NISTIR 4621

Electronics and Electrical Engineering Laboratory

Technical Progress Bulletin

Covering Laboratory Programs, January to March 1991, with 1991 EEEL Events Calendar

U.S. DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
Electronics and Electrical Engineering Laboratory
Semiconductor Electronics Division
Gaithersburg, MD 20899

July 1991

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U.S. DEPARTMENT OF COMMERCE
Robert A. Mosbacher, Secretary
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
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INTRODUCTION TO JULY 1991 ISSUE OF THE EEEL TECHNICAL PROGRESS BULLETIN

This is the thirty-fourth issue of a quarterly publication providing information on the technical work of the National Institute of Standards and Technology Electronics and Electrical Engineering Laboratory (EEEL) (until February 1991, the Center for Electronics and Electrical Engineering). This issue of the EEEL Technical Progress Bulletin covers the first quarter of calendar year 1991.

Organization of Bulletin: This issue contains abstracts for all relevant papers released for publication by NIST in the quarter and citations and abstracts for such papers published in the quarter. Entries are arranged by technical topic as identified in the Table of Contents and alphabetically by first author under each subheading within each topic. Unpublished papers appear under the subheading "Released for Publication." Papers published in the quarter appear under the subheading "Recently Published." Following each abstract is the name and telephone number of the individual to contact for more information on the topic (usually the first author). This issue also includes a calendar of Laboratory conferences and workshops planned for calendar year 1991 and a list of sponsors of the work.

Electronics and Electrical Engineering Laboratory: EEEL programs provide national reference standards, measurement methods, supporting theory and data, and traceability to national standards. The metrological products of these programs aid economic growth by promoting equity and efficiency in the marketplace, by removing metrological barriers to improved productivity and innovation, by increasing U.S. competitiveness in international markets through facilitation of compliance with international agreements, and by providing technical bases for the development of voluntary standards for domestic and international trade. These metrological products also aid in the development of rational regulatory policy and promote efficient functioning of technical programs of the Government.

The work of the Laboratory is conducted by four technical research Divisions: the Semiconductor Electronics and the Electricity Divisions in Gaithersburg, Md., and the Electromagnetic Fields and Electromagnetic Technology Divisions in Boulder, Colo. In 1991, the Office of Law Enforcement Standards, formerly the Law Enforcement Standards Laboratory, was transferred to EEEL. This Office conducts research and provides technical services to the U.S. Department of Justice, State and local governments, and other agencies in support of law enforcement activities. In addition, the Office of Microelectronics Programs (OMP) was established in EEEL to coordinate the growing number of semiconductor-related research activities at NIST. Reports of work funded through the OMP are included under the heading "Semiconductor Microelectronics."

Key contacts in the Laboratory are given on the back cover; readers are encouraged to contact any of these individuals for further information. To request a subscription or for more information on the Bulletin, write to EEEL Technical Progress Bulletin, National Institute of Standards and Technology, Metrology Building, Room B-358, Gaithersburg, MD 20899 or call (301) 975-2220.

Laboratory Sponsors: The Laboratory Programs are sponsored by the National Institute of Standards and Technology and a number of other organizations, in both the Federal and private sectors; these are identified on page 26.

Note on Publication Lists: Publication lists covering the work of each division are guides to earlier as well as recent work. These lists are revised and reissued on an approximately annual basis and are available from the originating division. The current set is identified in the Additional Information section, page 24.

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KEY CONTACTS IN LABORATORY, LABORATORY ORGANIZATION .... back cover

FUNDAMENTAL ELECTRICAL MEASUREMENTS

Released for Publication

Tew, W.L., Olsen, P.T., and Williams, E.R., **The Use of Magnetic Forces in the Alignment of a Radial Field Superconducting Magnet**, to be published in the Proceedings of the 5th Joint Magnetism and Magnetic Materials — Intermag Conference, Pittsburgh, Pennsylvania, June 18-21, 1991.

A detailed description of the forces between a special radial field superconducting magnet and a suspended current-carrying coil is given. A primary vertical force is used directly in the determination of the SI watt. In addition, small nonvertical forces and torques are monitored to determine the magnetic alignment stability. Results are compared with calculations.
[Contact: Weston L. Tew, (301) 975-6552]

SEMICONDUCTOR MICROELECTRONICS

Silicon Materials

Released for Publication

Thurber, W.R., Lowney, J.R., Larrabee, R.D., and Ehrstein, J.R., **AC Impedance Method for High-Resistivity Measurements of Silicon.**

An ac impedance method for measuring the average bulk resistivity of ingots and slices of high-resistivity silicon is presented. Easily removable contacts, such as silver paint, are applied to the end faces of the sample, and the complex impedance of the resulting capacitive sandwich is measured as a function of frequency. The resistivity can be calculated from the frequency of the negative peak in the imaginary part of the impedance and from the absolute values of the real and imaginary parts at that frequency. The spectroscopic nature of the method gives an inherent separation of contact, surface region, and bulk effects as the respective responses usually occur at widely different frequencies. In addition to its intended application for measuring bulk resistivity, the method is useful for determining the quality of applied contacts and the effect of surface treatments which result in a significant depletion layer. Plots and the required data can be obtained very quickly with an appropriate microprocessor-based impedance analyzer. Extensive measurements of high-resistivity silicon were made to compare the method with the dc resistance, van der Pauw, and four-probe techniques. The agreement was within 5% for slices and ingot sections greater than 0.1 cm in length and resistivity above 5 kΩ·cm.
[Contact: W. Robert Thurber, (301) 975-2067]

Compound Materials

Released for Publication

Bouldin, C.E., Forman, R.A., Bell, M.I., and Donovan, E.P., **Structural Relaxation in Ion-Damaged Amorphous Germanium.**

X-ray and optical studies of ion-damaged amorphous germanium reveal a structural relaxation produced by low-temperature (200 °C) annealing. This relaxation appears to be qualitatively different from that observed previously at higher annealing temperatures (250 to 500 °C). Extended X-ray absorption fine structure (EXAFS) measurements, made using total electron yield with a sampling depth of 600 to 800 Å, indicate a sharpening of the first shell in the radial distribution, but no change in the first-shell distance or coordination number. No higher shells in the radial distribution are observed, before or after annealing, indicating that these shells remain highly disordered. Infrared reflection and Raman scattering measurements confirm that a relaxation takes place, and that there is no nucleation of microcrystals in the implanted layer within the detection limit of 1.5% volume fraction. In contrast to previous studies, the present results exhibit no evidence of a reduction in bond-angle disorder.
[Contact: David G. Seiler, (301) 975-2081]

McKeown, D.A., **XANES of Transition Metal Zinc-Blende Semiconductors: Calculation** Versus **Experimental Data and the Pre-Edge Feature**.

XANES data were collected for Zn in sphalerite, and Cu and Fe in chalcopyrite, where all three cations are in nearly identical coordination environments. The data have similar features, except near the edge, where the edge maximum decreases in amplitude, while a pre-edge feature appears and increases in amplitude from Zn to Cu to Fe. This pre-edge feature has been previously assigned to a 1s-to-3d atomic transition in the absorbing cation. XANES calculations, incorporat-

ing five shells of atoms around the absorbing cation, best match the data. The calculations show that the edge shape (sharpness of the edge maximum and the energy range of the edge jump) is due to the atomic states of the absorber, while the more rapidly varying features on the edge are due to interference effects from the arrangement of atoms surrounding the absorber. A feature near the beginning of the edge jump is observed for both Cu- and Fe-edge calculations and mimics the pre-edge feature found in the data. The results from the calculations suggest that the pre-edge feature is due to interference effects from the crystal structure and not due to atomic bound state transitions of the absorbing cation.
[Contact: David A. McKeown, (301) 975-3095]

Insulators and Interfaces

Released for Publication

Richter, M., Woicik, J.C., Pianetta, P., Miyano, K.E., Kendelewicz, T., Bouldin, C.E., Spicer, W.E., and Lindau, I., **Surface EXAFS Studies of the Si(001) 2x1-Sb Interface.**

Surface X-ray adsorption fine structure (SEXAFS) has been used to investigate the structure of Sb on the Si(001) 2 x 1 surface. The coverage of Sb which remains after annealing thick layers at 375 °C, previously reported to be one monolayer (ML), is found in this work to form a disordered overlayer with three-dimensional Sb clusters. This finding is concluded from the Sb L_3 absorption spectra which are similar for this coverage to that of bulk Sb. After a 550 °C anneal, Auger electron spectroscopy and scanning tunneling microscopy (STM) show that about one ML of Sb remains. Phase and amplitude analysis of the Sb L_3 edge SEXAFS shows that the remaining Sb atoms occupy a modified bridge site with a Si-Sb bond length of 2.63 ± 0.04 Å. The Sb atoms form dimers with a Sb-Sb bond length of 2.91 ± 0.04 Å, which is almost identical to the bulk Sb-Sb bond length of 2.90 Å. The Sb atoms lie 1.74 ± 0.06 Å above the Si(001) surface. STM confirms the dimer structure of the Sb overlayer. Low energy electron diffraction performed on vicinal single domain Si shows that these dimers form rows that run perpendicular to the Si dimer rows.
[Contact: David G. Seiler, (301) 975-2431]

Integrated Circuit Test Structures

Released for Publication

Cresswell, M.W., Gaitan, M., Allen, R.A., and Linholm, L.W., **A Modified Sliding Wire Potentiometer Test Structure for Mapping Nanometer-Level Distances**, to be published in the Proceedings of the International Conference on Microelectronic Test Structures, Kyoto, Japan, March 18-20, 1991.

This paper presents a modified voltage-dividing potentiometer test structure which overcomes a problem typical in scaling electrical test structures; it provides a correction for electrical length shortening of a resistor strip caused by the attachment of voltage taps of non-negligible width. The test structure was implemented in chrome on quartz, and measurements of displacements between 10 and 500 nm with ±12-nm random error were made using available test equipment. The enhanced precision of the measurement derives from reducing the size of the structure from previous design methods. The enhanced accuracy of the displacement measurement derives from scaling the length of the potentiometer bridge while simultaneously providing for non-scaled widths of the voltage taps. Measurements using these corrections demonstrate an improvement of up to 20% in measurement accuracy, and further improvements can be expected with optimized designs. Applications for this test structure may include: monitoring the self-registration accuracy and precision of primary pattern generator systems and monitoring level-to-level overlay in advanced wafer fabrication.
[Contact: Michael W. Cresswell, (301) 975-2072]

Jones, M.A., Roberts, J.A., Ellenwood, C.H., Cresswell, M.W., and Allen, R.A., **Test Chip for the Evaluation of Surface Diffusion Phenomena in Sputtered Aluminum Planarization Processes**, to be published in the Proceedings of the International Conference on Microelectronic Test Structures, Kyoto, Japan, March 18-20, 1991.

