

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.

TRACE GAS METHOD BOOSTS SENSITIVITY

Bigger isn't always better. NIST chemists recently proved this is true for trace gas measurements of water vapor or oxygen. The team found they could make measurements of gas concentrations that are only 1 % of currently measurable concentrations and with a testing chamber that is only one-tenth the size of previous models.

The semiconductor industry has rigorous requirements for the purity of gases used in the fabrication of integrated circuits. One way to test for impurities such as water vapor or oxygen is a technique known as cavity ring-down spectroscopy. The conventional implementation of this technique involves putting a sample of the gas to be tested into a chamber about one meter long and shining an infrared laser into the enclosure. The infrared light bounces back and forth between two mirrors at the ends of the chamber. The laser light is tuned to a wavelength that is absorbed by the molecule to be detected. By measuring the rate that light leaks from the chamber, scientists can determine the concentration of the contaminant.

Conventional wisdom has held that longer chambers should provide better sensitivity. Longer chambers leak light at a slower rate, so small changes in light levels should be easier to detect. However, the NIST group observed that light wave interactions within meter-long chambers complicated the detected signals.

To eliminate these interactions, the NIST researchers used a pulsed laser and made a chamber only 10 cm cavity length to produce the simplest pattern, the un-

long. They found that tiny changes in the distance between the two mirrors in the chamber generated distinct wave patterns.

By carefully controlling the laser wavelength and wanted interactions were eliminated and sensitivity of the method was enhanced greatly.

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NIST CENTER DISTRIBUTES DRAFT TECHNICAL REGULATIONS

Draft technical regulations concerning toys, electrical appliances, chemicals, dyes and telecommunications equipment topped the list of inquiries that NIST fielded last year in its role as the U.S. inquiry point for questions on proposed domestic and foreign rules that may affect international trade.

Under the World Trade Organization's (WTO) Agreement on Technical Barriers to Trade, governments of the international body's 133 member countries are required to notify the WTO of prospective regulatory measures that may pose obstacles to market entry. The WTO, in turn, makes these one-page notifications available to NIST's National Center for Standards and Certification Information (NCSCI) and to other inquiry points around the globe. NCSCI and its counterparts distribute the notifications to domestic industrial organizations, government agencies and other groups to encourage review and comment. NCSCI also provides full-text copies of the draft regulations.

To allow for adequate review, NCSCI explains in its newly issued annual report, the WTO recommends a comment period of at least 60 days. In 1998, the average was 36 days for the 615 notifications issued by 39 WTO members. At 89, the Netherlands issued the largest number, followed by Belgium (49), Israel (46) and Brazil (43). Twelve U.S. agencies notified the WTO of a total of 33 proposed regulations in areas ranging from

children's sleepwear to spark ignition engines. The comment period for these proposals averaged 49 days.

In 1998, NCSCI staff responded to 240 inquiries on U.S. and foreign proposed regulations. The NIST center also provides translation services and transmits U.S. industry comments on proposed regulations to foreign governments. The center offers a WTO Hotline, which provides a recorded summary of the latest notifications of proposed foreign regulations. The number is (301) 975-4041.

For more information on NCSCI and its responsibilities under the TBT Agreement, contact JoAnne Overman, Standards Information Program, (301) 975-4037. To get a copy of NCSCI's annual report on TBT Agreement activities, contact NCSCI, (301) 975-4040, ncsci@nist.gov.

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NEW STANDARD DEBUTS AT SECOND eBook CONFERENCE

Electronic books (also known as eBooks) are integrated products that combine features found in books and computers. For example, touch screen technology allows a reader to touch an unfamiliar word to get an immediate dictionary definition. Touching the screen elsewhere can make the print larger or smaller.

The emerging industry's second conference, Electronic Book '99, was held in September 1999, at NIST Gaithersburg. Highlighting the event for the nearly 600 attendees from book publishers, hardware and software producers, and eBook manufacturers was the announcement of the first Open eBook Publication Structure Specification.

The technical specification developed by industry leaders creates a universal way to format text for electronic books. The use of a single format for electronic books is expected to accelerate the availability of electronic reading material. For example, the specification for eBook file and format structure is based on HTML and XML, the languages used to format information for web sites. A publisher can format a title once according to the specification and the content will be compatible with a wide variety of reading devices.

To download the Open eBook Publication Structure Specification, go to www.openebook.org on the World Wide Web. For technical information, contact Victor McCrary, NIST, 100 Bureau Drive, Stop 8951, Gaithersburg, MD 20899-8951, (301) 975-4321, victor.mccrary@nist.gov.

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VORTICES IMAGED IN BOSE-EINSTEIN CONDENSATES

NIST and University of Colorado researchers have created and imaged the first vortices ever seen in Bose-Einstein condensates, a form of matter first created in 1995. The condensate is a tiny, spherical ball of magnetically trapped rubidium gas atoms cooled to less than 10^{-6} K, in which the atoms exhibit their quantum mechanical wave-like properties and coalesce into a kind of "superatom."

All along the axis of the ball is a central region of swirling motion that resembles a miniaturized tornado. The center of the vortex, like the "eye" of a tornado, is filled with relatively calm, nonrotating gas. The concept of vortices lies at the heart of scientific understanding of residual dissipation (i.e., resistance) in nominally viscosity-free substances such as superfluids and superconductors. Ongoing studies of the "captive" vortex will shed light on this complex problem.

This achievement was reported in the Sept. 27 issue of *Physical Review Letters*.

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PHYSICISTS CATCH BEST WAVES EVER FROM IMPROVED SURF III

Upgrades to the Synchrotron Ultraviolet Radiation Facility at NIST are yielding greatly improved calibrations for a wide variety of optic and photonic devices from satellite instruments to medical lasers and environmental monitoring devices. The improved NIST synchrotron facility is designed to be the "nation's standard light bulb," a resource for optical calibrations for U.S. industry as well as government and academic researchers.

The facility, known as SURF III (which at more than 180 tons of solid steel may be the world's heaviest "light bulb") soon will be helping manufacturers improve a variety of processes. SURF III replaces SURF II, which served as the national synchrotron radiation standard from 1974 to 1998. Synchrotron radiation is the light emitted by electrons as they are propelled around a donut-shaped ring in a strong magnetic field. The light emitted from SURF III covers the infrared, visible, ultraviolet and extends into the x-ray region of the electromagnetic spectrum. It is exceptionally pure, and scientists can tune it to a desired wavelength to probe and measure a wide variety of materials and devices.

Measurements at SURF III will be much more accurate due to several improvements in the magnetic field, which is more uniform and much stronger than previously available in SURF II. Since variations in the magnetic field are extraordinarily small (only about 1 %

of the variations of the field in SURF II's magnet), electrons in the storage ring move in nearly perfect circular orbits. The result is significant improvement in the uncertainty of irradiance measurements at any given wavelength. Additionally, SURF III has two more beamlines than SURF II and a new accelerator control system.

More details on SURF III are available on the World Wide Web at www.physics.nist.gov/SURF. For technical information, contact Andrew Hamilton, (301) 975-6381, andrew.hamilton@nist.gov.

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NIST MODELS OF ELECTRONIC COMPONENTS BENEFIT U.S. INDUSTRY AND SOCIETY

Industry and society are using mathematical codes developed by NIST to design power electronic systems for automotive and consumer electronics. These mathematical models are providing important benefits to society, including decreased production costs, higher quality and lower prices for consumer goods and increased energy efficiency. The benefits are detailed in a report recently completed by a research institute for NIST, which developed the models.

The models have resulted in improved production costs for systems utilizing a type of device known as insulated-gate bipolar transistors (IGBTs). IGBTs are electronic switches that enable sophisticated electronic circuits to use small amounts of electricity to control devices that require much larger amounts of electricity. Applications include:

- automotive ignition systems;
- “adjustable speed drives,” which enable electric motors to run more efficiently and provide more accurate control of precision equipment such as robotic machinery and x-ray machines;
- compressors for refrigeration and air conditioning;
- controls for household appliances;
- equipment used to ensure the smooth flow of power during severe storms and the efficient regulation of power in factories; and
- industrial technologies such as welding and electroplating.

The models are used in software to simulate how IGBTs perform, enabling manufacturers to design and perfect “virtual prototypes” before investing in the parts, material and labor needed to build the actual prototypes.

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SCANNING PROBE MICROSCOPE OBSERVES SURFACE MODIFICATIONS BY EXOTIC ION BEAMS

Ion beams are a relative newcomer among the technology tools available to industry, but already numerous applications have been developed in areas such as microelectronics, deep space propulsion, and medicine. In most cases, stripping a single electron from the constituent atom and then accelerating the ion to high velocity using electric fields forms the ion beam. The kinetic energy of the ions is then used to perform the task at hand. A different approach is being explored at the NIST Electron Beam Ion Trap facility, where ions that have a huge charge—10 to 100 times higher than conventional ion beams—are being produced and studied. These exotic highly charged ions produce strong electric fields themselves and utilize their large free internal potential energy, instead of their kinetic energy, to produce changes in materials.

To explore these changes, NIST researchers have bombarded various surfaces under ultrahigh vacuum conditions and then observed them with atomic resolution using a scanning probe microscope that is integrated into the same vacuum chamber. Recent results on graphite, a semimetal, using 23- and 44-times ionized xenon, show that individual highly charged ions produce regular protrusions up to 6 nm wide with essentially 100 % efficiency. When the ion charge is varied, while keeping the kinetic energy constant, the researchers observe the size of the features to vary by a factor of 2. The NIST work extends similar Japanese work into a regime in which the available potential energy of the ion is 50 times stronger and the ion-induced features are large enough to be “mesoscopic” or between the atomic range (governed by quantum mechanics) and the macroscopic range (governed by ensemble averages).

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UNRAVELING THE PUZZLE OF MOLECULAR SIEVE CIT-1

Zeolitic molecular sieves are made mostly of silicon and oxygen and have tiny, precise holes that will only fit some molecules, so for example, gasoline can fit inside, but not crude oil. They are used commercially to make gasoline, separate air into oxygen and nitrogen, capture radioactive ions; they can be found between the panes of double-pane windows and are even put in laundry detergents to soften water. Making these molecular sieve materials is as much an art as a science

because so little is understood about how these materials form. One important question is why two reasonably different trimethylammonium cations will coax silicon, oxygen, and other atoms into exactly the right positions to make the molecular sieve CIT-1. In one cation, the ammonium group is attached to a tricyclodecane ring and in the other cation, the ammonium group is attached to a myrtanyl ring. However, moving the ammonium group over by carbon atom along the myrtanyl ring makes a cation that cannot be used to make a molecular sieve in the CIT-1 family. Researchers at NIST, along with collaborators at two universities, studied the CIT-1 zeolite, while the holes were plugged with ammonium cations. They used neutron and synchrotron diffraction as well as computer modeling and found that the shape of the cations that make CIT-1 were matched perfectly to the holes. However, when the researchers moved the ammonium group one position, the subtle shape change was just enough to keep the cations from fitting. This kind of information will help other researchers find new ways to make molecular sieves.

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NCNR CONFIRMS SILICONE-FILLER MODEL AND ACHIEVES A MEASURE BEYOND

NIST researchers, in collaboration with a private company, have completed a study of filled polymers using small-angle neutron scattering (SANS) instrumentation at the NIST Center for Neutron Research (NCNR). The measurements probed the influence of fillers on the silicone polymer chain dimensions as a function of filler concentration and polymer molecular mass. Silicone polymers blended with particulate fillers are used commercially in rubber products and sealants. The interactions between the fillers and the polymers are key factors that influence product performance.

Molecular simulations have predicted that polymer chain dimension in the presence of fillers is a function of the filler particle size and concentration. However, tests of these predictions have not been available.

The SANS measurements showed that polymer chains which are approximately the same size as the filler particle in the unfilled material experience a decrease in chain dimensions at all filler concentrations. In contrast, for larger chains, at low filler concentrations, an increase in chain dimensions relative to the unfilled chain dimensions is observed. Both results are in agreement with existing predictions from molecular simulations.

