, *Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices,* contains information needed to design or test

weighing and measuring devices for use in commerce. Its codes cover a wide variety of devices such as those used to dispense home heating oil and gasoline, food store scales, taxi meters, odometers and fabric measuring devices.

Handbook 130, *Uniform Laws and Regulations in the Areas of Legal Metrology and Engine Fuel Quality,* encourages standardization in weights and measures laws within the United States. The handbook contains 10 different model laws and regulations, plus the recommended procedure for verifying the accuracy of retail pricing. It includes regulations prescribing the method of sale for commodities and packaging and labeling requirements.

Both NIST Handbook 44 and NIST Handbook 130 are published by NIST and have been adopted by the National Conference on Weights and Measures, a voluntary standards organization that works closely with NIST to ensure uniform weights and measures in the United States.

The two handbooks are now available on the World Wide Web at www.nist.gov/owm under "General Information." Both are in Adobe Acrobat and Word Perfect formats.

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LOOKING FOR CERAMICS INFO? CLICK OPEN THE NIST CERAMICS WEBBOOK

Materials scientists wanting easy access to ceramics data on the World Wide Web should point their Internet browsers to a new resource: the NIST Ceramics WebBook at www.ceramics.nist.gov/webbook/webbook.htm. This WebBook contains evaluated data, a guide to data centers and sources, as well as software tools and other resources useful for materials research.

The Ceramics WebBook has a link to three NIST-developed materials databases: the NIST High Temperature Superconducting Materials Database, the NIST Structural Ceramics Database and the NIST Property Data Summaries for Advanced Materials. The superconducting materials database offers evaluated thermal, mechanical, structural and superconducting property data for oxide and borocarbide superconductors. The structural ceramics database contains evaluated thermal, mechanical, structural and chemical properties for a wide range of engineering ceramics. The property data summaries contain topical collections of materials property data, each focused on a particular material or a particular property.

In addition to the NIST databases, the Ceramics WebBook links to 22 other government and academic data centers and web resources devoted to biomaterials, ceramics, metals and composites, as well as chemical and physical data. Another page of tools and resources provides links to software tools, a ceramics virtual library, a discussion forum and educational sites.

For more on ceramics research at NIST, visit the Ceramics Division homepage at www.ceramics.nist.gov.

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NIST PARTICIPATES IN SECURE ELECTRONIC MESSAGING DEMONSTRATION

In April 2000 in Boston, MA, NIST participated with other federal agencies and industry partners in a demonstration of the Federal Bridge Certificate Authority (FBCA) using secure electronic mail applications.

Attended by 2500 people, the meeting focused on technologies that enable electronic commerce. The FBCA supports interoperability among federal agency Public Key Infrastructure (PKI) domains in a peer-to-peer fashion and identifies four policies that represent four different assurance levels (rudimentary, basic, medium, and high) for agency-issued public key digital certificates. For this demonstration, the FBCA consisted of two Certification Authorities (CA). It is expected that more internal CAs provided by different vendors will be added to the FBCA in the future.

The internal CA nodes of the FBCA were cross-certified with each other. This resulted in certificate or certificate status information issued by either CA to be accepted by the other CA. In addition, each organization chained an X.500 directory to the X.500 directory system provided by the FBCA. Each organization's e-mail client used a plugin that implemented S/MIME version 3 for encryption and decryption of messages and application and verification of message digital signatures. During the demonstration, digital signatures on the e-mail messages sent between different domains were successfully validated through the PKI. These signature validations demonstrated the most complex multivendor PKI built to date anywhere in the world.

The success of the FBCA demonstration illustrates how electronic commerce can be securely enabled across different governmental domains by providing the security services of authentication and technical non-repudiation by leveraging cryptographic digital signatures. The basic FBCA concept is not limited to electronic commerce between government domains but will enable electronic commerce between government and the industrial and business domains.

More information on NIST's PKI effort can be found at http://csrc.nist.gov/pki.

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NIST-SPONSORED REQUIREMENTS GROUP FOR REAL-TIME EXTENSIONS TO THE JAVA™ PLATFORM PUBLISHES FUNCTIONALITY REQUIREMENTS

Java™ is being deployed in many information technology (IT) areas, far beyond the jazzy web page applets. There are few IT industries where Java is not being mentioned. Real-time applications and embedded systems are two areas that are being addressed more recently in the Java development arena.

The NIST-sponsored Requirements Group for Real-time Extensions to the Java™ Platform has completed its work by finalizing NIST Special Publication 500-243, *Requirements for Real-time Extensions for the Java Platform: Report from the Requirement Group for Real-time Extensions for the Java Platform.* The goal of the Requirements Group was the development of a consensus-based set of real-time functionality requirements for the Java technologies. These requirements are currently serving as input to the Java real-time specification process. Industry participants invited NIST to sponsor and coordinate the requirements effort. Participants included organizations from the embedded, manufacturing, academia, development tool provider, and application developer communities. The group was open to all parties interested in developing requirements for real-time Java extensions. Currently, those interested in real-time extensions for Java are actively specifying those extensions in consortia. As such, the Requirements Group is no longer active.

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NIST SOFTWARE ENABLES CRITICAL METROLOGY FOR TRANSISTOR SHALLOW JUNCTIONS

NIST has released a beta version of software on CD-ROM to 40 semiconductor industry laboratories, which require accurate measurement of the level and distribution of dopant atoms within nanometer-scale transistor structures. The software provides an essential link between qualitative images measured by a scanning capacitance microscope (SCM) and quantitative data required in the fundamental design of the transistor. The International Technology Roadmap for Semiconductors identified SCM as a critical-path metrology for continued miniaturization of integrated circuits, and this software fanout highlights the success of a systematic effort at NIST since the mid-1990s to address the shallow junction profiling problem.