A test chip has been designed and fabricated to enable the evaluation of surface diffusion phenomena in sputtered aluminum planarization processes. New and unique features provide for cross-sectioning bevel angle validation for SEM inspection, multiple design rules for planarization parameter optimization, and positive feature identification for step coverage evaluation. The results presented here demonstrate

how the test chip is used to customize the deposition process variables for particular IC fabrication applications.
[Contact: Colleen H. Ellenwood, (301) 975-2236]

Troccolo, P., Mantalas, L., Allen, R. A., and Linholm, L.W., **Extending Electrical Measurements to the 0.5μm Regime**, to be published in the Proceedings of SPIE (The International Society for Optical Engineering, P.O. Box 20, Bellingham, WA 98227), Symposium on Microlithography, San Jose, California, March 3-8, 1991.

The purpose of this work was to extend the design criteria of electrical test structures to the half-micron linewidth region. At 0.5 μm, process limitations place constraints on the functionality and usefulness of electrical test structures based on conventional design criteria. In particular, small total variations from lens aberrations/distortions and proximity/corner rounding effects in the patterning of the smallest lines achievable (less than 0.5 μm) can result in structure failure. This was particularly significant when orthogonal voltage taps at minimum design geometries were used. As geometries decrease in size and control over the process and equipment tightens, the intrinsic error in conventional structures has increased as a percentage of the total measurement. The design criteria of these structures have been further modified and improved in order to address known lithographic limitations and establish a more process tolerant design. The resulting measurement precision accommodating these changes is discussed to provide the framework for achieving the highest practical performance attainable from both the test structure and the measurement system.
[Contact: Richard A. Allen, (301) 975-5026]

Recently Published

Khera, D., Linholm, L.W., Allen, R.A., Cresswell, M.W., Tyree, V.C., Hansford, W., and Pina, C., **Knowledge Verification of Machine-Learning Procedures Based on Test Structure Measurements**, Proceedings of the International Conference on Microelectronic Test Structures, Koyto, Japan, March 18-20, 1991, pp. 145-149 (1991).

This paper describes an approach for evaluating and refining the rules, based on test structure measurements, to be entered into the knowledge base of an expert system. The objective is to qualify the performance of rules determined by a machine-learning classification application with the best knowledge available from the human experts. The technique combines a machine-learning approach with the traditional heuristic-based development of an expert system. Strengths and weaknesses of the individual techniques are compared.
[Contact: Raj Khera, (301) 975-2240]

Power Devices

Released for Publication

Berning, D.W., **An Automated Reverse-Bias Second-Breakdown Transistor Tester**, to be published in the Proceedings of the Applied Power Electronics Conference and Exposition, Dallas, Texas, March 10-15, 1991.

An automated instrument is described for nondestructively generating curves for the reverse-bias, safe-operating area of transistors. A new technique for detecting second breakdown that makes automation possible is highlighted. Methods to reduce stress to the device under test are discussed, as are several other innovations that enhance automation. Measurements using the tester are described, and limitations on nondestructive testability are discussed.
[Contact: David W. Berning, (301) 975-2069]

Recently Published

Gao, G., Fan, Z., Blackburn, D.L., Unlu, M.S., Chen, J., Adomi, K., and Morkoc, H., **Uniform Junction Temperature AlGaAs/GaAs Power Heterojunction Bipolar Transistors on Silicon Substrates**, Applied Physics Letters, Vol. 58, No., 10, pp. 1068-1070 (11 March 1991).

AlGaAs/GaAs power heterojunction bipolar transistors on Si substrates exhibiting uniform junction temperature distribution are reported. Owing to a unique device design, the temperature spread across the entire device area is about 1 °C. The device exhibits a common emitter current gain of 20, a maximum collector current of 0.6 A, and a collector base junction breakdown voltage of 25 V.
[Contact: David L. Blackburn, (301) 975-2068]

Gao, G-B., Unlu, M.S., Morkoc, H., and Blackburn,

D.L., **Emitter Ballasting Resistor Design for and Current Handling Capability of AlGaAs/GaAs Power Heterojunction Bipolar Transistors,** IEEE Transactions on Electron Devices, Vol. 38, No. 2, pp. 185-196 (February 1991).

A systematic investigation of the emitter ballasting resistor for power Heterojunction Bipolar Transistors (HBTs) is presented. The current handling capability of power HBTs is found to improve with ballasting resistance. An equation for the optimal ballasting resistance is presented, where the effects of thermal conductivity of the substrate material and the temperature coefficient of the ballasting resistor are taken into account. Current levels of 400 to 800 mA/mm of emitter periphery at case temperatures of 25 to -80 °C for power AlGaAs/GaAs HBTs have been obtained using an on-chip lightly-doped GaAs emitter ballasting resistor.

Device temperature has been measured using both an infrared micro-radiometer and temperature-sensitive electrical parameters. Steady-state and transient thermal modeling were also performed. Although the measured temperature is spatially nonuniform, the modeling results show that such nonuniformities would occur for a uniform current distribution, as would be expected for an HBT with emitter ballasting resistors.
[Contact: David L. Blackburn, (301) 975-2068]

Photodetectors

Released for Publication

Geist, J., Chandler-Horowitz, D., Robinson, A.M., and James, C.R., **Numerical Modeling of Silicon Photodiodes for High-Accuracy Applications. Part I: Simulation Programs**, to be published in the Journal of Research of the National Institute of Standards and Technology.

The suitability of the semiconductor-device modeling program PC-1D for high-accuracy simulation of silicon photodiodes is discussed. A set of user interface programs optimized to support high-accuracy batch-mode operation of PC-1D for modeling the internal quantum efficiency of photodiodes is also described. The optimization includes correction for the dark current under reverse- and forward-bias conditions before calculating the quantum efficiency, and easy access to the highest numerical accuracy available from PC-1D, neither of which is conveniently available with PC-1D's standard user interface.
[Contact: Jon Geist, (301) 975-2066]

Geist, J., Kohler, R., Goebel, R., Robinson, A.M., and James, C.R., **Numerical Modeling of Silicon Photodiodes for High-Accuracy Applications. Part II: Interpreting Oxide-Bias Experiments**, to be published in the Journal of Research of the National Institute of Standards and Technology.

The semiconductor-device modeling program PC-1D and the programs that support its use in high-accuracy modeling of photodiodes, all of which were described in Part I of this paper, are used to simulate oxide-bias self-calibration experiments on three different types of silicon photodiodes. It is shown that these simulations can be used to determine photodiode characteristics, including the internal quantum efficiency for the different types of photodiodes. In the latter case, the simulations provide more accurate values than can be determined by using the conventional data reduction procedure, and an uncertainty estimated can be derived. Finally, it is shown that 0.9997 ± 0.0003 is a nominal value for the internal quantum efficiency of one type of photodiode over the 440- to 460-nm spectral region.
[Contact: Jon Geist, (301) 975-2066]

Phelan, R.J., Jr., Lehman, J.H., and Larson, D.R., **Reference Detectors for Spectral Responsivity Measurements**, to be published in the Proceedings of the 1991 Measurement Science Conference, Anaheim, California, January 31-February 1, 1991.

This paper presents a view of the need, use, design, and evaluation of detectors to be used for spectral responsivity measurements. The emphasis is on a design that is easy to use and for which the spectral responsivity can be understood and confirmed by the user.
[Contact: Robert J. Phelan, Jr., (303) 497-3696]

Released for Publication

Schafft, H.A., Baglee, D.A., and Kennedy, P.E., **Building-In Reliability: Making It Work**, to be published in the Proceedings of the International Reliability Physics Symposium, Las Vegas, Nevada, April 8-11, 1991.

Aggressive reliability and market-entry demands will require the use of a building-in approach to reliability. To adopt this approach and make it work require that very significant breaks be made from the traditional ways of improving and appraising reliability. The nature of these breaks are discussed in the context of describing the basic elements of the approach of building-in reliability and the obstacles that hinder its adoption. To help visualize how the approach can be implemented, initial steps to make the transition and some specific examples of its use are described.
[Contact: Harry A. Schafft, (301) 975-2234]

Other Semiconductor Metrology Topics

Recently Published

Parameswaran, M., Robinson, A.M., Blackburn, D.L., Gaitan, M., and Geist, J., **Micromachined Thermal Radiation Emitter from a Commercial CMOS Process** [original title: Micromachined Thermal and Visible Radiation Source Using a Commercial CMOS Process], IEEE Electron Device Letters, Vol. 12, No. 2, pp. 57-59 (February 1991).

Fabrication of a thermally isolated micromechanical structure capable of generating thermal radiation for dynamic thermal scene simulation (DTSS) is described. Complete compatibility with a commercial CMOS process is achieved through design of a novel, but acceptable, layout for implementation by the CMOS foundry using its regular process sequence. Following commercial production and delivery of the CMOS chips, a single maskless etch in an aqueous ethylenediamine-pyrocatechol mixture is performed to realize the micromechanical structures. The resulting structures are suspended plates consisting of polysilicon resistors encapsulated in the field and CVD oxides available in the CMOS process. The plates are suspended by aluminum heater leads that are also encapsulated in the field and CVD oxides. Studies of the suitability of these structures for DTSS have been initiated, and early favorable results are reported.
[Contact: Jon Geist, (301) 975-2066]

SIGNAL ACQUISITION, PROCESSING, & TRANSMISSION

DC & Low Frequency Metrology

Released for Publication

Lipe, T.E., **A Prototype Measurement Assurance Program for ac-dc Transfer Instruments**, to be published in the Proceedings of the 1991 Measurement Science Conference, Anaheim, California, January 31-February 1, 1991.

This paper describes the planning, initiation, and conclusion of a prototype Measurement Assurance Program (MAP) for ac-dc voltage transfer instruments supervised by the Electricity Division of the National Institute of Standards and Technology. The results of the MAP are presented, and future extensions to thermal current converters and high-frequency voltage standards discussed.
[Contact: Thomas Lipe, (301) 975-4251]

Waveform Metrology

Recently Published

Gans, W.L., **Dynamic Calibration of Waveform Recorders and Oscilloscopes Using Pulse Standards**, IEEE Transactions on Instrumentation and Measurement, Vol. 39, No. 6, pp. 952-957 (December 1990).

The purpose of this paper is to convince the reader of two key points. First, virtually no one calibrates oscilloscopes or waveform recorders properly and completely at present. Second, in most cases, the tools are now available to perform these complete and proper calibrations when the application requires it. After a brief introduction describing the current methods used to calibrate oscilloscopes, the problems associated with oscilloscope vertical channel bandwidth testing are discussed and illustrated. Then, a solution is described that involves using pulse signals and a NIST-developed deconvolution algorithm. Finally, an example of the calibration of a 20-GHz sampling oscilloscope is presented.

[Contact: William L. Gans, (303) 497-3538]

Souders, T.M., and Stenbakken, G.N., **Cutting the High Cost of Testing** [original title: New Solutions for the High Cost of Testing], IEEE Spectrum, Energy Outlook, Confusion and Indecision, pp. 48-51 (March 1991).