However, at even higher filler contents, which are beyond the scope of the molecular simulations, the chain dimensions reach a maximum value before decreasing to values that are still larger than the unfilled chain

dimensions. A qualitative excluded-volume model was proposed to account for the experimental results. The extension of the experimental data beyond the existing calculations provides researchers with the necessary data to supplement current predictions. Furthermore, the measurements suggest that changes in chain dimensions in filled polymers should be considered when predicting their mechanical performance.

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MOLECULAR ORIENTATION FOUND TO AFFECT WEAR IN ARTIFICIAL JOINTS

Ultrahigh molecular weight polyethylene (UHMWPE) is the material of choice for artificial joint replacement in orthopedic practice. Cobalt and chromium alloy is commonly used as the counterface against the UHMWPE. This material pair is currently used for hip and knee replacements and has proven to be durable and biocompatible. In the search for improved biomaterials, NIST and four private companies have teamed together to conduct research on understanding the wear mechanisms of these materials.

UHMWPE used in joints has an average relative atomic mass of 4 million to 6 million. Cross-linking of this material has produced extremely low wear. The mechanism of why cross-linking reduces wear is not understood. Using the Brookhaven Synchrotron ultra-soft beam line, NIST scientists have been able to measure quantitatively the degree of molecular orientation of UHMWPE as a function of rubbing direction and cycles.

Results suggest that the polymer is easily oriented by shear at the surface layer. If the motion is unidirectional, all the chains would align along the direction of motion, producing a semi-glassy solid which is prone to fracture. By cross-linking the amorphous region of the polymer, the molecular orientation from rubbing is reduced severely, producing much better wear resistance.

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SILVER-BASED SUBSTITUTE FOR MERCURY-CONTAINING DENTAL ALLOYS

As a result of a 4 year long program supported by the National Institute of Dental Research, NIST researchers have concluded the development of a mercury-free metallic alternative for conventional dental amalgams.

The use of mercury-containing dental restoratives is restricted severely in Japan and much of Europe. Several alternative materials are in use, but none of them is completely satisfactory. While mercury-containing restoratives are still in use in the United States, there has

often been discussion of restricting their use, and it is, therefore, desirable that a better alternative material should be available.

The technology developed at NIST is based on the ability of silver surfaces to adhere (cold weld) to each other after being treated in dilute fluoboric acid. Silver particles that have been immersed in such acid can be hand-consolidated into cohesive solids (78 % theoretical density) using conventional dental tools. Over the course of the program, several forms of silver powder were evaluated, and it was determined that the best source of silver was obtained from a two-solution chemical precipitation process (patent pending). The silver powder characteristics required for optimum hand consolidation properties also were determined.

Two of the most important parameters are the agglomerate size and individual particle size of the silver powder. Dramatic increase in both the transverse rupture strength and density of hand consolidated samples was achieved by optimizing the precipitation process and annealing the silver powder. Acid-assisted consolidation (three patents, two issued and one pending), however, was the major finding, which makes silver powder possible as a mercury-free metallic restorative because the acid removes the silver surface oxide and thereby promotes cold welding.

Using the current technology, hand consolidated silver equals or exceeds the transverse rupture strength, shear strength, creep, toughness, corrosion resistance, microleakage, cyclic contact fatigue, and wear properties of conventional amalgam. The results of *in vitro* biocompatibility testing have shown the mercury-free restorative to equal or exceed the biocompatibility of mercury amalgams. Licensing of this technology is available through the Office of Technology Partnerships. CONTACT: Christian E. Johnson, (301) 975-6409; christian.johnson@nist.gov.

THE DISPUTED DISCOVERY OF ELEMENT 43: A RE-EXAMINATION OF AN ELEGANT EARLY USE OF WAVELENGTH DISPERSIVE X-RAY MICROANALYSIS

Typical modern histories of the discovery of the chemical elements report that element 43 was discovered in 1937 by Perrier and Segre. According to these accounts, the discovery was made by chemical separation in a sample of deuteron-bombarded molybdenum, supplied by E. Lawrence, and thus represents the first discovery of an element produced artificially and is the reason for the name “technetium” (Tc) chosen by the investigators. Some accounts might note in passing that the element was reported as discovered in 1925 by Noddack, Tacke, and Berg utilizing x-ray emission spectroscopy in

natural samples and called “masurium” (Ma). These reports, however, invariably call this discovery erroneous and sometimes refer to the investigators (typically left unnamed) as “deluded.”

The fate of this early investigation has become an object of study by historians of science. Recently, Van Assche concluded that the experiment of Noddack et al. seemed self-consistent and valid. His conclusions have been the subject of some debate, with supporters on both sides.

To test if the claims of Noddack et al. are plausible, a NIST scientist utilized the NIST x-ray database and spectral analyzer program DTSA to simulate the 1925 data. The experimental configuration was deduced from the original paper and simulations were made for a range of compositions for the residue suggested by Van Assche. The relative intensities of the various x-ray lines and the peak-to-background ratios were determined and compared to the original spectrum.

The x-ray database in DTSA showed no interferences for lines at the Tc/Ma K-series wavelengths that were consistent with the Noddack et al. spectrum. The lines attributed to Ma appear consistent with element 43 at a value of at least five times the detection limit. The bulk composition (mole fractions) of a sample consistent with Noddack’s spectrum is: 70 % Nb, 20 % Mo, 7.6 % Ma(Tc), and 2.3 % Ru. The mass of Ma(Tc) calculated from the peak-to-background ratios is consistent with the amount expected from spontaneous fission of the U present in their starting material. The NIST simulation provides compelling support for the 1925 spectral claims and demonstrates the forensic capabilities enabled by recent advances in measurement science.

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TRANSITION-EDGE X-RAY MICROCALORIMETERS ACHIEVE NEW BEST-IN-THE-WORLD ENERGY RESOLUTIONS

NIST researchers have successfully fabricated new x-ray microcalorimeters with best-in-the-world energy resolution for nondispersive detectors. An energy resolution of $4.5 \text{ eV} \pm 0.1 \text{ eV}$ at 5.9 keV was achieved for x rays from an Fe^{55} radioactive source using a microcalorimeter with a newly developed Mo-Cu superconducting transition-edge thermometer. This detector was fabricated using a fully photolithographic process on a Si_3N_4 membrane structure micromachined in a “flyswatter” geometry to control the thermal conductance. The ability to photolithographically fabricate detectors will allow the construction of microcalorimeter arrays for imaging or for increased area and total count rate. In addition, another

best-in-the-world energy resolution of $2.0 \text{ eV} \pm 0.1 \text{ eV}$ at 1.5 keV was achieved using a low-energy-band transition-edge microcalorimeter fabricated with the groups original shadow-mask lithography process. This detector is designed for use in low-beam-voltage x-ray microanalysis, particularly to identify small contaminant particles in the semiconductor industry. It already has been used to observe the x-ray chemical shift in Al between particles of Al and Al_2O_3 , and the Ti chemical shift between Ti and TiN in thin films.

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NEW SINGLE-ELECTRON TUNNELING CAPACITANCE STANDARD

A prototype of a new capacitance standard based on counting electrons was recently developed by NIST scientists. The new "SET capacitance standard" was created by combining single-electron tunneling (SET) devices, which allow precise manipulation of electrons, with a cryogenic vacuum-gap capacitor having nearly ideal properties. The current prototype has a fractional repeatability of 3×10^{-7} and agrees with NIST's primary capacitance standard within the 2×10^{-6} relative uncertainty of the comparison. The researchers expect that a total relative uncertainty of 1×10^{-7} or less will be possible with further work. By exploiting the quantization of the electron charge, the SET capacitance standard offers a natural or quantum basis for capacitance metrology, analogous to the voltage standard based on the Josephson effect and the resistance standard based on the quantum Hall effect. The new standard was described in an article in the Sept. 10, 1999 issue of *Science*.

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NEW MEASUREMENT SERVICE ANNOUNCED FOR 193 nm LASER POWER METER CALIBRATIONS

NIST is now offering measurement services for the calibration of laser power and energy meters used with argon fluoride (ArF) excimer lasers emitting radiation at 193 nm. The explosive growth of ArF excimer laser-based systems for eye surgery and for high-resolution photolithography have resulted in an urgent need for better measurement standards and techniques for characterizing the pulsed, ultraviolet radiation produced by these lasers. Current computer microprocessor and memory chips require feature sizes that can be achieved only by using the short-wavelength radiation produced

by sources such as excimer lasers. Corneal sculpting techniques (e.g., PRK [photo-refractive keratectomy] and LASIK [laser in situ keratomileusis]) use the ArF laser radiation to correct or improve certain vision impairments. NIST scientists designed and built two electrically calibrated calorimeters, which are used as primary standards in a specially designed, beamsplitter-based measurement system to perform the calibration measurements in a purged-enclosure environment.

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JOINT EXPERIMENT ESTABLISHES CONFIDENCE IN TEMPERATURE PROBES

A joint experiment between NIST and a private company established confidence in both NIST's and the company's temperature probes used to measure short duration, small magnitude temperature changes of a molecular beam epitaxy (MBE) grown compound semiconductor sample with a sensitivity of about 1°C . Knowledge of these dynamic growth conditions is missed by conventional thermocouple temperature probes. This experiment provided the company with information vitally needed to evaluate future markets for their products, and may lead to improved device performance.

Last spring, the company installed one of their emissivity-corrected pyrometer temperature sensors NIST's MBE chamber. The sensor works by measuring light emitted from the wafer during growth, while a comparable sensor already in place on the NIST MBE determines temperature by measuring light absorption and reflectance during sample growth. The sensor improves on existing pyrometers by self-calibrating as the optical properties of the wafer change during deposition. The joint experiment demonstrated compatible results with both approaches, which boosted confidence in each method.

The company is a leading materials science company in the field of compound semiconductors. Compound semiconductors are materials fundamental to the manufacture of a broad range of commercial devices, such as high-speed transistors for cellular phones, solar cells for satellites, laser diodes for telecommunications, and high brightness light-emitting diodes. The company leads the world in the sales and manufacture of metal organic chemical vapor deposition (MOCVD) systems used to prepare mainstream compound semiconductor thin films (such as gallium arsenide, indium phosphide, and gallium nitride) on four- and six-inch wafer substrates. CONTACT: Jonathan Guyer, (301) 975-5329; jonathan.Guyer@nist.gov.

NIST RESEARCHERS COMPARE AND CHARACTERIZE DIELECTRIC MEASUREMENT METHODS FOR CIRCUIT BOARDS, PRINTED WIRING BOARDS, AND SUBSTRATES

NIST staff have evaluated a wide range of dielectric measurement methods used on thin materials such as circuit boards, printed wiring boards, and substrates. Dielectric measurements are extremely important to manufacturers of circuit-board and substrate materials especially as the frequency of operation increases. In most applications it is important to measure the dielectric constant with a relative uncertainty of 2%. It also is important to characterize the loss in these materials since in electronic applications loss produces unwanted heating. In this study, the most commonly used techniques used for measurements of thin dielectric materials were compared and uncertainties calculated. It was found that the full-sheet resonance technique works well for the dielectric constant but not for the loss in the material. The re-entrant cavity method works well for both the dielectric constant and loss but is limited to materials of thickness greater than 1 mm. It was concluded that dielectric-resonator techniques produce the most accurate results. The results of NIST's study on dielectric measurement methods on thin materials have been summarized in NIST Technical Note 1512.

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NIST RESEARCHERS DEVELOP BROADBAND MEASUREMENT METHOD TO CHARACTERIZE THIN FILMS

To improve the electrical performance of interconnects, the semiconductor industry is replacing traditional silicon dioxide thin films with lower permittivity (low- k) thin films. Reducing the permittivity of the dielectric separating the interconnects decreases the parasitic capacitive effects. As a result, smaller interconnects that operate at higher frequencies are feasible. Although many candidate low- k thin film materials exist, the permittivity of many of these new materials remains relatively unknown, especially at high frequencies.