The structure addressed by SCM is the doped junction of the transistor, which is particularly difficult to measure, because it contains mole fractions of only 10^{-6} of electrically active elements such as B or As (dopants) in a highly localized region. In the microscope, capacitance is sensed between the doped region and an ultrasharp tip positioned close to the surface of a cross section cut through the structure. Modern circuits require precise description of the dopant distribution with a spatial resolution better than 10 nm, to enable precise electric field-control of electrons flowing through the device.

The software makes it possible to transform pixel data from an SCM image into an accurate quantitative dopant atom distribution map. The underlying theory was developed at NIST and later reformatted into a package suitable for engineers in the manufacturing environment. The approach was to be (1) user friendly, by employing a graphical interface on a desktop PC, (2) extremely fast, requiring only a few seconds for calculation, and (3) highly accurate, by condensing a first-principles, full three dimensional Poisson solver solution to the problem.

The beta code was made available to all members of the SEMATECH 2-D Profile Working Group when it met at NIST last December. Members of the group are currently conducting round robin measurements of two-dimensional carrier profiles on a series of state-of-the-art circuits (MOSFETS, with channels of 0.5 μm, 0.25 μm and 0.18 μm). Results of the round robin were discussed when the working group reconvened at NIST in June.

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EXPERIMENTAL MEASUREMENTS DEMONSTRATE ADVANTAGES OF USING SUPERCRITICAL FLUIDS IN HEAT EXCHANGERS

For the first time, NIST researchers have measured the thermal performance of a type of process heat exchanger that has been proposed for a carbon dioxide-based alternative refrigeration cycle. This cycle could be used on a variety of heat pumps or air conditioning systems that contain supercritical carbon dioxide (7.38 MPa critical pressure, 31.1 °C critical temperature), a fluid potentially much less harmful to the environment than conventional refrigerants. Because the properties of a fluid vary considerably near the critical point with small changes in temperature or pressure, flow behavior and the transport of heat potentially are very different in this regime and must be studied carefully to develop accurate predictive methods for process design. The system tested was prototypical of the widely used shell-in-tube heat exchanger. Specifically, it was a horizontal tube 2.74 m long and inside diameter

10.9 mm, with cold water flowing countercurrent on the outside of the tube. Measurements were made at operating pressures from 7.4 MPa to 13.0 MPa, fluid flow rates from 1.0 kg/min to 5.0 kg/min, cooling rates from 1780 W to 6220 W, inlet temperatures from 31.6 °C to 88.6 °C, and outlet temperatures from 23.2 °C to 55.5 °C. The results showed significant improvement in thermal performance for the supercritical fluid when compared to a constant property fluid. This observation contrasts with what was found previously on the same tube when the carbon dioxide was heated instead of cooled; for that condition, excessive heating or low flow rates caused the supercritical fluid to perform more poorly than a constant property fluid. The present results also showed that existing engineering correlations could predict the measurements when the operating temperatures were above the critical, but not when they were below the critical. These experimental data will be valuable in developing predictive methods for design of heat exchangers in alternative refrigeration cycles or other modern technologies utilizing supercritical fluids.

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NIST DEVELOPS A NEW TECHNIQUE FOR MEASURING THE TEMPERATURES OF WEAKLY IONIZED GASES

A new diagnostic technique using non-linear variation of frequency-resolved Rayleigh scattering has been developed by NIST for probing neutral and ion temperatures in weakly ionized gases, such as occur in the shock waves of aircraft at high altitudes. The instrument consists of two frequency-doubled Nd:YAG laser systems, one running on a single longitudinal mode and the other running on several longitudinal modes. The beam from the multimode laser is split into two components, which counter propagate through the sample at an angle of approximately 175°. These beams interfere, creating a superposition of traveling-wave and stationary fringe patterns. The laser electric field works against the random thermal motion of the gas to compress the polarizable gas atoms or molecules into regions of high electric-field intensity. This compression leads to spatially periodic density perturbations that Rayleigh scatter the single-mode probe beam. The traveling components introduce Doppler shifts into the scattered light as well. By measuring the Doppler profile of the Rayleigh scattering, the underlying temperature of the gas is obtained. Initial tests indicate a greatly enhanced sensitivity over spontaneous Rayleigh scattering at low pressures.

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SURF III BOOSTS OPERATING ENERGY AND INCREASES CALIBRATION RANGE

In March 2000, the SURF III electron storage ring achieved a record electron beam operating energy of 387 MeV, with an injection current of 300 mA. Routine operation at SURF is now maintained at 362 MeV, with injected beam currents exceeding 250 mA. Since the high-energy end of SURF's optical radiation spectrum increases as the third power of the electron energy, these improvements provide a doubling of the photon energy range for which SURF can provide calibration services. The "water window" region (wavelength of 3 nm to 4 nm), which is important for biological x-ray microscopy, was previously outside SURF's practical operating range. SURF III now produces more useful radiation in the water window than did its predecessor machine, SURF II, which operated at 288 MeV.