An approach for reducing the test time for analog and mixed-signal devices is presented. This approach relies upon an error model for the device type. The paper describes how the error model can be developed from the physical description of the device or from empirical data taken on representative devices. Use of the error model to select an optimum set of test points and to predict the errors at all test points is described. Finally, the results of applying the method to a 13-bit analog-to-digital converter design is presented.
[Contact: T. Michael Souders, (301) 975-2406]

Cryoelectronic Metrology

Released for Publication

Grossman, E.N., McDonald, D.G., and Sauvageau, J.E., **Terahertz Detectors Based on Superconducting Kinetic Inductance**, to be published in the Proceedings of the Second International Symposium on Space Terahertz Technology, Pasadena, California, February 26-28, 1991.

The inductance of a superconducting stripline varies with the concentration of quasi-particles (unpaired electrons) in the superconductor. This inductance variation may be used as the basis for highly sensitive radiometers, bolometers, and heterodyne mixers. We describe recent progress on three kinetic inductance devices: a large-area, absolute radiometer intended for use in the NIST Low-Background Infrared Calibration Facility, and small, antenna-coupled devices used either in a bolometric mode as direct detectors, or in a non-equilibrium, "photoinductive" mode as heterodyne mixers. The photoinductive mixers are of particular interest because their frequency coverage starts at approximately the energy gap, 2Δ, and extends upward. The impedance matching concerns which make extension of SIS mixers to high frequencies so difficult in practice are greatly relaxed for photoinductors because they lack the large parasitic capacitances inherent in a junction-like geometry.
[Contact: Erich N. Grossman, (303) 497-5102]

Ono, R.H., Beall, J.A., Cromar, M.W., Harvey, T.E., Johansson, M.E., Reintsema, C.D., and Rudman, D.A., **High-T_c Superconductor-Normal-Superconductor Josephson Microbridges with High-Resistance Normal Metal Links.**

We have developed an in-situ process for fabricating high transition temperature superconductor-normal-superconductor (SNS) microbridges using a step edge to define the normal metal length. Critical current-normal resistance products over 1 mV have been measured at low temperature in devices with high-resistivity Ag-Au alloy bridges. Results on samples with Ag bridges are compared with the alloy data as an initial test of recent theories of SNS Josephson junctions. Josephson effects have been studied in these devices up to 80 K. High-quality radiofrequency steps have been observed, with power dependence qualitatively similar to theoretical predictions.
[Contact: Ronald H. Ono, (303) 497-3762]

Recently Published

Beall, J.A., Cromar, M.W., Harvey, T.E., Johansson, M.E., Ono, R.H., Reintsema, C.D., Rudman, D.A., Asher, S.E., Nelson, A.J., and Swartzlander, A.B., **$YBA_2CU_3O_{7-\delta}$/Insulator Multi-Layers for Crossover Fabrication**, IEEE Transactions on Magnetics, Vol. 27, No. 2, pp. 1596-1599 (March 1991).

The development of thin-film dielectrics compatible with epitaxial growth of $YBa_2Cu_3O_{7-\delta}$ (YBCO) is crucial to the fabrication of multilayer device and circuit structures. We have investigated the YBCO/$SrTiO_3$(STO) system by fabricating YBCO/STO bilayers and simple YBCO/STO/YBCO crossover structures. The thin films were deposited in situ by pulsed laser deposition and analyzed using X-ray diffraction and scanning electron microscopy. The film interfaces were characterized by secondary-ion-mass spectroscopy depth profiling. We have developed photolithographic and wet-etching processes for patterning the crossovers which are compatible with these materials. The crossover structures were characterized by resistance and insulator pinhole density as well as the superconducting properties of the patterned top and bottom YBCO electrodes (critical temperature, T_c and critical current density, J_c). Using $SrTiO_3$ as the insulating layer, we have made crossovers with good isolation between layers (>100 MΩ) and high J_c even in the top electrode (J_c(76) K > 10^5 A/cm^2).
[Contact: James A. Beall, (303) 497-5989]

Cunningham, C.E., Park, G.S., Cabrera, B., and Huber, M. E., **Correlation of Flux States Generated by Optical Switching of a Superconducting Circuit,**

initiating the service, what capacitors are appropriate for calibration, the measurement methods used, the instrumentation used for the measurements, and an analysis of the errors in the measurement. It also lists the calibration uncertainties for the stated frequencies and capacitance magnitudes. Finally, the document discusses the quality assurance program used at NIST to ensure the integrity of the calibration.
[Contact: George M. Free, (303) 497-3609]

Marks, R.B., and Williams, D.F., **Determination of Characteristic Impedance from Measurement of Propagation Constant.**

Although a fundamental parameter of transmission lines, the characteristic impedance is difficult to measure accurately. We suggest a method by which it may be easily determined from a measurement of the propagation constant. The method is based on a rigorous analysis from first principles using explicit and realistic approximations which include the effects of imperfect conductors. Results of numerical and experimental studies with coplanar waveguide indicate that high accuracy is possible.
[Contact: Roger B. Marks, (303) 497-3037]

Williams, D.F., and Marks, R.B., **The Interpretation and Use of S-Parameters in Lossy Lines**, to be published in the Proceedings of the 36th ARFTG Conference, Monterey, California, November 29-30, 1990.

Although a fundamental parameter of transmission lines, the characteristic impedance is difficult to measure accurately. We suggest a method by which it may be easily determined from a measurement of the propagation constant. The method is based on a rigorous analysis from first principles using explicit and realistic approximations which include the effects of imperfect conductors. Results of numerical and experimental studies with lossy coaxial lines and of experiments with coplanar waveguides indicate that high accuracy is possible.
[Contact: Dylan F. Williams, (303) 497-3138]

Williams, D.F., Marks, R.B., and Phillips, K.R., **Progress Toward MMIC On-Wafer Standards**, to be published in the Proceedings of the 36th ARFTG Conference, Monterey, California, November 29-30, 1990.

A prototype coplanar waveguide standard set suitable for the calibration of wafer probe stations has been developed through a cooperative effort between the National Institute of Standards and Technology and a MIMIC Phase 3 team. The coplanar standard set is intended primarily for in-process testing applications, although the characterization of coplanar waveguide circuits is also possible. In this paper, two sources of systematic errors associated with the prototype standard set, the propagation of undesirable modes and the influence of adjacent structures on the electrical connection to the elements of the standard set, are discussed.
[Contact: Dylan F. Williams, (303) 497-3138]

Wittmann, R.C., and Yaghjian, A.D., **Spherical-Wave Expansions for Piston-Radiator Fields.**

Simple spherical-wave expansions for the continuous-wave fields of a circular piston radiator in a rigid baffle are derived. These expansions are valid throughout the illuminated half space and are useful for efficient numerical computation in the near-field region. Multipole coefficients are given by closed-form expressions which can be evaluated recursively.
[Contact: Ronald C. Wittmann, (303) 497-3326]

Recently Published

Daywitt, W.C., **Determining Adapter Efficiency by Envelope Averaging Swept Frequency Reflection Data** [original title: Determining Adapter Efficiency from Swept Frequency Reflection Data], IEEE Transactions on Microwave Theory and Techniques, Vol. 38, No. 11, pp. 1748-1752 (November 1990).

A simple automated network analyzer (ANA) swept frequency technique for measuring adapter efficiency is described. Calculations show that errors arising from theoretical approximations (excluding ANA measurement errors) are around 0.004 dB for a common WR 42 waveguide-to-coaxial adapter.
[Contact: William C. Daywitt, (303) 497-3720]

Sherwood, G.V., **Air Gage Size Measurement of Microwave Standards**, Proceedings of the 1991 Measurement Science Conference, Anaheim, California, January 31-February 1, 1991. pp. 1-10 (1991).

Size measurement of waveguides and coaxial transmission line standards has been performed at the National Institute of Standards and Technology (NIST) for many years. Recently, the air gaging systems used to perform these measurements have been enhanced using digital data acquisition methods to facilitate computer analysis. Initial experiments were performed using air gaging probes on a coordinate measuring machine to correlate linear position with size attributes. Related geometric and dimensional characteristics that contribute to the uncertainty of measurement were also studied. Alternative assessment methods have been utilized to provide a more complete characterization of these features and complement air gage size measurements using a systems approach. This article is a report of these developments at NIST.
[Contact: Glenn V. Sherwood, (303) 497-3939]

Williams, D.F., Marks, R.B., and Phillips, K.R., **Translate LRL and LRM Calibrations** [original title: Translating Between LRL and LRM Calibrations], Microwaves & RF, Vol. 30, No. 2, pp. 78ff (February 1991).

The Line-Reflect-Match calibration technique (LRM) is reviewed. Unless the match standard is perfect, calibration using the most common form of LRM differs from that of the Line-Reflect-Line technique (LRL). We present an explicit transformation which relates the two calibrations.
[Contact: Dylan F. Williams, (303) 497-3138]

Electromagnetic Properties

Released for Publication

Estin, A.J., and Janezic, M.D., **Improvements in Dielectric Measurements with a Resonant Cavity**, to be published in the 1991 Instrumentation/-Measurement Technology Conference Record, Atlanta, Georgia, May 14-16, 1991.

This paper describes a technique for using the power of an automatic network analyzer to determine to very high accuracy the resonant frequency and intrinsic quality factor of a microwave resonant cavity. With this technique, measurement of complex permittivity of samples of dielectric material can be determined to new low levels of uncertainty.
[Contact: Michael D. Janezic, (303) 497-3656]

Janezic, M.D., and Grosvenor, J.H., Jr., **Improved Technique for Measuring Permittivity of Thin Dielectrics with a Cylindrical Resonant Cavity**, to be published in the IEEE Instrumentation/Measurement Technology Conference Record, Atlanta, Georgia, May 14-16, 1991.

A new technique for measuring the permittivity of thin, low-loss dielectric materials in a cylindrical resonant cavity has been developed. A thin dielectric sample is placed upon a thicker dielectric sample whose permittivity is well characterized. Both samples are then placed on the endplate in the cylindrical resonant cavity. In this way, the thin sample is placed in a region of the cavity where interaction with the electromagnetic fields is greater. From knowledge of the cavity's resonant frequency, dimensions of the cavity and both dielectric samples, and the permittivity of the thicker sample, one is able to use iterative techniques to accurately determine the permittivity of the thin dielectric sample.

A derivation and discussion of the theory used in this layered-dielectric permittivity measurement technique is provided. Also, measurement results, at frequencies between 9 and 10 GHz, of thin cross-linked polystyrene, alumina, and magnesium titanate samples confirm that this measurement technique is able to accurately measure the dielectric constant of thin low-loss materials. A preliminary error analysis is also given to show the worst-case uncertainties associated with this new method.
[Contact: Michael D. Janezic, (303) 497-3656]

Vanzura, E.J., and Rogers, J.E., **Evaluation of a Resonant Circuit Model Using Reflected S-Parameter Data**, to be published in the Digest of the 1991 IEEE Instrumentation and Measurement Technology Conference, Atlanta, Georgia, May 14-16, 1991.