NIST researchers, in collaboration with SEMATECH, have developed a new measurement method for characterizing the permittivity of dielectric thin films. The method utilizes printed microstrip transmission line test structures that incorporate the low- k thin film. From measurements of the test structures propagation constant and characteristic impedance, the thin film permittivity is determined over a frequency range of 50 MHz to 40 GHz. By measuring both the propagation constant

and characteristic impedance, they demonstrated the ability to separate the electrical properties of the dielectric thin film from the metal conductors. Recent measurements on both low- k and silicon dioxide thin films confirm that the relative uncertainty of the measurement of permittivity is within the goal of $\pm 5\%$. CONTACT: Jim Baker-Jarvis, (303) 497-5621; jjavis@boulder.nist.gov.

THINNEST CYLINDRICAL ARTIFACTS EVER MEASURED BY NIST

NIST scientists recently completed diameter measurements on a set of ultra-thin nickel-alloy fibers, only 13 μm in diameter. These artifacts will be used to provide traceable calibrations that will improve manufacturing of a new generation of carbon fibers. The fibers are the thinnest cylindrical artifacts ever measured by NIST; this measurement is indicative of new and expanding traceability requirements of emerging industries.

Measurement of the artifacts was made possible thanks to a unique contact micrometer designed by NIST scientists. A 50 mm section of fiber was mounted with wax in a thin aluminum frame to allow for easy manipulation of the artifacts. Each fiber was twisted approximately two rotations between the wax mounts allowing for sampling of two-point roundness errors of the fiber. Measurements were made at three applied forces on one of the samples to determine the elastic deformation of the material. The expanded uncertainty (coverage factor $k=2$) for the measurements was calculated to be 90 nm, with the primary source of uncertainty being the fiber taper and roundness geometry.

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NIST COOLS IT AGAIN!

A NIST researcher has observed a new form of matter—a Fermi degenerate gas. Every particle in nature can be classified as either a fermion—possessing a half integral value for spin—or a boson—possessing an integral value of spin. Fermions are subatomic matter such as the proton, neutron, electron, and neutrinos. Their behavior is described by Fermi-Dirac statistics. The most common example of the boson is a photon, and Bose-Einstein statistics describe the behavior of their systems. Atoms are composed of these fundamental particles and also can be either fermions or bosons depending upon their resultant spin.

Using techniques and insight gained with the discovery of the Bose-Einstein condensate (BEC), a NIST

researcher and a graduate student from the University of Colorado cooled approximately 1 million potassium-40 fermions to 290 nK—the coolest kinetic temperature for fermions ever observed. Unlike the boson, which will fall readily into the lowest energy state and condense, the fermion is an unwilling participant due to the Pauli exclusion principle, which prohibits two identical particles from occupying the same state and, therefore, stops the collisional thermalization process. The cooling of fermions is, in a way, more difficult than the cooling of bosons.

To overcome the Pauli exclusion obstacle to cooling fermions, the ^{40}K atoms were magnetically trapped in two different spin states and microwave radiation was used to selectively enable the evaporative cooling process. The resultant ultracold, nearly ideal, Fermi gas provided an environment ripe for observing quantum statistics.

Possible long-range applications of this work include atomic superconductivity and more accurate clocks.

This work was first reported in *Science*, Sept. 10, 1999, and likely will be named one of the most significant achievements in physics in 1999.

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TWO NEW PRECISION MEASUREMENT GRANTS AWARDED FOR FY 2000

Two new \$50 000 NIST Precision Measurement Grants have been awarded for fiscal year 2000. The recipients, Elisabeth G. Gwinn of the University of California, Santa Barbara, and Protik Majumder of Williams College, were selected from an initial group of 26 candidates. NIST sponsors these grants to promote fundamental research in measurement science in U.S. colleges and universities and to foster contacts between NIST scientists and researchers in the academic community actively engaged in such work.

The aim of Gwinn's project, "Combining the Quantum Hall and AC Josephson Effects for Electric Current Metrology," is to develop a new quantum standard of electric current by combining the ac Josephson effect (JE) and the quantum Hall effect (QHE) in an integrated, unique way. Further, this will allow one to check the internal consistency of the value of the elementary charge e that is characteristic of a single electron tunneling device and the combined JE and QHE. An important aspect of this work is the development of a new kind of Josephson junction array based on a superconductor, semiconductor-quantum-well, superconductor tunnel

ing device or S/QW/S, and a cryogenic semiconductor switch.

The aim of Majumder's project is to develop a high-finesse laser ring-cavity and to use it to search for long-range electron-nucleon forces in atomic thallium that violate time-reversal symmetry (T) but conserve parity (P). The proposed experiment would improve limits on possible T-violating (but P-conserving) forces of this type by four to five orders of magnitude. In this work, the signature for T-violation is a shift of the phase of counter propagating laser beams in the special ring-cavity when the optical path length for the beams is possibly changed when the direction of an electric field through which the beams pass is reversed. Observation of T-violation in atomic thallium would clarify the poorly understood observation of charge symmetry (C) violation and P-violation in the decay of the kaon and test the standard model of particle physics.

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NIST CONTRIBUTES TO RUSSIAN-AMERICAN SOLAR NEUTRINO EXPERIMENT

For more than 30 years, one of the outstanding problems in astrophysics has been the measured deficit of neutrinos produced in the solar interior. Several experiments have now confirmed this deficit. Since January 1990, the Russian-American Solar Neutrino Experiment (SAGE) has carried out measurements of the capture rate of neutrinos in 60 metric tons of ultrapure liquid gallium as a measurement of the solar neutrino flux. The reaction $^{71}\text{Ga}(\nu, e^-) \rightarrow ^{71}\text{Ge}$ provides the only presently feasible means to measure the predominant neutrinos produced by the fusion of protons in the sun. A NIST scientist is one of the U.S. collaborators on this experiment. The detector resides in an underground laboratory in the Caucasus Mountains of southern Russia.

In an article to appear in *Physical Review C*, the SAGE team present the analysis of 8 years of measurements of the solar neutrino flux. NIST has participated in the calibration of the detector using a 19 PBq, ^{51}Cr radionuclidic source along with analysis of the data. The result represents only about half of the predicted flux given by the Standard Solar Model. Although this model describing the processes of nuclear fusion in the sun has been very successful in explaining numerous solar features, the deficit in the solar neutrino flux still remains one of the unresolved problems.

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HELP TOOLBOX USER'S GUIDE PUBLISHED

NIST Technical Note 1428 has been published as a user's guide to the High Dimensional Empirical Linear Prediction (HELP) Toolbox, which was developed as a software optimization tool designed specifically to meet the requirements of test and measurement engineers. The approach is based on a simple mathematical model that relates the device response at all candidate test conditions to a set of underlying variables. Once an accurate model has been developed, algebraic operations on the model are used to:

- select an optimal set of test points that will minimize the effort to achieve a specified level of confidence,
- estimate the parameters of the model from measurements made at the selected test points,
- predict the response of the device at all candidate test points (from measurements made at the selected test points) as a basis for accepting or rejecting units, and
- compute statistical intervals (uncertainty bounds) for the predicted response, and test the validity of the model, on-line.

The entire process, including model development, can be performed with the HELP Toolbox, which is a graphical software package for use with a commercial mathematical programming language. While a general understanding of the underlying principles is desirable, no mathematical programming is required of the operator. HELP places special emphasis on empirical modeling using measurement data collected previously on devices similar to the units under test. In addition to test optimization, the HELP Toolbox is also useful for exploring the structures that underlie the behavior of the tested devices.

For many electronic devices and instruments, it is not physically or economically feasible to perform exhaustive testing. Therefore, test engineers must formulate abbreviated test plans that are economical to execute but still yield accurate measures of the overall performance of the tested products. Examples of products that can benefit from using the HELP approach range from programmable filters to analog-to-digital (A/D) and digital-to-analog (D/A) converters to multirange, multifunction precision instruments.

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NIST HOSTS WORKSHOP ON PRESSING NEEDS IN UV METROLOGY

A NIST physicist jointly organized and conducted a Workshop on the Pressing Needs in Ultraviolet Metrology in July 1999, with Rad Tech International.

Rad Tech is an industry association with more than 700 members that supply and use ultraviolet (UV) and electron beam (EB) equipment, raw materials, and formulated products. Over 60 people attended, including manufacturers of UV sources and metrology instrumentation, UV curing and coating processors, and representatives from the photolithography and semiconductor industries.

The goal of the meeting was to identify the industrial needs for ultraviolet metrology. The UV curing processors and photolithographers detailed their urgent need for improved UV standards and measurement methods. UV curing is a rapidly growing technology because it eliminates the need for volatile chemicals. UV, along with EB and visible light, are proven technologies that instantly "cure" or polymerize inks, coatings, and adhesives, making industrial processes more efficient, while virtually eliminating the air pollution and waste generated by traditional methods. UV/EB is used in a wide range of applications to protect, decorate, or bond items such as wood, fiber optics, compact discs, credit cards, beverage cans, food packaging, magazine covers, and automotive parts.

Representatives from the semiconductor industry expressed the need for improvements in metrology for the measurement of optical constants and UV radiation for photolithography processing. Photolithography is the process used for building microelectronic components on top of silicon wafers. A photoresist coating is applied to the wafer that reacts to UV light and is an integral step in the process.

A follow-up took place at the fall meeting of Rad Tech in October in Arlington, VA. It is anticipated that a NIST metrology program will be developed to address the needs of the UV/EB industries.

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WORKSHOP HELD ON CHARACTERIZATION OF NUCLEAR REACTOR PRESSURE VESSEL STEELS

A workshop entitled "Nondestructive Characterization of Embrittlement in Reactor Pressure Vessel Steels" was held at NIST Boulder in July 1999. The workshop was part of an ongoing NIST research program sponsored by the Nuclear Regulatory Commission. Experts in assessing radiation embrittlement of reactor pressure vessels provided overviews of the programs for monitoring embrittlement in the United States, Europe, and Japan. Researchers from universities and government laboratories in Germany, France, Belgium, and Japan described their R&D programs for developing nondestructive techniques for detecting embrittlement in the steels

used for pressure vessels in their countries. Many of the investigations used very sophisticated microscopy techniques to elucidate the mechanisms of embrittlement on an atomic level and thus defined the conditions that the nondestructive methods must detect. NIST scientists presented the results of their research on eight physical properties that were found to be sensitive to the microstructures associated with embrittlement and which could form the basis for non-destructive testing procedures. On the last day of the workshop, attendees addressed the preparation of a roadmap to guide future research toward the development of non-destructive evaluation methods that could be introduced into the maintenance programs of existing nuclear power plants to increase their safety and extend the useful life of their pressure vessels.

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CIPM WORKING GROUP FOR FLOW MEASUREMENTS ESTABLISHED

At its Fall 1999 meeting, the International Committee for Weights and Measures (CIPM) officially established a Working Group for Flow (WGF) within its Consultative Committee for Mass. In 1998 the international flow measurement community formed an Ad Hoc Group for Flow (AHGF) that could evolve into a WGF to conduct key comparisons of the flow standards in national measurement institutes (NMIs). The AHGF was convened in Denver, CO, in conjunction with the recent 4th International Symposium for Fluid Flow Measurement. A NIST scientist was elected by this international group to serve as chairman of the proposed WGF. A structure for the proposed WGF was arranged, and the first meeting of the WGF is now scheduled for June 2000 in conjunction with the FLOMEKO 2000 Symposium in Salvador, Brazil. The central issues will be to initiate specific key comparisons of flow standards for the wide ranges of fluid and flow conditions needed by the world's NMIs to quantify equivalencies.