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MILESTONES ACHIEVED FOR NIJ STANDARD 0115.00, STAB RESISTANCE OF PERSONAL BODY ARMOR

Significant milestones were reached in the development of National Institute of Justice (NIJ) Standard 0115.00, Stab Resistance of Personal Body Armor. The draft standard was distributed to members of the National Armor Advisory Board and the Law Enforcement and Corrections Technology Advisory Council for comment and review. A formal solicitation for potential test laboratories that wish to become certified to conduct compliance testing was issued in the *Commerce Business Daily.* Work will continue over the next couple months to address comments and concerns received from members of the body armor community on the standard and to identify test laboratories for the compliance test program.

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NIST 100 A CURRENT SHUNTS SUPPORT COMMERCIAL VERSIONS

A wideband (100 kHz), high-current (100 A rms) shunt, designed and developed by NIST, has been converted into a commercial version that is now available. The development of this shunt has been driven by the interest

in supporting a commercially available 100 A, 100 kHz transconductance amplifier that was also designed and developed earlier by NIST.

Under contract with the Air Force Primary Standards Laboratory, four of the commercial shunts were purchased by NIST and compared to the NIST-designed and fabricated shunts. These consisted of a 10 A to 30 A shunt, 30 A to 50 A shunt, 50 A to 80 A shunt, and 80 A to 100 A shunt. A current build-up from a 20 A NIST reference to the 100 A commercial shunt was performed; preliminary data indicate that the build-up measurements differ from direct comparisons to the NIST 100 A reference standard by only about 1 mA/A.

To support the NIST reference shunts, comparisons were made with a set of NIST-made two-stage, amplifier-aided current transformers (CTs) out to 100 kHz. The frequency coefficients of these CTs were characterized by direct comparison to NIST working standard thermal converters using an automated current comparator system, based on 50 Hz as the reference frequency.

The effort to develop these CT and shunt standards now permits NIST to offer measurement services for high-current ac shunts up to 100 A, the only national measurement institute with this capability.

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1×8 ARRAYS OF HIGH SENSITIVITY SUPERCONDUCTING TRANSITION-EDGE BOLOMETERS

NIST researchers, in collaboration with researchers at Goddard Spaceflight Center (GSFC), have fabricated and characterized, both electrically and radiometrically, several 1×8 arrays of superconducting transition-edge bolometers for NASA and European Space Agency (ESA) applications. These arrays are prototypes of a new generation of detector arrays for low background, far-infrared astronomy and were spotlighted in a recent article in *Superconductor Week.*

The NIST fabricated bolometer elements are comprised of Al-Ag bilayers; similar GSFC-fabricated elements are Mo-Au bilayers. The 1×8 arrays are fabricated on micromachined Si structures that enable construction of closely packed two-dimensional arrays (by folding the "legs" back out of the focal plane). The bolometers are operated in a voltage-biased mode, resulting in an electrical-substitution measurement of radiant power, similar to measurements performed by standards-grade, cryogenic radiometers even though there is no separate heater incorporated into the system. Readout is performed by a 1×8 SQUID multiplexer circuit previously developed by the NIST team (*Appl. Phys. Lett.,* June 1999), which greatly reduces the low-temperature wire count for large arrays. Typical operating parameters for the arrays are: $T_c = 450$ mK, $T_{base} = 300$ mK, saturation power is 5 pW, and time constant is 2 ms. Electrical noise-equivalent power (NEP), the basic measure of sensitivity, is roughly 2×10^{-17} W/Hz$^{1/2}$, the best ever reported for an IR bolometer operating with ^{3}He refrigeration (i.e., at 300 mK), and within a factor of 6 of the best reported for any IR bolometer. Radiometric efficiency is presently 30 %, limited chiefly by diffraction losses inherent to the measurement configuration. Shortly two of the Al-Ag arrays and two of the Mo-Au arrays, along with four of the 1×8 MUX chips and GSFC room-temperature electronics, will be assembled into a multiplexed 4×8 demonstration system and delivered to an ESA team at Queen Mary College, London. A field test of a single 1×8 array is planned for the California Institute of Technology Submillimeter Observatory later this winter.

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DIGITAL ELECTRONICS ENABLES NEW ASTRONOMY INSTRUMENT

NIST's Nanoscale Cryoelectronics Project has developed new digital electronics for reading out superconducting transition-edge sensor (TES) detectors for x-ray and optical photons. The electronics use a high-speed and high-performance analog-to-digital converter (ADC), a field-programmable gate array (FPGA), and a digital-to-analog converter (DAC) to form a feedback loop for sensor readout. The FPGA also has the capability to perform digital pulse processing on the feedback signal in real time. Parameters for the pulse processing and feedback control can be programmed via an optical fiber link with a computer; this can even be performed remotely over the Internet. For a collaboration with Stanford University, a set of electronics was built and used with a small array (2×2) of optical TES detectors (built by Stanford). Because of their relatively high quantum efficiency, reasonable energy resolution, and fast response, TES detectors appear very promising for astronomical observations of faint quasi-periodic objects such as pulsars, nebulae, and possible black holes. In early February, NIST researchers performed the first astonomical observations with this instrument at the 2.7 m Harlan J. Smith telescope at the McDonald Observatory. By using the new electronics, they were able to acquire data in real-time and at rates previously not achievable on objects like the Crab pulsar.