A nonlinear regression procedure is used to fit S-parameter resonance data to a full-circuit model that includes coupling factors and self-impedances. Such a model should provide an adequate mathematical representation of cavity resonator data. Our analysis shows that this model fits the data better than the simpler Q-circle model that can be derived from it, but that a systematic pattern in the residuals persists. This pattern indicates a discrepancy between the full-circuit model and the observed data. By looking at parameter estimates calculated from subsets of the

original data, we demonstrate that the cause of this discrepancy could also be introducing significant errors in the model's estimated parameter values.
[Contact: Eric J. Vanzura, (303) 497-5752]

Weil, C.M., and Kissick, W.A., **The NIST Electromagnetic Properties of Materials Program**, to be published in the Digest of the 1991 IEEE Instrumentation and Measurement Technology Conference, Atlanta, Georgia, May 14-16, 1991.

The Electromagnetic Properties of Materials program at the National Institute of Standards and Technology (NIST) is described, including an outline of the current goals of the project. Some details of measurement techniques being used at NIST for characterizing dielectric and magnetic materials at microwave frequencies are given.
[Contact: Claude M. Weil, (303) 497-5305]

Recently Published

van Roggen, A., Yuwono, L., Zhou, H., Meijer, P.H.E., and Kopanski, J.J., **Permittivity Measurements on Molecular-Sized Samples**, Extended Abstract, presented as poster only at the IEEE Conference on Electrical Insulation and Dielectric Phenomena (CEIDP), Pocono Manor, Pennsylvania, October 29-November 1, 1990, Paper 7-14, pp. 385-390 (January 1991).

A new laboratory on Molecular Electronics has been started at the Physics Department of the Catholic University of America. In our efforts to make organic bistable devices, one of the research functions of this laboratory is to measure the electrical properties of materials and active devices made with molecular (mainly organic) materials. The size of material samples, and the specimens used for measurement, is exceedingly small, typically layers with a thickness of the order of 100 nm. Consequently, the setups used for normal dielectric and conductivity measurements ($\geq$10 mm electrode size) cannot be used, and special cells and instrumentation have to be developed.
[Contact: Joseph J. Kopanski, (301) 975-2089]

Laser Metrology

Released for Publication

Scott, T.R., **Megawatt Laser Calorimeter Design**, to be published in the Proceedings of the IMTC/91 Conference, Atlanta, Georgia, May 14-16, 1991.

The accurate determination of laser energy becomes extremely difficult when seeking to measure the output of laser sources having average powers in the megawatt range. This paper describes the conceptual design of a calorimeter which could safely capture the output of megawatt-class, continuous-wave laser sources operating in the near infrared wavelength region. A primary consideration in this design was the possibility that at some point in the future it would have to be scaled to even larger dimensions. Accordingly, the design uses non-exotic optical techniques and a simple geometry to handle the high power densities expected from the laser sources. An array of curved, reflective rods is used to spread the laser radiation before it is absorbed by a black-walled cavity. The calorimeter is designed to capture the entire laser beam with subsequent conversion of the electromagnetic energy to thermal energy. The temperature of the calorimeter is monitored and used to determine the incident laser radiation.
[Contact: Thomas R. Scott, (303) 497-3651]

Recently Published

Paulter, N.G., Jr., and Majumdar, A.K., **A New Triple Correlation Technique for Measuring Ultrashort Laser Pulses** [original title: A New Triple Correlation Technique for the Measurement of Ultrashort Laser Pulses], Review of Scientific Instruments, Vol. 62, No. 3, pp. 567-578 (March 1991).

A new triple correlation technique for the measurement of the complete intensity profile of ultrashort optical pulses is described. In general, the triple correlation technique preserves the phase information of the input pulse so that a reconstruction of the triple-correlated signal will provide a unique reconstruction of the input. The new technique described here uses two second-order, nonlinear optical interactions for the generation of the triple correlation signal. A derivation of the measured triple correlation signal and the pulse reconstruction is given. The effects of noise on the measured signal are also examined.
[Contact: Nicholas G. Paulter, Jr., (303) 497-3400]

Paulter, N.G., Jr., and Majumdar, A.K., **A New Triple**

Correlator Design for the Measurement of Ultrashort Laser Pulses [original title: A New Proposed Triple Correlator for the Measurement of Ultrashort Laser Pulses], Optics Communications, Vol. 81, Nos. 1,2, pp. 95-100 (1 February 1991).

A measurement device, a triple correlator, is proposed for the characterization of ultrashort optical pulses. The proposed triple correlator uses two consecutive nonlinear optical interactions, a sum frequency generation followed by a difference frequency generation, to produce a triple correlation output at the same optical frequencies as the input pulse. Phase matching for the triple correlator is greatly simplified by using the given design. The operation of the triple correlator is described and examples of expected output signals are given. The reconstructed optical pulse is quite insensitive to noise, as shown by computer simulations.
[Contact: Nicholas G. Paulter, Jr., (303) 497-3400]

Optical Fiber Metrology

Released for Publication

Day, G. W., and Franzen, D. L., **Symposium on Optical Fiber Measurements, 1990**, to be published in the Journal of Research of the National Institute of Standards and Technology.

This is a meeting report from the Sixth biennial Symposium on Optical Fiber Measurements, held September 11-12, 1990, in Boulder, Colorado.
[Contact: Gordon W. Day, (303) 497-5204]

Franzen, D.L., **Precision Measurements on Optical Fibers.**

The precision and accuracy of single-mode optical fiber measurements are discussed. Included in the discussion are measurements for: attenuation, mode-field diameter, cut-off wavelength, and geometrical parameters.
[Contact: Douglas L. Franzen, (303) 497-3346]

Gallawa, R.L., Gardner, J.L., Nettleton, D.H., Stock, K.D., Ward, T.H., and Li, X., **A Limited International Intercomparison of Responsivity Scales at Fiber Optics Wavelengths**, to be published in the Journal of Research of the National Institute of Standards and Technology.

We report here on a recent limited international intercomparison of responsivity scales at wavelengths of interest to the optical communications community. Participants in the comparison were the national laboratories in the United States, the United Kingdom, Germany, and Australia. The wavelengths tested were 1300 and 1550 nm. Data taken at 850 nm are only briefly discussed. The disagreement between the national laboratories' responsivity scale is comfortably within the uncertainty claimed by each laboratory.
[Contact: Robert L. Gallawa, (303) 497-3761]

Gallawa, R.L., Goyal, E.C., and Ghatak, A.K., **Optical Waveguide Analysis Using Modified Airy Functions.**

We review a little-used but powerful method of solving one of the most fundamental equations of mathematical physics. The method is not new, but it is apparently not familiar to the optics community. It uses a modification of the well-known Airy functions, which are easily calculated on desktop computers. We will review the method through examples which have an exact solution. We trust that this review will serve to stimulate further examination of a method that seems to have considerable promise.

The method that we review here is reminiscent of the WKBJ methodology, but the solution, although approximate, is much more useful than the traditional WKBJ solution and can be used with almost as much ease. The method is extremely powerful but, to our knowledge, is not being used by the optics community, where its use in analyzing optical fibers and integrated optical waveguides would be beneficial.
[Contact: Robert L. Gallawa, (303) 497-3761]

Ghatak, A.K., Gallawa, R.L., and Goyal, I.C., **Accurate Solutions to Schrodinger's Equation Using Modified Airy Functions.**

A formalism that utilizes the Airy functions is applied to Schrodinger's equation for a spherically symmetric potential. We show that the computational procedure is very simple and allows us to have a very accurate description of bound state wavefunctions and the corresponding eigenvalues.
[Contact: Robert L. Gallawa, (303) 497-3761]

Pal, B.P., Tewari, R., and Das, U.K., **Optimization of**

Dispersion-Shifted Dual-Shape-Core Fibers Based on Spot Sizes, to be published in the Proceedings of the European Conference on Optical Communication '91, Paris, France, September 9-12, 1991.

We present design optimization of a dual-shape-core fiber that maintains cutoff wavelength at 1550 nm and Petermann-2 spot size (W) between 4 and 5 µm. The design restricts bend and splice loss by targeting $W_\infty/\bar{W}$ to be close to 1.
[Contact: Robert L. Gallawa, (303) 497-3761]

Tewari, R., Pal, B.P., and Das, U.K., **Optimisation of Dispersion Shifted Dual Shape Core Fibers: A Technique Based on Spot Size Definitions.**

Optimised design characteristics for attaining very low bend and splice losses in dispersion-shifted, dual-shape core (DSC) single-mode fibers are obtained in terms of characteristic mode spot sizes $\bar{W}$, responsible for splice loss, and W_∞, responsible for bend loss. DSC fiber designs are given for $W_\infty/\bar{W}$ lying between 1.16 and 1.33, for mode spot size ($\bar{W}$) between 4 and 5 µm, and for the total zero dispersion wavelength (λ_0) coinciding with the operating wavelength of 1550 nm. $W_\infty/\bar{W}$ should be close to unity for optimum splice and bending performance.
[Contact: Robert L. Gallawa (303) 497-3761]

Recently Published

Gilbert, S.L., **Frequency Stabilization of an Erbium-Doped Fiber Laser: A Potential Wavelength Standard for Optical Communications**, Technical Digest, 1991 Optical Fiber Communication Conference, San Diego, California, February 18-22, 1991, p. 85.

Wavelength standards in the 1.5-µm range are important for many of the proposed optical communication schemes involving frequency-division multiplexing and coherent heterodyne detection. Fiber lasers are attractive candidates for use in such wavelength standards because of their potential for narrow-linewidth operation. Previous studies of single-longitudinal-mode Er-doped fiber lasers have reported narrow-linewidth operation, but a complete analysis of the frequency noise characteristics has not been carried out. I have found that fluctuations in fiber laser frequency are small and are dominated by low-frequency (≤600-Hz) components arising from mechanical vibrations, thermal drift, and fluctuations of the pump laser intensity. This aspect makes fiber lasers particularly easy to stabilize by using an electronic servomechanism. In the apparatus two pieces of Er-doped fiber form a coupled-cavity system within a longer standing-wave cavity and a diffraction grating. The overlap of the transmission peaks of these cavities within the bandwidth of the 1200-groove/mm grating selects a single longitudinal mode. Course tuning of the wavelength is accomplished by translating and tilting the grating with a piezoelectric transducer (PZT) and stretching the longer fiber with another PZT. The laser is tunable from 1.52 µm to 1.58 µm and has a threshold of 30 mW (pump power coupled into the fiber) and a peak slope efficiency of 10%.
[Contact: Sarah L. Gilbert, (303) 497-3120]

Gilbert, S.L., **Frequency Stabilization of a Tunable Erbium-Doped Fiber Laser**, Optics Letters, Vol. 16, No. 3, pp. 150-152 (February 1, 1991). [Summary paper on the same topic (Frequency Stabilization of an Erbium-Doped Fiber Laser: A Potential Wavelength Standard for Optical Communications) was given at the Conference on Optical Fiber Communications, San Diego, California, February 18-22, 1991.]