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BIOTECHNOLOGY HOLDS WORKSHOP ON SCANNING PROBE MICROSCOPY OF SOFT MATERIALS

A NIST postdoctoral researcher organized and conducted a Workshop on "Scanning Probe Microscopy of Soft Materials" in August 1999. The workshop was

attended by more than 40 researchers from NIST, other DC area government labs, and universities as well as representatives from the scanning probe microscope industry (molecular imaging and digital instruments). The workshop consisted of a series of talks on the uses of scanning probe microscopy to image biological, polymer, and self-assembled systems. This was followed by a discussion of issues preventing progress in the field that focused on gaining a better understanding of phase measurements and the physical characterization of probe tip.

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WORLDWIDE COMPARATIVE ASSESSMENT OF MOLECULAR MODELING AND SIMULATION

NIST has joined with the National Science Foundation and the Department of Energy to fund a worldwide comparative assessment of molecular modeling and simulation. The study will focus on the development of new modeling and simulation technologies and the transfer of those technologies to industry. The study will be conducted by a blue ribbon panel of experts from academe and industry. Observers from NIST, the National Science Foundation, and the Department of Energy will accompany the panel as it visits national laboratories, universities, and industries in Europe and Asia. The panel will prepare a written report that will be released to the public at a workshop to be held next summer.

Advances in computing technology and the development of new modeling and simulation methods over the past two decades have created a significant scientific and technological resource that is becoming widely used in industry as a source of fundamental physicochemical and engineering properties for product and process design and optimization. The study, which is being run by the World Technology Evaluation Center of Loyola College, will compare the state of advance in molecular modeling and simulation in academia and national laboratories of the United States, Japan, the United Kingdom, Germany, and France. It also will assess the extent and effectiveness of transfer of this knowledge to various types of industries, primarily process and product-based ones such as chemical, energy, and materials. This information will be of value to U.S. researchers, academicians, strategic planners, and decision makers.

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STANDARD FOR AUTOMATED ACROSS-THE-ROAD RADAR SYSTEMS

Traditional speed enforcement involving traffic stops on densely traveled, fast-moving urban roads is dangerous for police officers and creates a potentially hazardous distraction for other motorists. A better method is to automatically photograph vehicles exceeding a specified amount above the posted speed and then to ticket the violators by mail. The automated across-the-road radar systems, popularly called “photoradars” and beginning to appear along U.S. roads, are capable of determining the directions, speed and type of vehicle (truck, car, or motorcycle) crossing its radar beam and then recording the speed-violating vehicle along with the time, date, location speed, and other information on photographic film as evidence. Systems requirements and methods of testing the performance of photoradar units appear in the standard “Model Minimum Performance Specifications for Automated Across the-Road Doppler Radar Systems” recently prepared by NIST for the National Highway Traffic Safety Administration.

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A NEW PERFORMANCE STANDARD FOR POLICE TRAFFIC RADAR DEVICES

As early as 1947, police officers began using Doppler radar devices to enforce traffic speed laws. Alongside the subsequent worldwide proliferation of radar devices among police departments, the need arose to ensure reliable and accurate speed measurements. In 1977, the U.S. Department of Transportation’s National Highway Traffic Safety Administration (NHTSA) entered into an inter-agency agreement with NIST to develop comprehensive performance requirements and methods of test for speed measuring devices, including police traffic radars. The radar performance specifications, first promulgated by NHTSA in 1981, have undergone several revisions to keep up with the technology. The current embodiment, “Speed Measuring Device Performance Specifications: Radar Module” is now being readied for distribution by NHTSA.

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CONFERENCE PROCEEDINGS PUBLISHED ON ULTRATHIN SiO₂ AND HIGH-*k* MATERIALS FOR ULSI GATE DIELECTRICS

Ultrathin SiO₂ and High-*k* Materials for ULSI Gate Dielectrics, the proceedings of a recent Materials

Research Society (MRS) Symposium, was published in September 1999 (high *k* refers to high permittivity). The symposium was part of the April 1999 meeting of the MRS in San Francisco, CA. The plenary speaker at this meeting noted that at the current pace (of dimensional shrinkage in integrated circuits) the industry would reach the limits of what can be accomplished with SiO₂ by about 2005. The symposium is believed to be the most comprehensive to date detailing the latest research on the potential showstopper issue of identifying a suitable production-worthy replacement material for SiO₂ as a MOS transistor gate dielectric.

The 615-page proceedings gives an account of fundamental research into the materials, processes, and manufacturing challenges that must be resolved before the high-*k* gate stack module can be used in mainstream IC manufacturing. The symposium, co-organized by a NIST researcher provided a means for leaders in the technical areas of ultrathin and high-*k* materials to share research on critical problems in technology associated with present-day and near-future MOS gate dielectrics.

The proceedings contains 81 published papers from the more than 100 presenters at the symposium. The symposium was truly international, with participants representing six different continents and 34 of the 81 published papers coming from countries other than the United States.

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NIST-DEVELOPED STANDARD BULLETS PREDICTED TO HAVE A WORLDWIDE IMPACT

The 1999 IBIS (Integrated Ballistics Identification System) users group meeting was held in August 1999, in Dallas, TX.

NIST developed prototype standard bullets in 1998. Those bullet signatures tested at NIST showed high uniformity and reproducibility. NIST standard bullets testing results showed highly repeatable and reproducible IBIS scores when compared to the quality assurance bullets now being used. Bullet examiners believe that the unique properties of the NIST standard bullets will make it very useful for instrument calibrations and measurement quality control and have a potential use for enabling nationwide and worldwide ballistics measurement traceability and unification.

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REALLY LARGE SCALE METROLOGY— GLOBAL POSITIONING SYSTEM MEASUREMENTS AT WASHINGTON MONUMENT

As part of a cooperative effort with the National Park Service and the National Geodetic Survey (NGS), NIST's large scale coordinate metrology group designed a metrology stand to aid in conducting a Global Positioning System (GPS) survey from atop the Washington Monument. A NIST machinist fabricated the metrology stand.

This GPS survey is part of the Height Modernization Initiative and will determine the height of the national monument. These surveys are performed on a regular basis by NGS, usually by using conventional surveying instrument. This survey took advantage of the fact that the monument top was accessible because of current cleaning/restoration operations. The last time that the top of the monument was accessible was in 1934.

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NIST PUBLISHES TREC-7 PROCEEDINGS

NIST published the proceedings of the seventh annual Text REtrieval Conference in August 1999 as NIST Special Publication 500-242, The Seventh Text REtrieval Conference (TREC-7). The TREC workshop series is sponsored by NIST and the Department of Defense to support the text retrieval industry by providing the infrastructure necessary for large-scale evaluation of text retrieval methodologies. TREC-7, the most recent workshop in the series, was held at NIST in November 1998, with 150 participants. Fifty-six groups from 13 different countries and 19 companies attended.

The proceedings contain an overview summarizing the retrieval tasks and main results of the conference, papers that were presented at the conference, and complete evaluations of individual group results. The proceedings also contain "track" reports, where a track is focused work on a particular retrieval subproblem. This years reports include a summary of the "Very Large Corpus" (VLC) track in which participants searched 100 GB of web pages. VLC systems not only were forced to handle much greater amounts of data (standard TREC collections are approximately 2 GB) but also to accommodate the different genre of data represented by web documents. An electronic version of the proceedings is available on the TREC web page at <http://trec.nist.gov>.

In other TREC news, the Japanese National Center for Science Information Systems held the first NTCIR Workshop on Research in Japanese Text Retrieval the end of August in Tokyo. The evaluation leading to this

workshop was based heavily on the NIST TREC model of evaluation; NIST supported this effort with advice and tools during the year. A NIST staff member presented the keynote for this workshop, which was attended by 28 participating groups, including the major Japanese companies involved in text retrieval and three U.S. groups.

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NIST SPONSORS INDUSTRY USABILITY REPORTING WORKSHOP

The NIST Industry USability Reporting (IUSR) project seeks to improve the testing and reporting of software product usability, thereby reducing the uncontrolled costs of poor usability. As part of this effort, NIST sponsored a 2 day Industry USability Reporting (IUSR) project workshop in September to begin a pilot trial to validate the value of reporting usability data in decision-making processes. Attendees included prominent industry representatives from software suppliers as well as organizations who are large software purchasers. The goal of the pilot trial is to determine how well the Common Industry Format (CIF) for usability reporting works and to determine the value of using the format in software procurement.

At the meeting, vendors and consumers discussed their responsibilities during the pilot trial and defined the metrics for NIST to use in measuring the effectiveness of the CIF. Participants also reviewed the CIF for reporting usability results and outlined how and when revisions will be made during the pilot study. Additional representatives from major corporations, not initially involved in the project, attended and many others expressed interest in participating in the trials, further publicizing this effort to trade publications and organizations, and planning for including future drafts of the CIF into their business processes. For more information, see <http://www.nist.gov/iusr>.

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NIST LAUNCHES CONFORMITY ASSESSMENT WEB SITE

Conformity-assessment issues, programs, and procedures are featured on a newly launched NIST web site (<http://ts.nist.gov/ca>). This will provide one-stop shopping for conformity assessment information. The site contains the 1999 edition of *NIST's Directory of Federal Government Certification and Related Programs*, which summarizes requirements issued by

federal departments and independent agencies. Entries include the purpose of each requirement, whether mandatory or voluntary, and methods used to ensure compliance. sources of documentation, reciprocity arrangement, enforcement approaches, and other items also are listed.

The new web site was developed in cooperation with the recently formed conformity Assessment Network, a government and private-sector partnership for improving business and consumer understanding of the sometimes confusing procedures used to assess the worthiness of products and services. Testing, sampling, inspection, certification, and other conformity assessment methods are intended to verify that a particular product meets a specified level of quality or safety or to accomplish other aims. They also can influence market entry and business competitiveness.

The site also includes sources for information on the international environment management standards (International Organization for Standardization (ISO) 14000), the international quality management standards (ISO 9000), certification programs related to fair labor practices (i.e., Social Accountability 8000), a large list of acronyms, and many links to other relevant conformity assessment sites.

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NIST DIGITAL MATH LIBRARY PROJECT RECEIVES NATIONAL SCIENCE FOUNDATION AWARD

NIST recently received funding from the National Science Foundation (NSF) to support the development of the NIST Digital Library of Mathematical Functions (DLMF). The NIST proposal entitled "Mathematical Foundations for a Networked Scientific Knowledge Base" was awarded \$1.3 million over 3 years through the NSF Knowledge and Distributed Intelligence (KDI) program.

The DLMF will provide NIST-certified reference data and associated information for the higher functions of applied mathematics. Such functions possess a wealth of highly technical and critically important properties that are used by engineers, scientists, statisticians, and others to aid in the construction and analysis of computational models in a wide variety of applications. The DLMF will deliver this data over the World Wide Web within a rich structure of semantic-based representation, metadata, interactive features, and internal/external links. It will support diverse user requirements such as simple lookup, complex search and

retrieval, a formula validation and discovery, automatic rule generation, interactive visualization, custom data on demand, and pointers to software and evaluated numerical methodology.

The DLMF was conceived as the successor for the NBS Handbook of Mathematical Functions (AMS 55), edited by M. Abramowitz and I. Stegun and published by NBS (National Bureau of Standards, now NIST) in 1964. AMS 55 is possibly the most widely distributed and cited NBS/NIST technical publication of all time. (The U.S. Government Printing Office has sold more than 150 000 copies, and commercial publishers are estimated to have sold several times that number). The DLMF is expected to contain more than twice as much technical information as AMS 55, reflecting the continuing advance of the intervening 40 years.

Further information on the project can be found at <http://math.nist.gov/DigitalMathLib/>.

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NEW NIST LASER MEASUREMENT SERVICE HAS USERS BEAMING

Argon-fluoride excimer lasers are shining brightly in both the medical and manufacturing worlds. These lasers, which produce pulsed, ultraviolet radiation at a wavelength of 193 nm, are commonly used in corneal sculpting techniques such as photorefractive keratectomy and laser *in situ* keratomileusis (abbreviated PRK and LASIK respectively) that correct vision impairments. The excimer laser's short wavelength also makes it perfect for the high-resolution photo-lithography needed to manufacture faster microprocessors and larger memory chips.