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INFRARED RECTIFICATION WITH NANOSCALE, ANTENNA-COUPLED, METAL-INSULATOR-METAL (MIM) DIODES

NIST scientists have fabricated and characterized a set of fully kithographic MIM diodes coupled to infrared antennas. Antenna-coupled MIMdiodes, in the form of electrochemically sharpened whiskers contacting macroscopic metallic surfaces, have been used for many years for infrared frequency metrology. The new, fully lithographic diodes have areas as low as (30×30) nm^2 and are fabricated by angled evaporation through a free-standing PMMA resist bridge defined by electron-beam lithography. (Small areas are required to minimize diode capacitance.) The diodes are coupled to planar dipole antennas, also defined by electron-beam lithography, and designed for resonance at 10 m wavelength. Diodes have been successfully fabricated and tested from Al-AlO_x-Al, Al-AlO_x-Pd, and Nb-NbO_x-Ag materials. Non-linearity in the current-voltage characteristics is measured in all cases. The Brinkman-Dynes-Rowell analysis of tunneling through trapezoidal barriers accurately fits the nanoMIM *I-V* characteristics, as well as those of separate, micrometer-sized Nb-NbO_x-Ag MIM diodes. Optical response on the nanoMIM diodes was measured using a few mW of 10 μm CO_2 laser radiation, coupled through the substrate via a Ge hemispherical lens. Previous attempts to fabricate fully lithographic MIM diodes have all foundered on the difficulty of separating optical signals due to rectification from those due to thermal mechanisms.

In the recent NIST experiments, two key observations rule out thermal mechanisms. Firstly, the bias dependence of the detected signal from IR illumination is accurately proportional to the second derivative of the dc current-voltage characteristic, a signature of classical rectification. Secondly, at 0 bias, there is substantial optical signal, the sign of which varies between devices, but always remaining the same as the sign of the 0-bias curvature in the *I-V* curve. The non-linearity observed in the large area diodes is, according to theory, sufficient to enable observation of photon-assisted tunneling steps at room temperature. These diodes are being developed under a cooperative research and development agreement with a thin film solar cell manufacturer, as part of a Defense Advanced Research Projects Agency-sponsored program to develop solar cells based on direct rectification of sunlight.

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MICROMECHANICAL DETECTION OF ENERGY AND ANGULAR MOMENTUM TRANSFER IN FERROMAGNETIC RESONANCE

A spinning top in a gravitational field undergoes precession. Since magnetic moments have angular momentum just like a spinning top, the magnetization of a ferromagnet precesses in a magnetic field. For the precession to persist, it must be driven with microwaves at the ferromagnetic resonance (FMR) frequency.

Natural damping of the precessional motion of magnetic spins in FMR results in a transfer of both energy and angular momentum to the crystal lattice of the ferromagnetic specimen. Absorption of the energy results in heating of the material, whereas transfer of the angular momentum results in a torque on the material. The source of the energy and angular momentum can be traced back to the energy and angular momentum of the microwave photons that induce the resonance.

NIST scientists have used silicon micro-cantilevers to detect both the heating and torsion of a thin film specimen when the ferromagnetic resonance condition is met. These new measurement techniques are applicable to the characterization of magnetic properties of very small samples as well as detection in magnetic resonance force microscopy. This is one example of new micro-cantilever based magnetic metrology methods developed at NIST and the first demonstration of torque detection from angular momentum transfer in FMR.

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SOUNDS RECONSTRUCTED FROM AUDIO TAPES

NIST researchers, in collaboration with the Institute for Telecommunication Sciences, have imaged audio tapes using scanning magneto-resistive (MR) microscopy and reconstructed the audio signals from the images. Four test tracks were produced, imaged, and reconstructed. Two of the test tracks were sine wave tones of 500 Hz and 700 Hz and the other two had test phrases such as "NIST" and "FBI." This work addresses the need of forensics analysts to search for traces of tampering and/or characteristic sounds (gunshots, etc.) in recorded evidence. The microscope is based on commercial MR heads from computer hard drives and has a resolution of ≈20 nm downtrack and ≈1 μm track width. The required sample rate for these reconstructions was only

5.9 μm; however, the higher resolution available with the MR heads is needed for media such as digital audio tapes and other computer storage media.
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OPTICAL FIBER BRAGG GRATING ROUND ROBIN

At the request of industry, NIST has administered a round robin for the measurement of optical fiber Bragg grating (FBG) characteristics. Fiber Bragg gratings are a relatively new component—a wavelength-selective reflector that can be written into the core of optical fiber. These components are extremely important for telecommunication and sensor applications. They are very useful as wavelength filters and dispersion compensators in the new wavelength division multiplexed (WDM) optical fiber communication systems, and also make excellent strain sensors that can be networked to obtain distributed strain measurements of large structures, such as bridges and ships. In spite of the numerous and growing commercial applications of fiber Bragg gratings, there are no standard measurement procedures and a variety of definitions are being used for important parameters.

The NIST-facilitated round robin began at an informal meeting during the Optical Fiber Communication Conference in February 1999. A quorum of industry representatives recommended measuring specific spectral and relative group delay (rgd) properties of FBGs. (The derivative of rgd versus wavelength gives a measure of dispersion in an optical component. Dispersion in optical fiber spreads optical pulses in time and limits the fiber link data rate.) In June 1999, NIST launched the round robin among two industry groups. One group, named "telecom," measured spectral properties and rgd for their gratings. The other industry group, named "sensors," measured only the spectral properties of their gratings. Raw data from the participants were sent to NIST because no formal methods for analyzing the spectral or rgd data existed.

To assist industry in this evaluation, NIST has developed high-sensitivity, state-of-the-art techniques to measure the spectral and rgd values of FBGs. For spectral quantities, a grating-tuned diode laser filtered by a tunable fiber Fabry-Perot interferometer was used to achieve a dynamic range of 68 dB, a wavelength resolution of ±0.1 pm, and wavelength uncertainty of 0.2 pm. NIST used two systems to measure the rgd of the gratings, an rf-modulated phase-delay method, which had an uncertainty of about 0.3 ps and a wavelength uncertainty of about 30 pm, and a low-coherence interferometer. The uncertainty analysis on a newly developed low-coherence interferometer method is still in progress.