A single-frequency erbium-doped fiber laser that is tunable from 1.52 to 1.58 µm has been constructed. The laser linewidth was determined to be less than 1.6 MHz full width half maximum by observing the spectrum of the beat between the fiber laser and a 1.523-µm helium-neon laser. The frequency of the fiber laser was locked to several absorption lines of acetylene near 1.53 µm. This research demonstrates the inherent stability of fiber lasers and their potential for use in a wavelength standard for optical communications.
[Contact: Sarah L. Gilbert, (303) 497-3120]

Optical Fiber Sensors

Recently Published

Deeter, M.N., Rose, A.H., and Day, G.W., **Iron-Garnet Magnetic Field Sensors with 100 pT/$\sqrt{\text{Hz}}$ Noise-Equivalent Field**, Proceedings of the Seventh Optical Fibre Sensors Conference, Sydney, New South Wales, Australia, December 2-6, 1990, pp.

341-344 (1991).

The sensitivity of Faraday-effect sensors incorporating diamagnetically-substituted yttrium iron garnet (YIG) is potentially much higher than of sensors employing pure YIG. Results of Faraday rotation linearity and sensitivity measurements are presented for gallium-substituted YIG. At 500 Hz, the noise-equivalent magnetic field is approximately 100 pT/$\sqrt{Hz}$.
[Contact: Merritt N. Deeter, (303) 497-5400]

Tang, D., Rose, A.H., and Day, G.W., **Optical Fiber Current Sensors with Temperature Stabilities Near the Material Limit**, Proceedings of the Seventh Optical Fibre Sensors Conference, Sydney, New South Wales, Australia, December 2-6, 1990, unpaged, (1991).

We describe an optical fiber current sensor with a normalized temperature coefficient of +8.4 x 10^{-5}/K over the range from -75 to +145 °C. This is within 20% of the limit set by the temperature dependence of the Verdet constant measured in bulk silica. Packaging of the sensor coil degrades its stability, but a fully packaged coil with a stability of +1.7 x 10^{-4}/K over the range from -30 to +125 °C has also been demonstrated.
[Contact: Allen H. Rose, (303) 497-5599]

Veeser, L.R., and Day, G.W., **Faraday Effect Current Sensing Using a Sagnac Interferometer with a 3x3 Coupler**, Proceedings of the Seventh Optical Fibre Sensors Conference, Sydney, New South Wales, Australia, December 2-6, 1990, pp. 325-328 (1991).

We demonstrate a fiber optic current sensor based on a Sagnac interferometer with a 3x3 fiber coupler. Compared to the more common Sagnac interferometer with a 2x2 coupler, this design offers the additional benefits of a greater response for small signals and the unambiguous interpretation of signals that exceed the period of the response function.
[Contact: Gordon W. Day, (303) 497-5204]

Electro-Optic Metrology

Released for Publication

Hickernell, R.K., Sanford, N.A., and Christensen, D.H., **Issues Affecting the Characterization of Integrated Optical Devices Subjected to Ionizing Radiation.**

We examine measurement issues which arise in the testing of integrated optical devices subjected to ionizing radiation. Many of these issues are not addressed by measurement procedures developed for optical fibers. We outline the complexities involved in integrated optical measurements related to size, function, and materials. Pertinent waveguide parameters include attenuation, changes in refractive index, photorefractive effects, and polarization effects. Optical measurement techniques are reviewed, with particular attention paid to spatial and temporal resolution, dynamic range, and the capacity for remote measurement. Suggestions are made to improve the reliability of testing and to allow better comparison between laboratories.
[Contact: Robert K. Hickernell, (303) 497-3455]

Phelan, R.J., Jr., Lehman, J.H., and Larson, D.R., **Reference Detectors for Spectral Responsivity Measurements**, to be published in the Proceedings of the 1991 Measurement Science Conference, Anaheim, California, January 31-February 1, 1991.

This paper presents a view of the need, use, design, and evaluation of detectors to be used for spectral responsivity measurements. The emphasis is on a design that is easy to use and for which the spectral responsivity can be understood and confirmed by the user.
[Contact: Robert J. Phelan, Jr., (303) 497-3696]

Sanford, N.A., Malone, K.J., Larson, D.R., and Hickernell, R.K., **Y-Branch Waveguide Glass Laser and Amplifier.**

A Y-branch channel waveguide laser operating near 1057 nm was fabricated in Nd-doped silicate glass by means of electric-field-assisted ion exchange. The overall length was 24 mm. Optical pumping was performed with a continuous-wave Ti:sapphire laser. Mirrors were bonded directly to the polished waveguide facets. Using a 4% transmitting output coupler, the slope efficiency was 5.1%; threshold was reached at 26-mW absorbed pump power. When operated as a single-pass Y-branch amplifier, the small-signal gain was 0.034 dB/mW. The 3-dB splitting loss of the Y-branch structure was overcome when the absorbed pump power was approximately 85 mW.
[Contact: Norman A. Sanford, (303) 497-5239]

Recently Published

Goyal, I.C., Gallawa, R.L., and Ghatak, A.K., **Methods of Analyzing Planar Optical Waveguides** [original title: A New Method of Analyzing Planar Optical Waveguides], Optics Letters, Vol. 16, No. 1, pp. 30-32 (January 1, 1991).

We present a new approximate solution of the scalar-wave equation for planar optical waveguides with arbitrary refractive-index profiles. Test calculations are done for an index profile with a known solution. The comparison demonstrates the accuracy of our method. The method may also be applied to circularly symmetric optical fibers.
[Contact: Robert L. Gallawa, (303) 497-3761]

Parameswaran, M., Robinson, A.M., Blackburn, D.L., Gaitan, M., and Geist, J., **Micromachined Thermal Radiation Emitter from a Commercial CMOS Process** [original title: Micromachined Thermal and Visible Radiation Source Using a Commercial CMOS Process], IEEE Electron Device Letters, Vol. 12, No. 2, pp. 57-59 (February 1991).

Fabrication of a thermally isolated micromechanical structure capable of generating thermal radiation for dynamic thermal scene simulation (DTSS) is described. Complete compatibility with a commercial CMOS process is achieved through design of a novel, but acceptable, layout for implementation by the CMOS foundry using its regular process sequence. Following commercial production and delivery of the CMOS chips, a single maskless etch in an aqueous ethylenediamine-pyrocatechol mixture is performed to realize the micromechanical structures. The resulting structures are suspended plates consisting of polysilicon resistors encapsulated in the field and CVD oxides available in the CMOS process. The plates are suspended by aluminum heater leads that are also encapsulated in the field and CVD oxides. Studies of the suitability of these structures for DTSS have been initiated, and early favorable results are reported.
[Contact: Jon Geist, (301) 975-2066]

Sanford, N.A., Malone, K.J., and Larson, D.R., **Integrated-Optic Waveguide Glass Lasers**, Technical Digest of the Optical Fiber Communication Conference, San Diego, California, February 18-22, 1991, p. 27 (1991).

Rare-earth-doped integrated-optic waveguide devices offer new miniaturized cw and pulsed lasers, amplifiers, and other active elements. Fabrication methods which use bulk glasses, as well as chemical-vapor deposition techniques, are being explored.
[Contact: Norman A. Sanford, (303) 497-5239]

Tu, Y., Goyal, I.C., and Gallawa, R.L., **Analyzing Integrated Optical Waveguides: A Comparison of Two New Methods** [original title: A Comparison of Two Recent Methods of Analyzing Integrated Optical Waveguides], Applied Optics, Vol. 29, No. 36, pp. 5313-5315 (20 December 1990).

We present here a comparison of two recent methods (one of which is numeric, the other an approximate analytic method) of predicting waveguide parameters, each with a particular strength. Although the methods are quite general, we restrict attention to a one-dimensional waveguide having an exponential profile with a known analytic solution to illustrate the strength of each of the two methods. We then use a quadratic (parabolic) profile that has no closed form analytic solution but is potentially useful inasmuch as it represents a profile which gives further insight into the strengths and weaknesses of the two present methods. This is the first comparison of these two new methods which we believe hold considerable promise for waveguide analysis. The purpose here is to prove the utility of the methods, that they might be used for more general profiles, for which parametric tendencies are now known.

Veasey, D.L., Larson, D.R., Phelan, R.J., Jr., and Batchman, T.E., **Semiconductor Claddings on Glass Waveguides for Polarizers and Detectors**, Optical Society of America 1990 Annual Meeting Technical Digest, Boston, Massachusetts, November 4-9, 1990, unpaged (1991).

TE and TM polarizers and polarization sensitive detectors were fabricated by cladding glass channel waveguides with hydrogenated amorphous silicon. Extinction ratios as high as 48 dB have been observed for the TE-pass device and up to 34 dB for the TM-pass device.
[Contact: David L. Veasey, (303) 497-3439]

ELECTRICAL SYSTEMS

Power Systems

Released for Publication

Stricklett, K.L., Fenimore, C., Kelley, E.F., Yamashita, H., Pace, M.O., Blalock, T.V., Wintenberg, A.L., and Alexeff, I., **Observations of Partial Discharges in Hexanes under High Magnification.**

Partial discharges are observed in hexanes by shadow photography under the application of dc voltages. A nonuniform field geometry is employed, and the growth of cavities associated with partial discharges at a point cathode is photographed at 200X magnification. The use of an image-preserving optical delay allows a record of the conditions which exist in the liquid prior to the initiation of the partial discharge to be obtained; a simultaneous record of the partial discharge current is obtained. Analysis of these data indicates that electrostatic forces are adequate to drive streamer growth.
[Contact: Kenneth Stricklett, (301) 975-3955]

Van Brunt, R.J., and Cernyar, E.W., **Influence of Memory Propagation on Phase-Resolved Stochastic Behavior of ac-Generated Partial Discharges.**

It is shown for the first time from measurements of phase-restricted conditional partial-discharge pulse phase and amplitude distributions that the stochastic properties of a dielectric-barrier type of partial discharge generated by an ac voltage are significantly influenced by memory associated with charge deposited on the dielectric surface by preceding discharge events. This memory effect must be considered in any attempt to interpret results of phase-resolved partial-discharge measurements.
[Contact: Richard J. Van Brunt, (301) 975-2425]

Van Brunt, R.J., Misakian, M., Kulkarni, S.V., and Lakdawala, V.K., **Influence of a Dielectric Barrier on the Stochastic Behavior of Trichel-Pulse Corona.**