The explosive growth in ArF excimer laser use demands that better measurement standards and techniques be available for calibrating these instruments. NIST scientists have designed and built two electrically calibrated laser calorimeters to accomplish the task. Accurate assessments of the ArF excimer laser beam's energy are made in an enclosed environment using a specially designed, beamsplitter-based measurement system.

For technical information on this new 193 nm measurement service, contact Marla Dowell, MC 815.01, NIST, Boulder, CO 80303; (303) 497-7455; mdowell@boulder.nist.gov.

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STUDY SHEDS LIGHT ON DEGRADATION OF SELF-ASSEMBLED MONOLAYER FILMS

Self-assembled monolayer films are the basis for promising new sensors and diagnostics currently under commercial development for a variety of uses—everything from detecting genetic diseases in humans to pinpointing pathogenic microbes in food or water.

These sensors are made of alkanethiol molecules that organize themselves spontaneously on a gold surface to form a uniform crystalline film just one molecule thick. Single-stranded DNA molecules are tethered to this layer and used to latch onto complementary DNA from a solution washed over the sensor.

Until recently, self-assembled monolayers were thought to be stable in an ordinary lab environment. However, studies have shown that ozone in the air can degrade these monolayers by oxidizing the thiol portion of the alkanethiol molecules.

A team of NIST scientists examined this process using scanning tunneling microscopy (STM) and photoelectron spectroscopy. To follow the time evolution of the reaction, they exposed monolayer films to increasing doses of pure ozone while recording STM data. This revealed that ozone attacks the crystalline monolayers preferentially at the network of domain boundaries between the molecules. As ozone exposure increases, the reaction spreads into the domains.

The images also provided evidence of an unexpected occurrence: the crystalline monolayer melts and forms either a liquid or noncrystalline solid.

The NIST study points to possible strategies to improve the monolayer's stability in ozone, such as decreasing the density of the domain boundaries or decorating the boundaries with molecules that are ozone-inert. The study will be reported in an upcoming issue of the *Journal of the American Chemical Society*.

For more information, contact Gregory E. Poirier, (301) 975-2603; gregory.poirier@nist.gov, or check out www.nist.gov/sams on the World Wide Web.

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LONG-DISTANCE WELD MONITORING NOW FEASIBLE

Quality control has gone remote. In a recent paper, a NIST researcher in Boulder, CO, reports that he monitored the quality of welds made in Gaithersburg, MD, via the Internet. The welds joined a mounting bracket to the shaft of an automobile suspension strut. A pair of 2 s welds were made with an approximately 1 s delay between welds. The monitoring was done through the arc sensing monitor (known as ASM), a through-the-arc sensing system.

In both cases, the network speed was adequate to transmit the data between welds and have the ASM be ready to process the next weld.

Approximately 3 kbit of data need to be transmitted for each second of weld. The web server, the engineering workstation and the database server all can run on a single personal computer.

Quinn says that remote monitoring has the advantage of allowing informed decisions to be quickly made—from anywhere—about maximizing a welding station's productivity or solving operating problems that occur. The only requirement is that a reliable Transmission Control Protocol and Internet Protocol (known as TCP/IP) network must be installed in the factory.

For a copy of the paper, 43-99, "Internet Based Management of Data from Welding Sensors," contact Sarabeth Harris, MC 104, NIST, Boulder, CO 80303-3337; sarabeth@boulder.nist.gov.

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NIST TURNS OVER CMRL MANAGEMENT AFTER 70 YEARS

NIST is transferring management of the Construction Materials Reference Laboratory (CMRL) to the private sector after 70 years of growth. At the same time, the CMRL's link to NIST research is being strengthened.

Stewardship of the two CMRL program components, the Cement and Concrete Reference Laboratory (abbreviated CCRL) and the American Association of State Highway and Transportation Officials (AASHTO) Materials Reference Laboratory (abbreviated AMRL), changes this month. Taking over for NIST are the sponsoring organizations: AASHTO for AMRL and the American Society for Testing and Materials for CCRL. Both the CCRL and AMRL will continue to operate from NIST.

Launched in 1929 because of concerns about the quality of cement used in the construction of federal facilities, the CMRL now includes more than 1200 laboratories that test materials used by the construction industry.

Participants use a variety of AASHTO and ASTM standard test methods to help assure that high-quality materials will be the norm in the American construction industry. These labs test everything from concrete to asphalt and serve many private-sector firms, as well as state and local governments.

Participation in the CMRL programs is voluntary. They have grown steadily over the decades to keep up with the demand for quality assurance in the testing of building materials such as concrete, cement, soil and asphalt. The CMRL now carries out on-site assessment

programs for over 700 testing labs. It evaluates test equipment, identifies testing deficiencies and supplies proficiency samples.

Currently, the CMRL distributes more than 13,000 proficiency samples annually to laboratories in the United States, Canada, Mexico and more than a dozen other countries. The CMRL's role in the construction industry is significant because inadequate testing can lead to good materials being rejected, poor materials being accepted, construction delays and even structural failures.

Participating laboratories should not see any significant changes in the CMRL or either of its components as a result of the management change.

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INTERNATIONAL MEASUREMENTS WILL NO LONGER BE BEYOND COMPARE

The United States and 37 other nations agreed recently to launch a system for assessing the accuracy and reliability of measurements made worldwide, aiding efforts to resolve technical and regulatory differences that impede global trade flows.

Efforts to link national measurement standards within a global framework were formalized in a "mutual recognition arrangement" signed by a NIST representative and representatives of other countries participating in the 21st quadrennial meeting of the Conference on Weights and Measures earlier this month.

The arrangement calls for a systematic series of "key" measurement comparisons among the signing countries' national metrology institutes (known as NMIs). These comparisons will establish how closely a particular measurement (of voltage, for example) performed at one NMI agrees with results achieved in other countries. Levels of agreement among NMIs establish the basis for linking measurements across international borders.

Such measurement traceability should make it easier for exporters to demonstrate compliance with measurement requirements embodied in nations' regulations and voluntary standards.

Results of key comparisons will be recorded near an Internet-accessible database hosted by the International Bureau of Weights and Measures (BIPM) near Paris. All nations can participate in the new system. Through its membership in one of the world's six regional metrology organizations, any NMI can list its measure-

ment capabilities in a portion of the database, subject to review by expert committees.

The database system was developed at NIST, a strong proponent of efforts to strengthen measurement traceability on a global basis. NIST will maintain and further develop the system.

Information on the mutual recognition arrangement is available on the World Wide Web at www.bipm.fr/enus/8_Key_Comparisons/key_comparisons.html.

For more information on the International Comparisons Database, contact NIST's Robert L. Watters, Jr., Senior Scientific Advisor, (301) 975-4122; robert.watters@nist.gov.

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STEPS TO STEP DOCUMENTED IN NEW PUBLICATION

Not long after manufacturers first got a taste of computer-aided design and computer-aided manufacturing in the 1970s, they recognized that a key to the new technology's success would be the development of a universal, unambiguous language for exchanging product information. The chronicle of the public-private effort that brought that language to life and standardized its use can be found in *STEP: The Grand Experience*, a new publication from NIST.

STEP (the Standard for the Exchange of Product model data also known as ISO 10303) enables companies and suppliers to digitally express and share a product's design, manufacturing and support processes via computer in a standard format. The new 185-page book takes its readers from the definition of a drawing exchange capability (the Initial Graphics Exchange Specification, or IGES) in 1979 through to the future plans for the international STEP specification. In between, the story of STEP's emergence and worldwide acceptance is divided into topical areas such as "Modeling," "Conformance and Interoperability Testing" and "Managing the Process to Achieve the Product-Standards."

Other milestones and accomplishments detailed in the text include:

- the formation, work and contribution of PDES Inc., the joint industry/government consortium set up to accelerate the development and implementation of STEP;
- the creation of the Integrated Product Information Model (or IPIM) in 1988, described in the book as the "grand big daddy" summarizing all models up to that point;

- the first product manufactured using STEP—an automobile connecting rod—in 1993; and
- the initial publication of ISO 10303 in 1994.

Additionally, the book features a detailed glossary of STEP-related terminology and an extensive bibliography.

A single copy of NIST Special Publication 939 is available from NIST's Manufacturing Engineering Laboratory by sending an electronic message to debras@nist.gov. An Adobe Acrobat version on the World Wide Web is expected in the near future.

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NIST X-RAY PATENT LICENSED

On Aug. 12, 1999, a private company received an exclusive license to a joint invention with NIST, "Method and Apparatus for Diffraction Measurement Using a Scanning X-Ray Source," NIST Docket #97-026US. The concept came from a combination of the high-energy x-ray diffraction technology that has been developed at NIST during the past 5 years with the unique area-scanned x-ray tube developed by the private company, which will take over the responsibility for developing the method into commercial products.

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EXCLUSIVE LICENSE GRANTED FOR SOLAR WATER HEATING SYSTEM

A novel system that uses the power of the sun to heat water is about to become commercially available after years of development and testing at NIST. An exclusive license has been granted to a private company to use the NIST patented technology. The company is in a unique position to make use of NIST's solar hot water heating system by the use of integrated photovoltaic panels in their sun room and skylight products.

The solar water heating system is the first to use photovoltaic cells and computer chips to harness and direct the sun's energy. Photovoltaic (PV) cells are used to convert energy from sunlight into electricity. The NIST system was developed to use an array of PV cells to transfer solar power to specially designed heating elements inside a hot water tank.

The system was developed and tested at NIST's Gaithersburg campus. Several other successful pilot projects have shown that the system works well in different climates.

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AMERICAN CONCRETE INSTITUTE ACKNOWLEDGES NIST RESEARCHERS

In September 1999 the American Concrete Institute (ACI) published provisional standard ACI-ITG/T1.1-99 "Acceptance Criteria for Moment Frames Based on Structural Testing." With this standard in place, the construction industry has now moved forward swiftly to make use of novel structural systems in earthquake-prone regions of the country. The most notable of these new structures is a 40-story high-rise office in San Francisco that uses precast moment-resisting concrete frames technology that was pioneered at NIST.

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NEW MEASUREMENT SYSTEM FOR TESTING THE EFFECT OF FATIGUE ON THE CRITICAL CURRENT OF SUPERCONDUCTORS

A new measurement system for testing the effect of cyclic transverse compressive stress on the critical current of superconducting wires and tapes has been developed by NIST staff. The system is capable of cyclic application of transverse stress over 100 MPa to superconductor samples at low temperatures, while simultaneously applying currents of up to 300 A in magnetic fields of 11 T. The system is being developed to test superconductors for use in large magnet systems that will be energized repeatedly and consequently be subjected to several thousand stress cycles in actual operation. Static stress tests have been performed on many of the candidate superconductors for these systems, but preliminary data from the new fatigue system suggests that additional critical-current degradation can accumulate from cyclic loading. Because of the expense of large superconductor magnet systems being proposed for particle accelerators and electric utility power conditioning, the apparatus will provide a unique, but relatively inexpensive, testing capability for qualifying superconductors for use in their construction.

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NIST DEVELOPS KEY MEASUREMENTS FOR OPTICAL TELECOMMUNICATIONS INDUSTRY

The growth of wavelength-division multiplexing in optical fiber systems has resulted in new measurement requirements for a variety of optical components for telecommunication systems. In particular, the measurement of group delay, or the propagation time delay among the various wavelengths, has become increasingly important for dispersion management in lightwave

systems. In response to industry requests for these measurements, NIST researchers have developed and demonstrated a low-coherence interferometric method for measuring dispersion and group delay in waveguide devices. Fiber Bragg grating group delay has been measured with 1 ps repeatability, and this method shows 1.5 ps agreement with the more commonly used, but much slower, modulation phase-shift method. Dispersion, the change in group delay with wavelength, can be measured with better than 1 % repeatability (0.02 ps/nm standard deviation for a grating with 7 ps/nm dispersion).