The results of the round robin showed that measurements of the central wavelength of a FBG appear to be adequate for telecom systems. However, current metrology is clearly inadequate for bandwidth, minimum transmittance, and rgd linear slope. For a rgd linear slope of about –6.8 ps/nm the range in measured values was 1.1 ps/nm. The participants' minimum transmittance values were about 5 dB above the true value because of inadequate filtering of source spectral noise. The bandwidth of a FBG, determined from relative reflectance data, depends on the criteria used to determine the band-edge. When two different popular criteria (–3 dB and –0.5 dB) were used to determine the bandwidth of a 50 GHz grating, the bandwidth differed by about 11 GHz. Also, sensor applications need better absolute wavelength calibration. The spread in values for the center wavelength of the sensor grating (27 pm) will not meet the needs of long-term structural monitoring. Data analysis methods developed by NIST during this study have now been incorporated into a draft Telecommunications Industry Association (TIA) standard test procedure document. NIST plans to continue working with the TIA to develop standard test procedures and evaluate measurement capabilities.
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KEY COMPARISON OF LONG END STANDARDS

NIST researchers just completed measurements for a key international comparison of long end standards. This is one of a series of comparisons that will help to establish the degree of equivalence between length measurements made by various national measurement institutes throughout the world.

The end standards, gage blocks ranging in length from 175 mm to 900 mm, were measured by NIST metrologists using several different techniques. All but the longest (900 mm) block were measured both by static interferometry and by mechanical comparison; the 900 mm standard was measured on a linescale interferometer. As a check, all of the blocks also were measured on a coordinate measuring machine. In all cases, measurement results obtained on different instruments for a given block did not differ from each other by more than 135 nm, well within expected uncertainties. The excellent agreement between differing methods gives good confidence in the NIST results.

NIST is the second of 16 laboratories spread throughout all regions of the world that will participate in this comparison.This is one of a number of measurement comparisons sponsored by the CIPM (Comité International des Poids et Mesures) that will form the technical underpinning of the recently signed Mutual

Recognition Arrangement. This agreement is intended to reduce barriers to trade by establishing mutual recognition of measurements and tests between trading nations. CONTACT: John Stoup, (301) 975-3476; john.stoup @boulder.nist.gov or Bill Penzes, (301) 975-3477; william.penzes@nist.gov.

FLUCTUATIONS IN THERMAL SPRAY PROCESS MEASURED

Thermal spray is a relatively low cost, but difficult to control, process for applying protective coatings to material surfaces. These coatings are often of metals or ceramics, and are used for a variety of purposes such as thermal, wear, or corrosion protection. The use of thermal spray technology is often limited, however, by the difficulty of obtaining reproducible coating quality. NIST has therefore instituted a program to use advanced sensors to study and control the spray plume, and correlate process parameters to spray characteristics and coating properties.

Using a novel two-color imaging pyrometer, NIST researchers are obtaining time-resolved spray particle temperature and velocity data in thermal spray plumes and correlating these to the selectable process parameters of the thermal spray torch control system. Combining this with a thermodynamic model of the spray torch is providing information on strategies for independent control of particle temperatures and velocities.

Other sensors are being used to analyze time-dependent fluctuations in the thermal spray plume. Such fluctuations recently have been studied by several laboratories, but their exact origin and their possible effects on the quality of the deposits have not been determined. The NIST program is using a high-speed schlieren method to visualize the hot thermal spray plume, revealing some significant low-frequency processes in addition to the higher frequency fluctuations which other investigations have revealed.
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FANS-I COMMISSIONED AT THE NCNR, WITH 20 TIMES THE INTENSITY OF INELASTIC NEUTRON SCATTERING

The increasing complexity of new materials and processes is an important factor driving the development of new characterization tools. The traditional vibrational spectroscopies, infrared absorption and Raman scattering, have long played a central role. Neutrons are a more versatile dynamical probe than photons, but inelastic neutron scattering long has suffered from the comparatively low intensity. To address this, a new, high-intensity filter-analyzer neutron spectrometer (FANS) is being constructed in two phases at the NIST Center for Neutron Research (NCNR) by a consortium of scientists from NIST academe, and industry. The first phase of FANS recently has been commissioned. The measured intensity exceeds that of the previous instrument by a factor of $\approx$20, providing significant new measurement opportunities for the U.S. scientific community. For instance, FANS will be used to study intra- and intermolecular vibrations in molecular crystals; polymers; and guest-host systems including hydrogen in metals, hydrocarbons in zeolite catalysts, sorbed gases on surfaces and clathrates for fine chemical separation. It also will be used to characterize novel forms of carbon including fullerenes, nanotubes, foams and aerogels, amorphous carbons, and fibers as well as environmentally acceptable refrigerants, gas separation materials, and the hydration reaction of cements.
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COMBINATORIAL CHARACTERIZATION OF POLYMERIC THIN FILMS AND COATINGS

Recently, NIST scientists have developed methods for rapid measurements of the properties of polymer coatings. Polymeric coatings play an important role in many industrial applications, such as automotive, electrical, and aerospace industries where their stability and integrity is of fundamental importance. The NIST researchers adapted the concept of combinatorial and high-throughput analysis for rapid acquisition of properties data on polymer coatings that would be useful in fundamental studies, validation of physical models, or exploration of industrial applications. Combinatorial methods of drug discovery in pharmaceuticals research are well known, and more recent applications of the methodology have led to the discovery and synthesis of new inorganic materials, catalysts, and organic polymers.