The stochastic behavior of a negative, point-to-plane (Trichel-pulse) corona discharge in air has been investigated for the case where the plane electrode is partially covered with a solid PTFE (polytetrafluoroethylene) dielectric of varying size and position relative to the point electrode. This behavior is revealed from measurements of conditional and unconditional corona pulse-amplitude and pulse-time-separation distributions. The results indicate that the presence of a dielectric surface on the anode does not affect the occurrence of Trichel pulses provided the point-to-plane gap spacing is greater than a critical value d_c which depends on the size of the dielectric and the applied voltage. As the gap spacing approaches d_c, the effect of dielectric surface charging by the corona introduces measurable "memory effects" indicated by correlations between pulse amplitude and time separation from the previous pulse. For spacings less than d_c, detectable corona-pulse activity is quenched by the presence of a quasi-permanent surface charge on the dielectric.
[Contact: Richard J. Van Brunt, (301) 975-2425]

Van Brunt, R.J., Stricklett, K.L., Steiner, J.P., and Kulkarni, S.V., **Recent Advances in Partial Discharge Measurement Capabilities at NIST.**

This report describes three techniques under development at the National Institute of Standards and Technology (NIST) to measure the properties of partial discharges (PDs). These measurements are useful in providing new insight into the mechanisms that influence or control P-D behavior and in affording a means of locating P-D activity in cables. The first is concerned with an advanced, real-time P-D measurement system which allows a "complete" characterization of the stochastic properties of partial discharges. With this system, it is possible to measure a set of conditional P-D pulse-amplitude and pulse-time-separation distributions from which memory effects characteristic of the discharge phenomena can be quantified and interpreted. Examples of results obtained for pulsating negative discharges in gases are shown. The second technique allows P-D location in cables using a time-domain reflectometry technique with appropriate statistical analysis. With the third technique discussed here, simultaneous measurements are made of the optical and electrical characteristics of PDs in liquid dielectrics using fast photography combined with broad-band low-noise pulse current measurements. This method provides a detailed description of the temporal and spatial development of PDs in highly nonuniform field configurations. Examples of results are shown for the case of PDs in hexanes when a dc voltage is applied to a point-rod electrode gap.
[Contact: Richard J. Van Brunt, (301) 975-2425]

Yamashita, H., Kawai, H., Stricklett, K.L., and Kelley,

E.F., **The Effect of High Pressure on Cathode Streamer Initiation in Hexanes.**

The effect of pressure on the initiation of prebreakdown streamers in hexanes under nonuniform field conditions is investigated. Using a high-magnification (100X) high-resolution (1-μm) optical system, and a high-speed (2, 5, and 20 × 10^6 frames/s) camera, the initial growth of low-density streamers propagating from a needle cathode is examined at pressures ranging from 0.1 to 1.1 MPa. The initial streamer appears to be a single cylindrical channel that expands and contracts radially as the streamer grows and is approximately 4 μm in diameter and 8 μm in length at the transition to a dense bushy structure. The pressure dependence of the minimum voltage required for streamer initiation and the average voltage at the streamer inception are shown.
[Contact: Kenneth Stricklett, (301) 975-3955]

Recently Published

Fenimore, C.P., Jr., and FitzPatrick, G.J., **Measurement Reliability: The Detection of Nonlinearities**, Proceedings of the Space Nuclear Power Systems Eighth Symposium, Albuquerque, New Mexico, January 7-10, 1991, pp. 1113-1118 (1991).

The detection of a single measurement failure in a compound measurement system consisting of a voltage divider and a Kerr cell is demonstrated. The comparison of measurement devices based on distinct technologies is inherently robust; they may be expected to have distinct failure characteristics. The Kerr comparison is based on model fitting applied to numerically generated data and experimental, digitally recorded waveforms. The characteristic signatures of two measurement errors are found for a quadratic nonlinearity in the detector and for an overdriven photodetector. The length of the data records permits the detection of nonlinearities which are comparable to the noise in magnitude. Detection of such errors is a prerequisite to recalibration in software which enables error correction in remote applications, such as space power systems.
[Contact: Charles P. Fenimore, Jr., (301) 975-2428]

Fenimore, C.P., Jr., and Martzloff, F.D., **Incompatibility Between the 100/1300 Surge Test and Varistor Failure Rates**, Proceedings of the Ninth International Zurich Symposium and Technical Exhibition on Electromagnetic Compatibility, Zurich, Switzerland, March 12-14, 1991, pp. 525-530 (1991).

A proposed high-energy surge test featuring a 100/1300-μs waveform and a peak voltage of 2.3 times the peak voltage of the low-frequency mains is under consideration by the IEC. The energy storage capacitor suggested for the surge generator, originally specified as high as 25 000 μF, has been scaled down, but is still at a level of several thousand microfarads. A simple but realistic mathematical model is integrated numerically to determine the energy dissipated in such a test. The energy that would be deposited into a varistor of the voltage rating commonly used in protecting load equipment, if subjected to this test, far exceeds the capability of the varistor, but reported varistor failure rates do not reflect such a situation. Thus, a reexamination of the premises that led to the 100/1300-μs test specifications appears necessary.
[Contact: Charles P. Fenimore, Jr., (301) 975-2428]

Magnetic Materials & Measurements

Released for Publication

Brug, J.A., Goldfarb, R.B., and Chen, D.-X., **Demagnetizing Factors for Cylinders.**

We have calculated fluxmetric (ballistic) and magnetometric demagnetizing factors N_f and N_m for cylinders as functions of susceptibility χ and the ratio γ of length to diameter. Using a one-dimensional model when $\gamma \geq 10$, we calculated N_f for $-1 \leq \chi < \infty$ and N_m for $\chi \rightarrow \infty$. Using a two-dimensional model when $\gamma \leq 10$, an important range for magnetometer measurements, we calculated N_m and N_f for $-1 \leq \chi < \infty$. Demagnetizing factors for $\chi < 0$ are applicable to superconductors. For $\chi = 0$, suitable for weakly magnetic or saturated ferromagnetic materials, N_f and N_m are computed exactly using inductance formulas.
[Contact: James A. Brug, (303) 497-5557]

Recently Published

Cross, R.W., and Goldfarb, R.B., **Hall Probe Magnetometer for SSC Magnet Cables: Effect of Transport Current on Magnetization and Flux Creep**, IEEE Transactions on Magnetics, Vol. 27, No. 2, pp. 1796-1798 (March 1991).

We constructed a Hall probe magnetometer to measure the magnetization hysteresis loops of superconducting-super-collider magnet cables. The instrument uses two Hall-effect field sensors to measure the applied field H and the magnetic induction B. Magnetization M is calculated from the difference of the two quantities. The Hall probes are centered coaxially in the bore of a superconducting solenoid with the B probe against the sample's broad surface. An alternative probe arrangement, in which M is measured directly, aligns the sample probe parallel to the field. We measured M as a function of H and field cycle rate both with and without a dc transport current. Flux creep as a function of current was measured from the dependence of ac loss on the cycling rate and from the decay of magnetization with time. Transport currents up to 20% of the critical current have minimal effect on magnetization and flux creep.
[Contact: R. William Cross, (303) 497-5300]

Cross, R.W., Patton, C.E., Srinivasan, G., Booth, J.G., and Chen, M., **Anomalous Low Frequency Butterfly Curves for Subsidiary Absorption and FMR Overlap at 3 GHz**, Journal of Applied Physics, Vol. 69, No. 3, pp. 1569-1573 (1 February 1991).

Subsidiary absorption butterfly curves of spin-wave instability threshold versus static in-plane field have been obtained for yttrium-iron-garnet (YIG) thin films at 3 GHz. The butterfly curves have been found to be rather anomalous, typically displaying a pronounced dip and a very low minimum threshold. These anomalous features are attributed to the overlap of the subsidiary absorption field region with ferromagnetic resonance (FMR). First-order instability theory was extended to include the uniform mode response near FMR. The extended theory yields good fits to the data for reasonable values of the YIG FMR linewidths. The theoretical analysis also shows a predicted flip in the azimuthal propagation angle ϕ_k for the unstable spin waves in the region of FMR overlap. With increasing field, there are predicted discontinuous changes in ϕ_k from 90° to 0° and back to 90° in the region of FMR.
[Contact: William R. Cross, (303) 497-5300]

Deeter, M.N., Rose, A.H., and Day, G.W., **Iron-Garnet Magnetic Field Sensors with 100 pT/$\sqrt{Hz}$ Noise-Equivalent Field**, Proceedings of the Seventh Optical Fibre Sensors Conference, Sydney, New South Wales, Australia, December 2-6, 1990, pp. 341-344 (1991).

The sensitivity of Faraday-effect sensors incorporating diamagnetically-substituted yttrium iron garnet (YIG) is potentially much higher than of sensors employing pure YIG. Results of Faraday rotation linearity and sensitivity measurements are presented for gallium-substituted YIG. At 500 Hz, the noise-equivalent magnetic field is approximately 100 pT/$\sqrt{Hz}$.
[Contact: Merritt N. Deeter, (303) 497-5400]

Rice, P., and Moreland, J., **A New Look at the Bitter Method of Magnetic Imaging**, Review of Scientific Instruments, Vol. 62, No. 3, pp. 844-845 (March 1991).

A scanning-tunneling microscope (STM) was used in place of an optical microscope in the Bitter method to image the magnetic ferrofluid particles on the surface of a hard disk. The Bitter method is a reliable method to look at magnetic patterns on magnetic storage media. The resolution obtainable is limited by the optical viewing of the magnetic particles. Using the scanning tunneling microscope, we have obtained image resolution limited only by the ferrofluid particle size and the sharpness of the STM tip.
[Contact: Paul Rice, (303) 497-3841]

Superconductors

Released for Publication

Ekin, J.W., **Superconductor Specification**.

The specification of superconductors is needed both in the purchase of practical superconductors as well as in the characterization of superconductor materials for research. In the case of research, the emphasis is usually in specifying parameters that are intrinsic to the material such as the critical temperature T_c and upper critical field H_{c2}. In the case of procuring superconductors for practical applications, the primary concern is, rather, with the extrinsic parameters such as the physical shape of the conductor, critical current, matrix resistivity, and mechanical properties. The emphasis of this article is on practical superconductors and, consequently, specification of the extrinsic parameters. The extrinsic parameters are described under three general headings: physical, electrical, and mechanical specification.

[Contact: John W. Ekin, (303) 497-5448]

Walsh, T., Moreland, J., Ono, R.H., and Kalkur, T.S., **The Bi-Sr-Ca-Cu-O Thin Film Energy Gap as a Function of Temperature and Force Applied to Squeezable Electron Tunneling Junctions.**

Tunneling spectroscopy measurements have been performed on Bi-Sr-Ca-Cu-O squeezable electron tunneling (SET) junctions. Two distinct features have been seen in the current (I(V)) and conductance-voltage (G(V)) characteristics. One of these features has the appearance of an energy gap signature, while the other may be due to the switching to the voltage state of a grain boundary junction that is in series with the SET junction. The latter feature can mimic the energy gap signature in I(V) and G(V) characteristics. The two types of features respond very differently to changes in temperature and the force applied to the SET junctions.
[Contact: Thomas Walsh, (303) 497-5430]

Recently Published

Beall, J.A., Cromar, M.W., Harvey, T.E., Johansson, M.E., Ono, R.H., Reintsema, C.D., Rudman, D.A., Asher, S.E., Nelson, A.J., and Swartzlander, A.B., **$YBA_2CU_3O_{7-\delta}$/Insulator Multi-Layers for Crossover Fabrication**, IEEE Transactions on Magnetics, Vol. 27, No. 2, pp. 1596-1599 (March 1991).