Concurrently, there was a round robin of dispersion measurements among industrial laboratories. This set of dispersion measurements showed a 16 % range for the same grating, indicating the real need for these improved measurements. A key benefit of the low-coherence interferometric method is the fast measurement time. Measurements with 7 pm wavelength resolution can now be made in 1 min compared to the hours required to obtain measurements with reduced wavelength resolution using current methods. This may prove valuable for commercial measurements of the large number of fiber Bragg gratings being used in fiber telecommunications systems.

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INTERNATIONAL ROUND ROBIN TESTING COMPLETED ON CERAMIC POWDERS

NIST completed an international round robin study on properties of advanced ceramic powders. Thirty-four laboratories participated, including those in Belgium, Germany, Japan, Sweden and the United States. The ultimate goal of this activity, conducted under the auspices of the International Energy Agency (IEA), is to draft uniform standard test methods in each participating country and through the ISO. The properties measured included those used for characterization of powders suspended in water (particle dispersion and rheology), characterization of spray dried powders (flow rate, particle size distribution, moisture and binder content), and green body evaluation (bulk density and green strength). The compiled data were analyzed to determine the repeatability of the data within each laboratory and to examine variations in the data obtained by different laboratories. In general, no significant variations occurred within the laboratories. However, significant variations between laboratories were observed for a few measurement procedures, even though the procedures had been predefined. The measurement procedures that resulted in unacceptable variation will need further evaluation and improvement before establishing national

and international standard test methods for characterization of ceramic powders.

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NEW VOLTAGE STANDARD ATTACHED TO WATT EXPERIMENT

NIST researchers have completed the first programmable Josephson voltage standard system and have made it available for the moving coil watt-balance experiment. The latter may eventually lead to a new definition of the kilogram, the unit of mass in the International System of Units (SI). The system operates as an instrument that can be commanded over the IEEE 488 bus to produce any voltage within its output range of ± 1.1 V. When not being used as a voltage reference, the system automatically executes a variety of self-tests to confirm correct operation and to evaluate uncertainties. Once set up, the system can operate unattended 24 hours a day. It will be connected directly as the voltage reference for the Watt experiment and is expected to eliminate uncertainties associated with a chain of voltage comparisons used previously.

The new system has attracted much interest internationally and is a prospect for replacing dc voltage standards around the world.

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MODEL DEVELOPED FOR BONDING OF SUPERALLOYS

A model has been developed by NIST researchers describing the process of transient liquid phase (TLP) bonding, which can be used to make high-quality joints in superalloys and other materials. An important application of this process is to make large, complex single-crystal components by joining together smaller single crystals, since defect-free small single crystals can be produced more easily than large ones. In TLP bonding, the pieces to be joined are fitted together, with a thin foil of a lower-melting alloy between them. When the assembly is heated, the foil melts but then resolidifies isothermally as its constituents diffuse into the adjoining crystal, leaving a virtually invisible joint.

The model is based on a thermodynamic model of the single crystal and bonding foil materials, a matrix of diffusivities, and a reaction path model describing the diffusion process. A major consideration in the design of a TLP bonding process is the possibility that undesired crystallographic phases will form in the vicinity of the joint, causing unacceptable weakness. Use of the

model enables a designer to analyze how the formation of such undesired phases will be affected by the bonding foil composition and the thermal cycle to which the assembly is exposed, and thus to design a process to avoid formation of the undesirable detrimental phase.

Application of the model has been demonstrated for a simple Ni-based alloy with a bonding foil containing boron. Application to a more complex superalloy system will require incorporation of additional thermodynamic data. With successful application of TLP, industry will be able to create stronger, more complex part geometries enabling higher efficiency engines.

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POLYMER CHAIN MOTION

The first experiments on the nation's only neutron spin echo (NSE) spectrometer recently have been performed at the NIST Center for Neutron Research (NCNR). This cold neutron spectrometer allows measurements of key dynamic process in macromolecular systems essential to researchers in polymer, biomedical, and colloid science. The instrument covers a combination of time—(0.01 ns to 100 ns) and length-scales (0.2 nm to 20 nm) previously inaccessible in the United States. Unique measurements of slow dynamics in other areas of materials and chemical engineering—including, for example, giant magnetoresistance materials and supercritical fluids—are also expected. The measurement of dynamic processes out to 100 ns is 1000 times longer than previous U.S. capabilities.

This new instrument was developed in partnership with a private company and a research institution in Germany. Work on the spin echo spectrometer is expected to allow more realistic models of why and how molecules move. Thus scientists will be able to better predict and improve macromolecular properties. A general call for experiment proposals from the research community will be issued at the end of 1999.

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NIST DATABASE ON COMPOSITE REINFORCEMENTS NOW AVAILABLE ON WWW

A NIST database for composite reinforcements is now available on the World Wide Web. A critical manufacturing variable of reinforcements used in structural composites is their permeability, which is the ability of polymeric resins to flow through their porous structures. The database was developed to report permeability data from NIST measurements. Companies in the

automotive and other industries have been purchasing the database since it was released in 1998 in disk format and they use the data in process design activities. The availability of the database on the World Wide Web will improve industry access as well as provide the opportunity for expansion through additional data from external laboratories.

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NIST DEVELOPS A NEW MAGNETIC RESONANCE SPECTROMETER BASED ON A MICROMECHANICAL CALORIMETER SENSOR FOR MEASUREMENTS OF THIN-FILM MAGNETIC SAMPLES

Work at NIST on an atomic scale magnetism has led to the development of a new type of ferromagnetic (FMR) resonance spectrometer. The instrument is a result of ongoing research that focuses on new types of scanned probed microscopes (SPMs) for high-resolution imaging of nanometer scale magnetism. In particular, the research aims to develop SPM technology that combines atomic force microscopy with the essential features of magnetic resonance imaging (MRI).

The project responds to the need to develop instrumentation for nanometer scale microscopes and magnetometers for metrology of disk drive components. Currently, the data storage industry is producing thin film recording heads with reader and writer dimensions below 100 nm. Recorded bits on hard disk media have 60 nm lengths and 1 mm widths, and there is a substantial economic pressure to reduce these dimensions with the growing demand for higher density digital data storage devices.

The FMR spectroscopy probe is based on a calorimeter sensor. The sensor is an atomic force microscope (AFM) cantilever coated with a ferromagnetic thin film that serves as a bimaterial thermal sensor to measure absorption of microwaves. Spectra show a peak in the cantilever deflection as a function of applied magnetic field corresponding to a peak in the absorbed microwave power that occurs under FMR conditions for the ferromagnetic film. The saturation magnetization M_{eff} , and the damping factor α , determined from the FMR microwave absorption spectra for Co, NiFe, and Ni thin films correlate well with conventional FMR spectra taken with a tuned cavity spectrometer. The instrument can detect magnetic moments as small as $1.3 \times 10^{-12} \text{ A} \cdot \text{m}^2$ ($1.3 \times 10^{-9} \text{ emu}$) with prospects for sensitivity improvements to the $1 \times 10^{-16} \text{ A} \cdot \text{m}^2$ ($1 \times 10^{-12} \text{ emu}$) level.

The technique provides a potentially superior way to make quantitative measurements of the saturation

magnetization of thin-film samples with very small total magnetic moments. The Brownian motion of the cantilever sensor fundamentally limits its ultimate sensitivity—at room temperature it should be possible to measure 1 pW. This corresponds to the FMR power absorbed by a 30 nm thick magnetic sample with an area of $2.6 \times 10^{-16} \text{ m}^2$ (16 nm \times 16 nm). In the future, the group plans to combine microtorque magnetometry with FMR calorimeter spectroscopy in one apparatus. In this way they will be able to perform M - H loops on thin-film samples and calibrate the saturation magnetization directly with FMR.

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NIST TAKES LEAD ON VIDEO QUALITY ANALYSIS

NIST is helping to conduct a multilaboratory, multinational examination of objective methods for the measurement of video quality through the Video Quality Experts Group (VQEG), a joint working party of the International Telecommunications Union (ITU). Traditionally, subjective measurement studies are used in the television industry for evaluation of video systems, however such methods involve the assembly of groups of viewers to evaluate carefully selected video sequences displayed on special equipment and under controlled conditions. Such tests are costly and impractical for the frequent, or even continuous “in-service” measurement of video quality. Accordingly, the VQEG has undertaken a study of proposed computational models that mimic subjective tests. The study consisted of assembling appropriate source material, rating that material using the 10 proposed objective models, and analyzing the correlation of the model scores to previously determined subjective scores. NIST, as an impartial participant, was responsible for the study logistics and data analysis, preparing a report that was presented at the latest VQEG meeting in the Netherlands. The most significant outcome of the testing was the unexpectedly poor correlation of all objective measures with the subjective scores. The group decided that the model proponents would improve their models based on the information derived from this test and then an additional round of testing would be conducted.

A constrained monotonic cubic fitting function formulated and implemented by NIST proved to be exceptionally useful for the analysis. The objective test plan had recognized that non-linearities were likely to occur in the data and specified that prior to correlation, each objective data set could be transformed using either a four-parameter logistic function or a cubic

polynomial, provided that the cubic was constrained to monotonicity.

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POWER CALIBRATION SERVICE FOR 2.4 mm COAXIAL CONNECTORS

NIST has established a new calibration service for 2.4 mm coaxial power standards. The service covers a frequency band of 0.05 GHz to 50 GHz. The new calibration service addresses an industry need for power measurements in 2.4 mm coaxial line (0.05 GHz to 50 GHz) that are traceable to NIST. Previously industry traceability was achieved through adapters and multiple waveguide and coaxial power standards. Making measurements in this fashion not only degrades the accuracy but is also a laborious time-consuming process that involves measurements in four different connector types.

The 2.4 mm calibration service is based on a new type of detector specifically developed for calorimetric measurements. The detector is unique in that it is constructed using semiconductor fabrication techniques and the microwave power is measured using a dc substitution method. NIST collaborated with a commercial company in the development and testing of the 2.4 mm detector. A 2.4 mm microcalorimeter, which measures the effective efficiency of the 2.4 mm detectors also was designed, built, and evaluated. The new detectors are calibrated in the microcalorimeter and then are used as transfer standards to calibrate other devices.

Currently, industry uses either thermoelectric or diode detectors for 2.4 mm power measurements. These detectors cannot be measured in the microcalorimeter. In order to transfer the measurement services to industry, two automated direct comparison transfer systems were developed and constructed to calibrate 2.4 mm power meters and thermoelectric electric and diode power meters. These systems also can calibrate power sensors in other connector types such as Type N and 3.5 mm. A typical expanded (2σ) uncertainty in effective efficiency for the direct comparison system varies from 0.005 at 50 MHz to 0.023 at 50 GHz.

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EXPANDED WR-15 NOISE-TEMPERATURE MEASUREMENT SERVICE REOPENED

NIST has reopened its measurement service for the noise temperature of WR-15 waveguide noise sources for the frequency range 50 GHz to 65 GHz. The service

originally covered only 55 GHz to 64.5 GHz, but it was closed about 5 years ago because of concerns about the repeatability of the measurements and the histories of the check standards. To recertify the system, critical system checks were performed, the software for the six-port reflectometer was improved, the uncertainty analysis was checked and updated, and the check standards were remeasured and compared to previous results. Typical expanded uncertainties (coverage factor $k = 2$) for the revived service are expected to be about 1.9 % for noise temperatures of 5000 K to about 12 000 K. The WR-15 band extends from 50 GHz to 75 GHz. Principal applications are cross links between or among satellites around 60 GHz and short-range terrestrial wireless local area networks.

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SWITCHING IN SUB-MICROMETER DEVICES ON SUB-NANOSECOND TIME SCALES

NIST researchers completed a study of high-speed switching in 0.5 μm to 0.8 μm wide “spin valves.” These devices are similar to those being developed for “giant magnetoresistive” (GMR) read heads and magnetic random access memory (MRAM) elements for data storage. The devices were repeatedly switched with pulses whose widths ranged from 0.2 ns to 2 ns.