The material properties of polymeric coatings are sensitive to a variety of factors, including composition, temperature, and thickness. Most polymeric coatings are also multicomponent blend materials and the miscibility of the blend components is an important issue that affects ultimate properties. To acquire data covering a range of variables is both time consuming and expensive when done by traditional methods. The novel approach developed included methods for depositing polymeric coating libraries that employ continuous gradients in thickness, composition, and temperature. Each

"library," which is the size of a standard microscope slide, contains as many as 1500 differentiable conditions such as film thickness, composition, and temperature. Analysis of these libraries provides characterization of fundamental properties and thin-film phenomena occurring in such coatings. By automating ellipsometry and optical microscopy for high-throughput screening, the dewetting and polymer blend phase separation behavior were characterized in orders of magnitude less time than with conventional methods. The high-throughput techniques produce a large amount of data over a broad range of parameter values, so that novel regimes of kinetic and thermodynamic behavior can be observed.
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NIST BURNS TOWNHOUSES IN ARIZONA

NIST's Large Fire Research Group conducted 24 full-scale fire experiments in a two-story, six-unit townhouse structure provided by Pinal County, AZ, during a 2 week period in March 2000. The townhouses were in excellent condition, which provided a great opportunity to collect "real world data for five different different NIST research projects."

In addition, the experiments were used as a basis for the International Association of Arson Investigators' seminar on fire dynamics and burn pattern analysis being conducted during the same time period. Four engineers from the NIST Large Fire Research Group made presentations to more than 135 student and local fire officials during the course of the seminar. Students witnessed several of the fire experiments conducted in the townhouses. NIST measurements provided the students with additional useful information about the fires.
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WORKSHOP ON TELECOMMUNICATIONS SYNCHRONIZATION HELD AT NIST BOULDER

In cooperation with Technical Sub-Committee T1X1 of the American National Standards Institute (ANSI), Standards Committee on Telecommunications, NIST co-sponsored and hosted the "Workshop on Synchronization in Telecommunications Systems." The workshop was held in Boulder in March 2000, immediately following the meeting of the T1X1 Sub-Committee, for which NIST also served as host.

This workshop series, which started as a NIST tutorial workshop dealing with noise-measurement metrics, has grown to be the major U.S. forum for discussion of industry synchronization issues. It is a unique forum on this topic, since no similar meeting exists anywhere else in the world. Total participation for the 3 day workshop was 104 people, including representatives of major telecommunications carriers and synchronization-equipment manufacturers. Twenty-four speakers from 13 different companies and NIST presented ideas on a wide range of topics affecting network synchronization. For the first time, the workshop included equipment exhibits, giving the equipment manufacturers a forum for discussing the merits of their respective products.
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NIST COLLABORATES WITH CARNEGIE MELLON UNIVERSITY ON LARGE-SCALE COMPUTATION IN MATERIALS SIMULATION

A NIST researcher, along with a staff member from Carnegie Mellon University, organized a successful meeting entitled "Large-Scale Computations in the Simulations of Materials" on March 30-April 1, 2000, at Carnegie Mellon University in Pittsburgh. The meeting was hosted by the university's Center for Nonlinear Analysis, a National Science Foundation (NSF)-sponsored research and training center concentrating in non-linear analysis, mechanics, scientific computation, and mathematical finance. NSF and the Army Research Office funded the event. The highly interdisciplinary meeting brought together about 120 scientists from a wide spectrum of academic, government, and industrial laboratories where contemporary challenges imposed by advances in industry, technology, and biomedical sciences are being confronted with state-of-the-art mathematical and computational tools. The topics covered were wide-ranging, from the simulation of micromagnetic materials to prediction of nerve transmissions and blood flow.
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NIST SPONSORS THIRD ADVANCED ENCRYPTION STANDARD CANDIDATE CONFERENCE

In April 2000, NIST sponsored the Third Advanced Encryption Standard (AES) Conference in New York City. The purpose of the international conference was to help answer the question: "Which algorithm(s) should NIST include in the AES Federal Information

Processing Standard (FIPS) and why?" Conference participants included more than 200 cryptographers and other parties interested in participating in the evaluation and analysis of the five finalist candidate algorithms being considered for the AES. Announced in August 1999, the finalists are MARS, RC6TM, Rijndael, Serpent, and Twofish. Conference attendees heard the results of experts who have analyzed the finalist algorithms for security, efficiency, and other algorithm characteristics, as well as recommendations for the selection of the winner(s). Representatives from the teams of submitters for each of the finalists had an opportunity to make final arguments as to why their algorithm should be selected. Following the close of the Round 2 public analysis period in May 2000, NIST will study all available information and propose the AES (hopefully by late summer), which will incorporate one or more of the AES algorithms selected from the finalists. NIST will then request public comments on the draft AES. The web site for the AES project is http://www.nist.gov/aes.

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NIST ADVANCES SOFTWARE USABILITY

At the International Human-Computer Interface Conference (CHI 2000) in The Hague, The Netherlands, in April 2000, a NIST staff member conducted a Special Interest Group (SIG) entitled "Common Industry Format for Usability Test Reports." The session was based on the Industry USability Reporting (IUSR) Project, which is led by NIST and includes members from industry. The primary goal of the project is to raise the visibility of usability as a factor when buying software. The key idea is that software purchases are costly, but the more usable a piece of software is, the lower the post-purchase maintenance costs will be. More information about the IUSR project can be found at http://www.nist.gov/iusr.