The development of thin-film dielectrics compatible with epitaxial growth of $YBa_2Cu_3O_{7-\delta}$ (YBCO) is crucial to the fabrication of multilayer device and circuit structures. We have investigated the YBCO/$SrTiO_3$(STO) system by fabricating YBCO/STO bilayers and simple YBCO/STO/YBCO crossover structures. The thin films were deposited in situ by pulsed laser deposition and analyzed using X-ray diffraction and scanning electron microscopy. The film interfaces were characterized by secondary-ion-mass spectroscopy depth profiling. We have developed photolithographic and wet-etching processes for patterning the crossovers which are compatible with these materials. The crossover structures were characterized by resistance and insulator pinhole density as well as the superconducting properties of the patterned top and bottom YBCO electrodes (critical temperature, T_c and critical current density, J_c). Using $SrTiO_3$ as the insulating layer, we have made crossovers with good isolation between layers (>100 MΩ) and high J_c even in the top electrode (J_c(76) K > 10^5 A/cm^2).
[Contact: James A. Beall, (303) 497-5989]

Cross, R.W., and Goldfarb, R.B., **Enhanced Flux Creep in Nb-Ti Superconductors After an Increase in Temperature**, Applied Physics Letters, Vol. 58, No. 4, pp. 415-416 (28 January 1991).

The magnetic fields of superconducting-super-collider (SSC) dipole magnets change with time when the magnets are operated at constant current. The decay of the field is thought to be a consequence of flux creep in the Nb-Ti filaments in the superconducting cables. However, measured magnetic relaxation of small samples of SSC cable as a function of time is unlike the large decays that are observed in the fields of the actual magnets. We have made relaxation measurements on sample SSC conductors at 3.5 and 4.0 K after field cycling. The decay at both temperatures was 2.8% in 50 min. However, the relaxation measured after a temperature increase from 3.5 to 4.0 K was 4.8% in 50 min. A likely reason for the greater magnetization decay is that, after an increase in temperature, the Nb-Ti is in a supercritical state, with shielding currents flowing at a density greater than the new critical current density. This causes enhanced flux creep. We suggest that a small temperature rise during the operation of SSC magnets may contribute to the unexpectedly large magnetic field decay.
[Contact: R. William Cross, (303) 497-5300]

Cross, R.W., and Goldfarb, R.B., **Hall Probe Magnetometer for SSC Magnet Cables: Effect of Transport Current on Magnetization and Flux Creep**, IEEE Transactions on Magnetics, Vol. 27, No. 2, pp. 1796-1798 (March 1991).

We constructed a Hall probe magnetometer to measure the magnetization hysteresis loops of superconducting-super-collider magnet cables. The instrument uses two Hall-effect field sensors to measure the applied field H and the magnetic induction B. Magnetization M is calculated from the difference of the two quantities. The Hall probes are centered coaxially in the bore of a superconducting solenoid with the B probe against the sample's broad surface. An alternative probe arrangement, in which M is measured directly, aligns the sample probe parallel to the field. We measured M as a function of

H and field cycle rate both with and without a dc transport current. Flux creep as a function of current was measured from the dependence of ac loss on the cycling rate and from the decay of magnetization with time. Transport currents up to 20% of the critical current have minimal effect on magnetization and flux creep.
[Contact: R. William Cross, (303) 497-5300]

Ekin, J.W., Salama, K., and Selvamanickam, V., **Current Record in Superconductors**, Nature, Vol. 350, p. 26 (7 March 1991).

We report the first direct demonstration that high transport J_c can be achieved in bulk melt-grown $YBa_2Cu_3O_7$ at magnetic fields up to 30 T at liquid nitrogen temperature.
[Contact: John W. Ekin, (303) 497-5448]

Goodrich, L.F., Moreland, J., and Roshko, A., **Switching in High-T_c Superconductor Current Transport Measurements**, IEEE Transactions on Magnetics, Vol. 27, No. 2, pp. 1194-1197 (March 1991).

Switching voltages can occur in four wire current transport measurements of sintered high-T_c superconductors. These switching voltages are irreversible shifts in the voltage-current characteristic of the superconductor that result in multiple branches of the voltage-current characteristic. The voltage along these branches can be very nonlinear with respect to current and can be positive or negative in polarity relative to the current direction. These voltages can interfere with the correct determination of resistivity and critical current density. Experimental data on nonaligned sintered high-T_c materials are presented which illustrate the complex nature of the voltages and the confusion they can create. Models based on weak links and H_{c1} and other effects are discussed along with observations in conventional (low T_c) superconductors.
[Contact: Loren F. Goodrich, (303) 497-3143]

Moreland, J., and Rice, P., **Tunneling Stabilized Magnetic Force Microscopy: Prospects for Low Temperature Applications to Superconductors**, IEEE Transactions on Magnetics, Vol. 27, No. 2, pp. 1198-1201 (March 1991).

We have recently demonstrated an imaging technique referred to as tunneling stabilized magnetic force microscopy (TSMFM). TSMFM is performed using a scanning tunneling microscope (STM) with a flexible, magnetic, tunneling tip in place of the usual rigid tunneling tip. TSMFM images are therefore combinations of topography and the magnetic forces between the tip and the sample. Room-temperature TSMFM images of bit tracks on a hard disk have 100-nm resolution and are comparable to Bitter patterns made using a ferrofluid. We are presently building a low-temperature STM for TSMFM of the flux lattice in superconductors. Design and testing of the apparatus are discussed along with preliminary results.
[Contact: John Moreland, (303) 497-3641]

Petersen, T.W., and Goldfarb, R.B., **Effect of Mechanical Deformation on Nb-Ti Filament Proximity-Effect Coupling at the Edges of SSC Cables**, IEEE Transactions on Magnetics, Vol. 27, No. 2, pp. 1809-1810 (March 1991).

Magnetization as functions of transverse magnetic field and time was measured for short strands extracted from the centers and edges of five Nb-Ti Rutherford cables designed for use in superconducting-super-collider dipole magnets. The strands all had 6-μm diameter filaments. Edge samples, which had severe mechanical deformation, showed small magnetic coupling losses at low fields, compared to no coupling losses for undeformed center strands. This suggests that the cabling process decreases the interfilament spacing to the order of the coherence length in the normal matrix material, resulting in an increase in effective filament diameter and hysteresis loss at low fields. Microscopic studies of the cables' cross sections confirmed smaller interfilament separations in these samples. Flux creep measurements, represented by the time dependence of magnetization, showed little difference between edge and center samples. This indicates that the proximity-coupled matrix in edge samples is not a significant source of flux creep.
[Contact: Timothy W. Petersen, (303) 497-5333]

Roshko, A., Ono, R.H., Beall, J.A., Moreland, J., Nelson, A.J., and Asher, S.E., **Morphology of Silver on $YBa_2Cu_3O_{7-\delta}$ Thin Films**, IEEE Transactions on Magnetics, Vol. 27, No. 2, pp. 1616-1618 (March 1991).

The morphology of silver layers deposited and annealed on laser ablated YBCO films has been

examined as a function of the microstructure of the $YBa_2Cu_3O_{7-\delta}$ film, the thickness of the Ag layer, and the anneal time, temperature, and atmosphere. The most important parameter for maintaining uniform silver coverage during anneals is the thickness of the silver layer. For thin silver films, it may be possible to prevent dewetting of the YBCO by using short anneals at low temperatures.
[Contact: Alexana Roshko, (303) 497-5420]

Russek, S.E., Jeanneret, B., Rudman, D. A., and Ekin, J.W., **Properties of $YBa_2Cu_3O_{7-\delta}$ Thin Films Grown on Off-Axis-Cut MgO Substrates**, IEEE Transactions on Magnetics, Vol. 27, No. 2, pp. 931-934 (March 1991).

A series of $YBa_2Cu_3O_{7-\delta}$ films has been reactively sputtered on off-axis-cut MgO substrates. All the films were oriented with the c-axis normal to the substrate regardless of substrate orientation, indicating that growth dynamics is a major factor influencing film orientation on non-lattice matched substrates. As the substrate orientation is moved off the (100) direction, the films showed a decrease in transition temperature and showed properties indicative of an increased density of weak links. On high-angle substrates, the films showed improved properties over the films on low-angle substrates. Films grown on (110) MgO were as good as films grown on (100) MgO.
[Contact: Steven E. Russek, (303) 497-5097]

ELECTROMAGNETIC INTERFERENCE

Conducted EMI

Recently Published

Fenimore, C.P., Jr., and Martzloff, F.D., **Incompatibility Between the 100/1300 Surge Test and Varistor Failure Rates**, Proceedings of the Ninth International Zurich Symposium and Technical Exhibition on Electromagnetic Compatibility, Zurich, Switzerland, March 12-14, 1991, pp. 525-530 (1991).

A proposed high-energy surge test featuring a 100/1300-µs waveform and a peak voltage of 2.3 times the peak voltage of the low-frequency mains is under consideration by the IEC. The energy storage capacitor suggested for the surge generator, originally specified as high as 25 000 µF, has been scaled down but is still at a level of several thousand microfarads. A simple but realistic mathematical model is integrated numerically to determine the energy dissipated in such a test. The energy that would be deposited into a varistor of the voltage rating commonly used in protecting load equipment, if subjected to this test, far exceeds the capability of the varistor, but reported varistor failure rates do not reflect such a situation. Thus, a reexamination of the premises that led to the 100/1300-µs test specifications appears necessary.
[Contact: Charles P. Fenimore, Jr., (301) 975-2428]

Martzloff, F.D., and Pellegrini, G., **Real, Realistic Ring Waves for Surge Testing**, Proceedings of the Ninth International Zurich Symposium and Technical Exhibition on Electromagnetic Compatibility, Zurich, Switzerland, March 12-14, 1991, pp. 499-504 (1991).

Five independent investigations on the coupling of surges into low-voltage circuits (data or power lines), and of their effects, show that a damped oscillatory transient is a real, realistic stress for equipment connected to these lines.
[Contact: Francois D. Martzloff, (301) 975-2409]

Radiated EMI

Released for Publication

Randa, J., Kanda, M., and Orr, D., **Resistively-Tapered-Dipole Electric-Field Probes up to 40 GHz**, to be published in the Proceedings of the IEEE International EMC Symposium, Cherry Hill, New Jersey, August 13-15, 1991.