While the low-frequency characterization showed that the devices were bistable, many of the devices actually exhibited long-lived metastable states when driven by fast magnetic field pulses. Micromagnetic simulations indicate that the devices should be reversing by domain wall motion for the low amplitude pulses and by magnetization rotation for the large field pulses. The simulations, at present, do not predict the existence of long-lived metastable states or an observed oscillation of the switching probability.

The data suggest that there are given field ranges where different reversal mechanisms are efficiently driven. If the system is overdriven, it can get stuck in a metastable state accessible only by the large transient energy that is available during a high-speed switch. This work is one of the first to analyze the details of dynamical switching in sub-micrometer devices on sub-nanosecond time scales. The results are important for the development of MRAM, where reproducible switching of 100 billion sub-micrometer elements will be required, and magnetic read heads, where the switching studies provide a much more rigorous test of the accuracy of micromagnetic simulations.

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FIRST OBSERVATION OF TRANSIENT SPIN WAVES IN MAGNETIC FILMS

NIST has an active program to measure the speed of magnetic switching for application to problems in data storage. Using a new technique of vectorial second-harmonic magneto-optic Kerr effect, NIST scientists detected the transient generation of spin waves during magnetic field step excitations in Permalloy Ni-Fe films.

The effect manifests itself as a 50 % reduction in average magnetization during the first few nano-seconds of dynamical magnetization response. This is the first time that experimental measurements have shown that coherent magnetization response to an applied field pulse can result in efficient spin wave generation.

A key aspect of the experiment is creating in the sample a highly “rippled” state through the application of a bias field orthogonal to the preferred anisotropy axis. When the bias field is equal to the anisotropy field, the magnetization falls into a relaxed state that is highly susceptible to spatial variations in the anisotropy, resulting in magnetization ripple. The ripple state acts to nucleate the spin waves during the dynamical response to an applied field pulse, much as vortex generators on the leading edges of commercial aircraft wings induce turbulent airflow along the wing surface, preventing stall at low air velocities.

This discovery will lead to further understanding of the fundamental limits of high-speed switching in data storage devices. Further work will address how to control spin wave generation in response to the application of pulsed magnetic fields. A paper has been submitted to Physical Review Letters.

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NIST RELEASES INTERACTIVE NIST CGM TEST SUITE

NIST recently released the NIST Computer Graphics Metafile (CGM) Test Suite, which is available in an interactive format from the NIST CGM web site <http://www.itl.nist.gov/div897/ctg/cgm.htm>. In the Air Transport Association (ATA) CGM Certification Program, ATA Recognized Laboratories use the CGM Test Suite to determine conformance to the ATA Specification 2100. The updated test suite utilizes the Extensible Markup Language (XML), the Document Object Model (DOM), and JavaScript to create an interactive environment allowing users to control the access and view of the test suite. The interactive test suite can be queried for specific versions, category, or by individual file.

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NIST'S LINE SCALE INTERFEROMETER MEASUREMENT ASSURANCE NOTED

The "International Meter bar" S.N. 12924 was on loan from the Bureau International des Poids et Mesures (BIPM) for 2 years, and extensive measurements were conducted with NIST's Line Scale Interferometer (LSI). This bar was used from 1975 to 1988 for the round robin measurements conducted by BIPM among 12 national laboratories around the world, including NIST. At that time, the NIST measured value was within 30 nm of the mean of the international values including BIPM's values. The last time the bar was measured by BIPM was in June 1992, and the correction to the nominal 1 m was +823 nm. If that value is used as the reference for NIST's recent measurement, the measured value was within 13 nm to the BIPM value, or +810 nm. The BIPM's value has a great importance, because their value is the average of three different methods used to determine the bar's length.

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NIST TAKES DELIVERY OF XCALIBIR

NIST has completed installation of the X-Ray Optics Calibration Interferometer (XCALIBIR). XCALIBIR is a general-purpose 300 mm aperture interferometer for measuring surface figure error of precision optics with a measurement capability target of 0.25 nm standard uncertainty for flats, spheres, and mild aspheres. The optical table for the instrument, a 16 metric ton slab of granite, was delivered in July, followed by the final stages of laboratory construction. The interferometer is housed in an environment-controlled enclosure, and preliminary evaluations show temperature stability as good as 0.01 °C. The interferometer itself was installed during the months of August and September.

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MAGNETIC FIELD CONTROL OF COLD ATOMS

Researchers at NIST have constructed a model to explain the response of a pair of cold, trapped atoms to a time-dependent magnetic field. This is important because variable magnetic fields offer a means to manipulate the interactions between atoms in this unique environment. These interactions play a crucial role in Bose-Einstein condensation (BEC), a phase transition which occurs due to quantum statistics when a dilute gas of bosonic atoms approach near zero temperature and all the atoms occupy a single quantum state. BEC provides a source of coherent matter for a

variety of applications in metrology and fundamental physics.

The stability and dynamics of a condensate depends on whether the effective interactions between the atoms comprising it are attractive or repulsive. It was proposed some time ago that magnetically tunable resonant scattering states of the atom pair could be used to vary these effective interactions over a wide range. The effect was demonstrated recently on a sodium atom condensate at a U.S. university but was accompanied by a large loss of atoms when the field was tuned near the resonance condition. The NIST researchers constructed a highly quantitative model for calculating the properties of two colliding sodium atoms in a magnetic field. The model is an extension of one previously constructed from precise spectroscopic data obtained at NIST. The model predicts the magnetic fields for which such resonance tuning occurs.

By introducing the effect of a time-varying magnetic field into the model, the NIST group found that such a field could cause large changes in the number condensate atoms. The field tunes the energy of a special resonance state of the atom pair so that it is nearly the same as the energy of two separated atoms. This resonance state is one where the two colliding atoms are temporarily bound tightly together as a diatomic molecule before they separate again. If the time-varying magnetic field raises the energy of the resonance state, the resonant scattering process can convert initially cold atoms to hot atoms. On the other hand, if the time-varying field lowers the energy of the resonance state, unbound atoms can be converted to cold diatomic molecules. In either case, atoms are rapidly lost from the condensate. Although such a mechanism is harmful to a condensate, magnetic tuning of cold atom scattering may find applications in cold molecule production or even in novel forms of quantum information processing. CONTACT: Paul Julienne, (301) 975-2956; paul.julienne@nist.gov.

CHROMIUM ATOMS TRAPPED

Building on expertise developed over the past few years on laser manipulation of chromium atoms, researchers at NIST recently have demonstrated, for the first time, the cooling and trapping of chromium atoms in a magneto-optical trap. Using laser light tuned to the ${}^7S_3-{}^7P_4$ Cr atomic transition at 425 nm, they were able to cool and collect over 10^6 atoms in a sub-millimeter sized cloud. Because Cr has an intermediate metastable 5D level, extra care was needed to make the cooling and trapping effective. Two extra laser frequencies, generated by laser diodes at 654 nm and 663 nm, had to be introduced and locked on the transition to pump atoms

back into the cooling process. Once the atoms were trapped, observations of the trap lifetime revealed interesting results: non-exponential, density-dependent trap loss was seen, indicating a surprisingly high level of excited-state collisions. Applications of this work include forming a highly coherent source of atoms for atom-optically controlled nanofabrication, generating a precursor to creating a quantum degenerate gas in a system with either fermionic (^{53}Cr) or bosonic (^{52}Cr) particles, or providing a new arena for studying ultracold collisions.

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OPTICAL FREQUENCY MEASUREMENT USING MODELOCKED LASERS

The measurement of frequencies in the optical domain is a challenging problem due both to the large difference between optical frequencies and the 9.192 GHz cesium standard and to the difficulty in comparing two optical sources to one another. Recently, several groups around the world began exploiting the regularly spaced comb of frequencies produced by a modelocked laser to produce a “ruler” of optical frequencies.

Researchers at NIST have spectrally broadened (in optical fiber) the output from a Ti:sapphire laser that produces 10 fs pulses. The resulting comb was used to measure the 104 THz gap between a single frequency Ti:sapphire laser locked to rubidium and a Nd:YAG laser locked to iodine with a relative uncertainty of 2×10^{-11} . The measurements using a modelocked laser were significantly simpler than those performed previously.

Techniques using modelocked lasers are under development that will allow the measurement of optical frequencies directly from a cesium clock.

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NEW SI UNIT ADDED

The 21st General Conference on Weights and Measures (CGPM, *Conférence Générale des Poids et Mesures*), which met in Paris in October 1999, added a new derived unit with a special name and symbol to the International System of Units (SI, *Système International d'Unités*), the modern metric system. The unit is the katal, symbol kat.

These are, respectively, the special name and symbol for the coherent, SI derived unit mole per second and its symbol mol/s for use in the fields of medicine and biochemistry to express values of enzyme catalytic

activity in terms of the rate of conversion of a specified indicator reaction. Although the CGPM recognizes that the proliferation of special names and symbols for derived units could undermine the universality and ease of understanding of the SI, it also recognizes the need to make exceptions in matters related to human health and safety. In the case of the katal, a non-SI unit called “unit,” symbol U, equal to $\mu\text{mol}/\text{min}$, which is not coherent with the SI, has been used widely in medicine and biochemistry for the past 35 years for expressing values of enzyme catalytic activity. Furthermore, the lack of a special name and symbol for the coherent SI derived unit mole per second has led to results of clinical measurements being given in various local units, even though the use of SI units in medicine and clinical chemistry is strongly recommended by the international unions in these fields.

The CGPM is one the international bodies established by the Meter Convention (Convention du Mètre), which was signed in Paris in 1875 by 17 countries, including the United States (nearly 50 countries are now members of the convention). The SI was established by the 11th CGPM in 1960; one of the responsibilities of the CGPM is to ensure that the SI is disseminated widely and that it reflects the latest advances in science and technology. CONTACT: Barry N. Taylor, (301) 975-4220; barry.taylor@nist.gov.

ASTROPHYSICISTS BRING NEW HIGH-RESOLUTION, BROAD-BAND X-RAY DETECTOR TO THE NIST ELECTRON BEAM ION TRAP FACILITY

X-ray detection is an essential tool for the study of highly charged ions, whether in the laboratory or in astrophysical environments. To date researchers typically have had two types of x-ray detectors to choose from: solid-state detectors and x-ray crystal spectrometers. Solid-state detectors are very efficient and have broad spectral bandwidth, but suffer from poor energy resolution. Crystal spectrometers offer unprecedented resolution, but they have poor efficiency and have limited spectral bandwidth. Recent advances in single photon calorimetry have produced x-ray detectors, which for the first time combine the strengths of these two devices. The resulting x-ray microcalorimeters have nearly 100 % detector efficiency, a broad energy bandwidth that allows the simultaneous observation of photons from a few hundred eV to tens of keV, and an energy resolution better than 5 eV, approaching that of crystal spectrometers.

Recently, a group of scientists from a U.S. university and an Italian observatory brought a microcalorimeter to the NIST electron beam ion trap (EBIT) facility to

study the x rays emitted by highly charged ions. Originally developed for space bound x-ray observatories, the microcalorimeter is ideal for studying the photons emitted by highly charged ions in an EBIT. The EBIT, in turn, provides a well controlled environment for “laboratory astrophysics,” allowing the study of energetic atomic processes occurring in many astrophysical environments and in a wide variety of Earth-based plasmas such as tokamaks.

In a preliminary study, the scientists measured the x-ray spectra from highly charged nitrogen, oxygen, neon, argon, and krypton, with photon energies that differ by more than a factor of 10. The teams made preliminary measurements of the electron density dependence of the line ratios in helium-like oxygen, a system that has potential use as an electron diagnostic in land-based plasmas and in the solar corona. Future experiments will continue to provide atomic data of interest for plasmas and will be extended to include the study of highly charged ion/surface interactions.