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NIST CO-SPONSORS BioAPI USERS' AND DEVELOPERS' SEMINAR

In April 2000, NIST, the National Security Agency, and the BioAPI Consortium co-sponsored the BioAPI Users and Developers Seminar in Pentagon City, VA.

The seminar focused on the recent release of the BioAPI Specification Version 1.0. A common specification will accelerate adoption of biometric technologies and biometric-based identification and verification solutions in multiple markets. At the meeting, NIST announced the BioAPI Interoperability Test Bed being developed at NIST's Biometrics and Smart Cards laboratory in support of the BioAPI Consortium, the biometric industry at large, and users of these technologies. NIST and the Financial Management Service of the Department of the Treasury will collaborate in this effort.

The release of the BioAPI Specification Version 1.0 is an important step for the biometrics industry, system developers, and end-users. It is significant that a number of organizations are working together to develop and support biometrics common standards. The BioAPI Consortium (www.bioapi.org) was founded to develop a multi-leveled biometric Application Programming Interface (API) that brings platform and device independence to application programmers and biometrics service providers. Seminar presentations are at the web site www.nist.gov/bioapi-seminar.

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NIST HOSTS SIXTH IEC MEETING ON SUPERCONDUCTIVITY

NIST researchers organized, hosted, and participated in the sixth meeting of International Electrotechnical Commission (IEC) Technical Committee 90 (TC 90) on superconductivity in Boulder, CO, in March 2000. The meeting allowed experts from around the world to come together and work to advance the draft international standards in six working groups (WGs). In addition, results from pre-standards research and interlaboratory comparisons were presented on four new working drafts and on six future drafts. To date, two IEC measurement standards have been published and a third standard is being published that covers the terms and definitions used in superconductor technology. As a result of this meeting, three more draft standards are now ready for the final voting stage.

One key technical breakthrough during these meetings occurred in the WG on electronic characteristic measurements, specifically the microwave surface resistance of a superconducting thin film. Such films now are being demonstrated on-line for large-scale introduction as filters for the cellular telephone industry. The draft standard as written contained a procedure for the determination of the loss in a dielectric that has been shown to be problematic, and the U.S. members had recommended significant and potentially controversial changes. During the course of discussion and consensus building, a new technical approach to the problems was invented through concerted work by the U.S. and

foreign experts. This new approach will be adopted in the next draft and represents a significant success of the process for writing international standards.
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NEOLITHOGRAPHY CONSORTIUM FORMED

Five major companies in semiconductor manufacture and process modeling agreed to form the nucleus of the NIST-conceived Neolithography Consortium. Their agreement followed a presentation on the subject and a pre-inception meeting at the SPIE Annual Symposium on Microlithography in March 2000. More companies are expected to join before the next meeting at SEMICON West.

The Neolithography Consortium's goal is to realize the virtual semiconductor wafer fabrication process ("the virtual fab") on the process designer's desktop. This means a process engineer will be able to assemble simulation software products from diverse manufacturers into an integrated computer application that can simulate and optimize the entire microlithography process, from the wafer pattern specifications to the final wafer etch. This will require development of interoperability standards, development of missing simulation components, development of a global optimization program, and removal of any other impediments to realizing the "virtual fab" that may be identified by the consortium members. The potential benefits of the "virtual fab" are impressive and the costs minimal. With this tool the wafer patterning process engineer can optimize, globally and automatically, both the photomask pattern design and all of the adjustable process parameters. The engineer then can print virtual wafers in his computer and compare the sizes and placements of the virtual features with their specifications and tolerances. In contrast to the expensive printing and metrology of real test wafers, virtual wafers are free and require no metrology. After the real photomask is fabricated to the specifications derived in the "virtual fab," mask metrology data from the emulated exposure aerial image can be inserted into the simulation at the appropriate point. The resulting emulated virtual wafer features include the effects of any errors and defects in this specific mask and can again be compared with their specifications to qualify the mask or re-optimize the process parameters. This consortium is open to all interested parties. Members benefit because a members product is more valuable to customers because it is easier to use and it forms an essential part of an integrated simulation package; members can influence standards development; common file formats, user interfaces, etc. reduce software product design workload. The integrated circuit industry benefits because the virtual fab reduces design-to-product time and lowers production costs, and open standards encourage new and innovative simulation products.
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METROLOGY TERMS AND DEFINITIONS BECOME SEMICONDUCTOR INDUSTRY STANDARD

The work of the Semiconductor and Materials International (SEMI) Standards task force on metrology terms and definitions has become the industry standard SEMI P35-0200, "Terminology for Microlithography Metrology." This is the first edition of an ongoing accumulation of metrology definitions appropriate to semiconductor manufacture. To better coordinate semiconductor metrology terms with usage in other industries, this standard contains definitions from the ISO "International Vocabulary of Basic and General Terms in Metrology," reference to the ISO "Guide to the Expression of Uncertainty in Measurement," and terms describing some new concepts in the measurement of microscopic feature size or linewidth. This SEMI Standards task force, the NIST project on the international comparison of linewidth measurements for the Bureau International des Poids et Mesures (BIPM), and the calibration of NIST Photomask Linewidth Standard Reference Materials all have to deal with the difficult issue of measurement uncertainty of imperfect microscopic objects. The synergy between these projects has been helpful to all.
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NIST/INDUSTRY INTERLABORATORY COMPARISON COMPLETED

Manufacturers of thermal insulation in the United States and Canada require reliable thermal resistance measurements to market their products effectively. An important component of their measurement process is the determination of the level of uncertainty attainable with current commercial equipment. In collaboration with American Society for Testing and Materials (ASTM) Committee C-16 on thermal Insulation, NIST has completed a "round-robin" laboratory comparison of small heat flow meter apparatus. This apparatus is a popular instrument used by industry for checking the quality assurance of insulation products. Twelve industry laboratories in the United States and Canada participated by circulating specimens of NIST high-density fibrous-glass board among the participants. Using NIST's 1 m guarded-hot-

plate apparatus, the specimens were characterized at 24 °C providing accepted reference values of thermal resistance. From the test results, the 95 % repeatability (within-laboratory) and reproducibility (between-laboratory) imprecision indexes were 1.1 % and 4.0 %, respectively. Bias, characterized by the difference of the test results and the NIST accepted reference values, was determined to be statistically insignificant at the 95 % confidence level for these materials. The results have been documented in the *ASTM Journal of Testing and Evaluation* and will be included in future revisions of ASTM Test Method C 518 on heat-flow-meter apparatus.

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CONFERENCE EXPLORES IT APPLICATIONS AND INTEGRATION

A practical review of the challenges that manufacturers face when striving to integrate their information technology—from in-house engineering to supply chain execution—and, then laboring to make it all work together was the purpose of a conference sponsored by NIST in June 2000, at its Gaithersburg, MD, headquarters.

Information Technology for Engineering and Manufacturing 2000 addressed the interests of a wide range o IT users, from manufacturing managers and engineers to systems integrators and software developers. In five conference sessions, NIST scientists and engineers, joined by experts from industry and universities, examined key issues in five major areas of IT applications: product data management, manufacturing simulation, knowledge-aided engineering, process representation and electronic commerce. A sixth session evaluated the potential of XML—the eXtensible Markup Language—to overcome today's obstacles to integration and interoperability.

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Standard Reference Materials

SRM 2100: FIRST IN THE WORLD FOR CERAMIC FRACTURE TOUGHNESS

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SRM 2100 consists of five hot-pressed silicon nitride flexure specimens cut from a single master billet. The SRM may be used with any credible fracture toughness test method, but has been optimized for beam bending type tests. ASTM C 1421 features three such tests: the surface crack in flexure (SCF), precracked beam (PB) [also known as single-edged precracked beam (SEPB)], and chevron notch in bending (CNB) methods. The SRM specimens are common 3 mm × 4 mm × 47 mm beams which must be precracked by the users.

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The International System of Units (SI)
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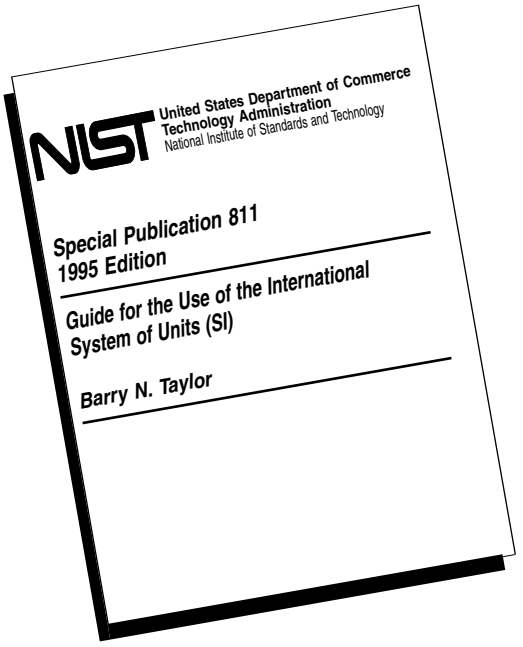

Uncertain about the International System of Units (universally abbreviated SI), the modern metric system used throughout the world? Do you need to know the proper way to express the results of measurements and the values of quantities in units of the SI? Do you need to know the NIST policy on the use of the SI? Then you need the 1995 edition of the National Institute of Standards and Technology Special Publication 811, *Guide for the Use of the International System of Units (SI)*.

The 1995 edition of the National Institute of Standards and Technology Special Publication 811, *Guide for the Use of the International System of Units (SI)*, by Barry N. Taylor, is now available.

The 1995 edition of SP 811 corrects a number of misprints in the 1991 edition, incorporates a significant amount of additional material intended to answer frequently asked questions concerning the SI and SI usage, and updates the bibliography. The added material includes a check list for reviewing the consistency of written documents with the SI. Some changes in format have also been made in an attempt to improve the ease of use of SP 811.

The topics covered by SP 811 include:

- NIST policy on the use of the SI in NIST publications.
- Classes of SI units, those SI derived units that have special names and symbols, and the SI prefixes that are used to form decimal multiples and submultiples of SI units.
- Those units outside the SI that may be used with the SI and those that may not.
- Rules and style conventions for printing and using quantity symbols, unit symbols, and prefix symbols, and for spelling unit names.
- Rules and style conventions for expressing the results of measurements and the values of quantities.
- Definitions of the SI base units.
- Conversion factors for converting values of quantities expressed in units that are mainly unacceptable for use with the SI to values expressed mainly in units of the SI.
- Rounding numbers and rounding converted numerical values of quantities.

Single copies of the 84-page SP 811 may be obtained from the NIST Calibration Program, 100 Bureau Dr., Building 820, Room 236, Stop 2330, Gaithersburg, MD 20899-2330, telephone: 301-975-2002, fax: 301-869-3548.

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