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MAPPING PHASE DYNAMICS OF CONDUCTING POLYMER BLEND FILMS WITH NEAR-FIELD SCANNING OPTICAL MICROSCOPY

Conventional methods to fabricate small structures and patterns (e.g., electronic devices, and chips for analyzing biological molecules such as DNA and proteins) mainly employ high-resolution lithographic techniques, which are costly. More recently, innovative techniques are being investigated that involve the control and use of the “molecular microenvironment” in polymer blends for generating submicron patterns and devices. Self-assembly of macromolecules using phase separation in polymer blends is one technique. Some aspects of phase separation in these multicomponent polymer systems have been studied by conventional optical techniques. However, these techniques have resolution that is diffraction limited so there is still little information available on the nanoscale electric, mechanical, or optical properties of phase separated films.

NIST researchers, using NIST-built near-field scanning optical microscopes (NSOMs), have completed a study mapping the phase dynamics of polymer blend films in which one of the polymer components is conducting. NSOM uses the near-field interaction of light from a sharp fiber-optic probe with a sample of interest to image surfaces at a resolution beyond the diffraction limit of conventional optics. Simultaneous topography,

transmission, and fluorescence NSOM images taken on these polymer samples at different annealing stages revealed many previously unobserved details of phase separation that are relevant for the manufacture of optoelectronic and organic-electronic devices. The results showed that conducting polymer molecules in the blend are mobile even under the glass transition temperature of the conducting component alone. High-resolution NSOM measurements revealed many other details of restructuring dynamics during the annealing process. Further investigation in this line of research will greatly benefit the industry of polymer processing and device fabrication.

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ICFRE3 FIRE CONFERENCE A SUCCESS

NIST and the International Association of Fire Safety Science hosted 129 delegates from 145 countries at the Third International Conference on Fire Safety and Engineering in Chicago. The bi-annual conference, held this year in October, provides a venue for interchange between practicing engineers and fire researchers. Approximately two-thirds of the presentation during the four day conference featured results that utilized NIST computer fire models and/or data from the Web site (fire.nist.gov). This web site has become so well known by the fire research and engineering community that it was acknowledged to be the first source looked to for information by this audience. The conference proceedings are available from SFPE (www.sfpe.org).

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SECOND WORKSHOP HELD ON HEAT FLUX TRANSDUCER CALIBRATION

A second workshop on heat flux transducer calibration was held recently in Gaithersburg. Questions were posed to ascertain how the heat flux measurement needs of industry had changed since the first workshop held in 1995, what the implications were for the transducer manufacturers and calibration services, and what would be the best way for NIST to interact with manufacturers, university researchers, and government laboratories.

More than 40 attendees were drawn from U.S. industry, academia, and government organizations. Representatives of a spectrum of industries that rely upon accurate measurement of heat flux described their applications and calibration needs. The effort being undertaken in Europe to standardize heat flux calibration methods for fire safety standards was discussed.

Discussions involving all the workshop participants were organized around special considerations and calibration needs of heat flux measurement devices for three different situations: (1) convection dominated, moderate temperature, quasi-steady environments with size and cost as major constraints; (2) convection dominated, high temperature, transient environments with small size and accuracy highly desirable; (3) radiation dominated with high flux levels, with applications constrained by government regulations. A summary of the workshop is available in NISTIR 6424.

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CIRMS HOLDS EIGHTH ANNUAL MEETING AT NIST

The Council on Ionizing Radiation Measurements and Standards (CIRMS) held its eighth annual meeting at NIST in October 1999. The organization represents thousands of users of ionizing radiation and radioactive sources engaged in industrial radiation processing and sterilization, medical radiation diagnostics and therapy, nuclear power generation, worker radiation protection, and environmental measurement programs. CIRMS provides a forum for discussing ionizing radiation issues; identifying, defining, and prioritizing needed work; disseminating information on standards; and organizing workshops and meetings to advance ionizing radiation technology.

More than 160 participants from industry, federal and state agencies, and national laboratories attended the meeting and presented lectures and posters in four parallel workshops that addressed the specialties of the four CIRMS subcommittees: Medical Applications, Occupational Radiation Protection, Public and Environmental Radiation Protection, and Industrial Applications and Materials Effects. Participants seem to prefer the parallel focus-workshop format for the meeting, as there was a 50 % increase in attendance over last year. The main issues in medical applications were needs for standards and methods for radioactive sources used in radiation therapy. The environmental subcommittee focused on a single topic: performance evaluation materials for use in quality control programs for radioactivity measurements. The occupational radiation protection subcommittee dealt with facilities, measurements, and standards for neutrons. This topic was particularly timely in light of the recent criticality accident in Japan. The materials effects subcommittee

this year concentrated on radiation effects on materials for space applications.

The annual gathering of the radiation user community is a key element of the planning processes for state and federal agencies. CIRMS encourages one-on-one interactions, open group discussions, and prioritization of the national measurements and standards needs through consensus. These collective efforts help industry and government to solve short-term problems more effectively and to prepare adequately for the future needs of emerging radiation technologies.

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45TH ANNUAL CONFERENCE ON BIOASSAY, ANALYTICAL, AND ENVIRONMENTAL RADIOCHEMISTRY

NIST organized and co-sponsored the 45th Annual BAER conference in October 1999 with 15 industry sponsors. Over the past 45 years, the Annual Conference on Bioassay, Analytical, and Environmental Radiochemistry (BAER) has been a forum where professionals can discuss works-in-progress and common problems encountered during the development of state-of-the-art methods and procedures for detecting, measuring, and analyzing radioactive materials found in a large variety of environmental and biological media. The unique objective of the BAER Conference is to provide a test crucible for pre-publication ideas, assumptions, and approaches. The participants engage in intense interactions to share new discoveries, challenge axioms, gain insights, seek solutions to technical problems and barriers, and examine the impact of new policies and regulations. Two hundred and twenty participants attended the conference from universities; federal and state national and defense laboratories; nuclear power stations; instrument manufacturing companies; commercial service laboratories; geoscience institutes; and the International Atomic Energy Agency. The technical contributions highlighted new advances that were presented in 45 oral presentations, 33 poster presentations, 14 topical and vendor workshops, and by 25 exhibiting companies.

Selected highlights of the conference included new developments in the areas of oceanographic radionuclide speciation, characterization of single particle hot spots and virtual gamma-ray calibrations for complex extended volume reference and biological sources. CONTACT: Kenneth G.W. Inn, (301) 975-5541; kenneth.inn@nist.gov.

NIST HOSTS WORKSHOP ON LUMINESCENCE STANDARDS FOR CHEMICAL ANALYSIS

About 35 scientists from the clinical and biotechnology communities, instrument and standards vendors, federal agencies, academia, and five national metrology institutes (NMIs) attended a workshop on standards for fluorescence-based chemical analyses jointly sponsored by NIST in September 1999. The goals of the workshop were to assess the importance and needs for fluorescence standards as well as to appraise new materials and technologies that might be candidates for such standards.

Luminescence measurements have become the methods of choice for new clinical and biochemical analyses due to their extraordinary selectivity and high sensitivity. Reporter gene and green fluorescent protein (GFP) technologies now make it possible to label specific bio-chemical entities with high specificity and then to detect the marked species at near single molecule levels in extremely heterogeneous environments such as living cells. Luminescence measurements provide the analytical grease for many current fast track chemical technologies—today's genetic engineering and high-throughput screening for drug discovery could not be happening without luminescence measurements. For many years, luminescence has been a qualitative screening technique—"does it or doesn't it glow?" However, now that many screening technologies have been automated and new leads are easy to generate, the question has changed to assess the quality of new leads—"if it glows, how much does it glow?" To provide this sort of answer, standards are needed to calibrate luminescence measurement instruments and to validate the analytical methods themselves. In the highly regulated pharmaceutical and clinical industries, such standards are needed to satisfy the quality assurance and validation requirements of regulatory agencies. The increasing importance of drug and food testing is making the needs for such standards increasingly important for trade and sparking collaborations and future intercomparison activities among the NMIs.

The workshop agenda and abstracts can be found at <http://www.cstl.nist.gov/nist839/839.04/index.html> (click "Agenda").

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WORKSHOP HELD ON VALIDATION OF MULTIPHASE COMBUSTION MODELS

NIST sponsored a 1 day workshop in Gaithersburg in June 1999, to address benchmark experimental needs of industry for input and validation of multiphase com-

bustion models. Thirty-five people attended the workshop, representing industry (chemical, power, energy, and software developers), other government agencies, and academia.

All attendees were provided the alpha version of a benchmark database developed at NIST and published earlier this year (NISTIR 6286). The focus of the workshop was to familiarize the participants with NIST's reference spray combustion facility, assess the information currently provided in the database, review preliminary findings from simulations of the NIST facility, allow modelers to express their data needs, and provide an opportunity for feedback concerning future measurements.

An overview of the benchmark experimental database for the baseline case was given by several NIST personnel. Four invited speakers, involved in the development of spray combustion models for industry, described their efforts to use the benchmark data.

Discussions focused on the industry needs and what should be the next phase of the NIST program. A wide range of needs were discussed with some topics prioritized. Follow-up discussions are currently under way with the participants to determine the most critical industrial needs and how NIST can provide the greatest impact.

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WORKSHOP HELD ON SCANNING PROBE MICROSCOPY OF SOFT MATERIALS

Atomic force microscopists met at NIST for a Workshop on Scanning Probe Microscopy of Soft Materials in August 1999. "Soft" materials include biological molecules and assemblies, and the talks covered diverse topics such as the effect of infectious agents on live cells, polymer phase separation, the binding of water to lipid headgroups, and engineered hybrid cell membranes. Presentations were given by researchers from NIST, National Institutes of Health, Naval Research Laboratory, and a private company. Reports on fundamental studies such as the use of scanning probe microscopy to determine the phase behavior of alkanethiols on gold, and measuring friction at different length scales, led to discussions of the promises and pitfalls of using scanning probe microscopy on soft samples, and how to improve the information gained. An improved understanding of phase imaging—the measurement of the phase lag between the drive signal and response during tapping or modulating imaging—was singled out as a particularly important technique for these materials. The workshop was capped with a demonstration by the private company of their magnetic

AC (MAC) mode atomic force microscope a new technology that enhances the ability to image soft materials under fluids. Nearly 50 people from industry, government labs, and academia attended.

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lished in an SP-260 series document, will be valuable to producers of high-purity fine platinum wire elements as a benchmark for these properties.

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Standard Reference Materials

NEW PLATINUM SRM THERMOMETER

The International Temperature Scale of 1990 (ITS-90) is defined over the range 13.8033 K to 1234.93 K through the use of standard platinum resistance thermometers (SPRTs). The scale is disseminated from NIST throughout this range through calibrations of customer SPRTs using any one of 11 ITS-90 defined sub-ranges. Heretofore, a customer requiring a NIST calibration on one of the lowest sub-ranges, those spanning temperatures below 83.8 K, would typically invest some \$10 000 or more in the combined costs of a suitable capsule SPRT and the calibration fee. In addition, customers would sometimes be required to wait up to 6 months before a batch calibration run could be scheduled. The combination of this relatively high initial capital investment and the relatively long lead-time had discouraged some private firms from using these types of standards to help maintain their quality control.

NIST has now addressed these problems through the preparation of a set of Standard Reference Material (SRM) SPRTs. The SRM 1750 is a batch of 20 SPRTs, built to NIST specifications, which have been calibrated in two back-to-back batches over the ITS-90 sub-range of 13.8033 K to 429.7485 K. The economy of scale produced by fabricating, calibrating, and certifying all 20 SPRTs in two batches of 10 devices each has produced a net savings that will be passed on to the end users of the SRM 1750, the projected unit cost of which will be about \$6000. In addition, the individual units will be available as an “off-the-shelf” item, for immediate delivery for an end-user.

As a whole, the data produced for the SRM 1750 has illustrated the exceptional uniformity in purity and annealing that is possible today in the fabrication of fine-wire platinum elements. The high degree of correlation found in the resistance-ratio data throughout the temperature range studied is a characteristic of a high sample-to-sample uniformity. These data, to be pub-