We have developed an electric-field probe for use as a transfer standard at frequencies up to 40 GHz. The lower frequency cutoff is below 1 MHz. The design is based on the resistively-tapered-dipole (RTD) probes developed for frequencies up to 18 GHz. Those probes used 8-mm tapered dipoles. In this work, we have used 6-, 4- and 2-mm dipoles to extend the frequency range. Because the new probes are isotropic, have relatively flat frequency response, and have a response which drops off outside their operating frequency range, they could also be used as hazard meters.
[Contact: James P. Randa, (303) 497-3150]

Recently Published

Adams, J. W., **Status Report on Shielding Effectiveness Measurements: Release of ASTM Standard D4935-89**, Proceedings of the Fourth International Society for the Advancement of Material and Process Engineering (SAMPE) Conference, Albuquerque, New Mexico, June 13, 1990, pp. 1-9 (1991).

ASTM (formerly the American Society of Testing and Materials) released Standard D4935-89, Standard Test Method for Measuring the Electromagnetic Shielding Effectiveness of Planar Materials, in November 1989. Some background efforts of ASTM Committee D.09.12.14 to accomplish this are reviewed, with emphasis on results of the measurement round robins that led to the acceptance of the standard in April of 1989. Very good agreement was obtained during these round robins conducted by five different workers at five different organizations. The samples used were plastic based, but treated three different ways. Surface roughness of the sample is an important factor in determining measurement uncertainty. The design of the sample holder and the measurement procedure given in this ASTM standard were developed at the National Institute of Standards and Technology (NIST). The comprehensive effort at NIST also established why this measurement method was chosen over numerous others. How and when calculations can be used to obtain near-field data from the measured far-field data are covered.
[Contact: John W. Adams, (303) 497-3328]

Camell, D.G., Larsen, E.B., Cruz, J.E., and Hill, D.A., **NIST Calibration Procedure for Vertically Polarized Monopole Antennas, 30 kHz to 300 MHz**, NIST Technical Note 1347 (January 1991).

This report describes the theoretical basis and test procedure for vertically polarized monopole antenna calibrations at the National Institute of Standards and Technology (NIST). The standard field method applies the theoretical equations of a vertical monopole antenna to calculate the vertical electric field. This method is used at the NIST open-field site in the frequency range of 30 kHz to 300 MHz. The uncertainty in the antenna factor of the antenna under test (AUT) is now ±1 dB.
[Contact: Dennis G. Camell, (303) 497-3214]

Hill, D.A., **A Generalization of the Cornu Spiral for Lossy Media**, Journal of Applied Physics, Vol. 69, No. 3, pp. 1772-1774 (1 February 1991).

The classical problem of Fresnel diffraction by a straightedge is extended to allow for loss in the medium. The loss modifies the usual Cornu spiral solution because the argument of the Fresnel integral becomes complex. For high loss the contributions of the outer Fresnel zones are highly attenuated.
[Contact: David A. Hill, (303) 497-3472]

Kanda, M., and Randa, J., **Estimation of Electromagnetic Fields in Complex Environments** [original title: Possible Estimation Methodologies for Electromagnetic Field Distributions in Complex Environments], Proceedings of the Ninth International Zurich Symposium and Technical Exhibition on Electromagnetic Compatibility, Zurich, Switzerland, March 12-14, 1991, pp. 337-342 (1991).

The problem of measuring and characterizing complicated multiple-source, multiple-frequency electromagnetic environments is becoming more important and more difficult as electrical devices proliferate. This paper reviews three general approaches to the problem which have been investigated at the National Institute of Standards and Technology. The three approaches are: 1) a statistical treatment of the spatial distribution of electromagnetic field intensities, 2) a numerical computation using a finite-element (or lattice) form of the electromagnetic action functional, and 3) use of a directional probe to scan a volume. All three methods are still in the development stage, but each appears promising.
[Contact: Motohisa Kanda, (303) 497-5320]

Randa, J.P., **Simultaneous vs. Independent Injection Testing of Nonlinear Multiport Systems**, Proceedings of the Ninth International Zurich Symposium and Technical Exhibition on Electromagnetic Compatibility, Zurich, Switzerland, March 12-14, 1991, pp. 71-74 (1991).

This paper is a theoretical investigation of the question whether, in injection testing of a multiport system, all ports must be injected and tested simultaneously. A general, nonlinear, three-port system is analyzed. Conditions under which the ports can be tested separately are derived, and problems with the practical application of these conditions are pointed out. Systems with memory are also treated,

and the extension to general multiports is given. The relevance to bulk injection testing is discussed.
[Contact: James P. Randa, (303) 497-3150]

Wilson, P.F., and Ma, M.T., **Fields Radiated by Electrostatic Discharges**, IEEE Transactions on Electromagnetic Compatibility, Vol. 33, No. 1, pp. 10-18 (February 1991).

Electrostatic discharge (ESD) metrology has, to date, primarily focused on the ESD current waveforms in order to develop simulators for susceptibility testing. Significantly less attention has been given to the fields generated by an ESD event. This paper examines ESD fields both analytically and experimentally. Measurements indicate that the electric fields can be quite significant (≥150 V/m at a distance of 1.5 m, for example) for short periods of time (a few nanoseconds), particularly for relatively low-voltage events (≤6 kV). A relatively simple dipole model of an ESD spark is developed and used to predict the radiated fields. The agreement between theory and experiment is fair. The model may be used to predict ESD fields for a wide range of possible configurations, particularly in the near-field zone where no measurements are presently available.
[Contact: Mark T. Ma, (303) 497-3800]

ADDITIONAL INFORMATION

Lists of Publications

DeWeese, M.E., **Metrology for Electromagnetic Technology: A Bibliography of NIST Publications**, NISTIR 3946 (August 1990).

This bibliography lists the publications of the personnel of the Electromagnetic Technology Division of NIST in the period from January 1970 through publication of this report. A few earlier references that are directly related to the present work of the Division are included.
[Contact: Sarabeth Moynihan, (303) 497-3678]

Lyons, R.M., and Gibson, K.A., **A Bibliography of the NIST Electromagnetic Fields Division Publications**, NISTIR 3945 (August 1990).

This bibliography lists publications by the staff of the National Institute of Standards and Technology's Electromagnetic Fields Division for the period from January 1970 through August 1990. Selected earlier publications from the Division's predecessor organizations are included.
[Contact: Kathryn A. Gibson, (303) 497-3132]

Palla, J.C., and Meiselman, B., **Electrical and Electronic Metrology: A Bibliography of NIST Electricity Division's Publications, NIST List of Publications 94** (January 1991).

This bibliography covers publications of the Electricity Division, Center for Electronics and Electrical Engineering, NIST, and of its predecessor sections for the period January 1968 to December 1990. A brief description of the Division's technical program is given in the introduction.
[Contact: Jenny C. Palla, (301) 975-2220]

Walters, E.J., **Semiconductor Measurement Technology, NIST List of Publications 72** [a bibliography of NIST publications concerning semiconductor measurement technology for the years 1962-1989] (March 1990), and **LP72 Supplement, Publications for the Year 1990** (April 1991).

The bibliography contains reports of work performed at the National Institute of Standards and Technology in the field of Semiconductor Measurement Technology in the period from 1962 through December 1990. An index by topic area and a list of authors are provided. The supplement provides information on technology transfer at NIST for calendar year 1990, not only from those groups specializing in semiconductor electronics, but also including NIST-wide research now coordinated by the NIST Office of Microelectronics Programs.
[Contact: E. Jane Walters, (301) 975-2050]

New NIST Research Material

NIST has announced the availability of **Research Material 8458**, a well-characterized artificial flaw used as an **artifact standard in eddy current nondestructive evaluation (NDE)**. The new Research Material (RM) is the outcome of work carried out by the Electromagnetic Technology Division to address the need for calibration standards for eddy-current NDE, for example, as used to detect fatigue cracks in aircraft structures. The RM flaw is produced in an annealed aluminum alloy block by first indenting the block and

then compressively deforming the resulting notch until it is tightly closed. The next operation is to restore a flat finish to the block face, after which the block is heat treated to the original temper. The controlled flaw has been named the "CDF notch," after its inventors (listed on patent application) Thomas E. Capobianco (Electromagnetic Technology Division), William P. Dube (Division 832), and Ken Fizer (Naval Aviation Depot, NAS Norfolk, Virginia).

In the past, the challenge has been to manufacture artificial flaws that closely simulate the mechanical properties of fatigue cracks. Currently used artifacts include electrical-discharge-machined and saw-cut notches, both of which are relatively poor representations of fatigue cracks as their widths are too great. The Division-developed method provides notches that can be made controllably in a variety of geometries, have known dimensions, with widths that are narrow enough to provide an acceptable representation of fatigue cracks.

An NIST Research Material is not certified by NIST, but meets the International Standards Organization definition of "a material or substance one or more properties of which are sufficiently well established to be used in the calibration of an apparatus, the assessment of a measurement method, or for assigning values to materials." The documentation issued with RM 8458 is a "Report of Investigation." Contact: technical information — Fred Fickett, (303) 497-3785; order information — Standard Reference Materials Program, (301) 975-6776.

Emerging Technologies in Electronics ... and Their Measurement Needs, Second Edition

This report assesses the principal measurement needs that must be met to improve U.S. competitiveness in emerging technologies within several fields of electronics: semiconductors, superconductors, magnetics, optical fiber communications, optical fiber sensors, lasers, microwaves, video, and electromagnetic compatibility. The report seeks feedback from industry and Government agencies on the assessment. The feedback will guide the development of NIST programs that provide U.S. industry with new documented measurement methods, new national reference standards to assure the accuracy of those measurement methods, and new reference data for electronic materials. Copies may be obtained by ordering Report No. PB90-188087/AS ($23.00 hard copy, $11.00 microfiche) from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161, (703) 487-4650.

1991 EEEL CALENDAR

August 27-30 (Vail and Boulder, CO)

Laser Measurements Short Course. In cooperation with the University of Colorado and industry, NIST is offering a three-and-one-half day course emphasizing the concepts, techniques, and apparatus used in measuring laser parameters. Topics in the course syllabus include optics for laser measurements, attenuation techniques, laser operation, basic laser power/energy standards, laser power/energy measurement techniques, optical fiber power measurements, pulse measurements, transfer standards, beam-profile measurements, diode lasers, laser measurements for optical communications, statistics and error analysis, laser safety, and detectors. The course will incorporate a visit to the NIST laser measurement laboratories. [Contact: Thomas Scott, (303) 497-3651 for information on the technical content of the program; for all other information, Office of Conference Services, University of Colorado at Boulder, (303) 492-5151.]

September 5, 1991 (Gaithersburg, MD)

Ion Implant Users Group. Upgrades to ion implanters extend their useful life and expand their flexibility. At this meeting, a series of technical presentations on ion implanter upgrades is planned. The general topic for the meeting is *Retro-fits* and *Upgrades*. The Group is open to anyone who has an interest in ion implantation.
[Contact: John Albers, (301) 975-2075]

September 8-11, 1991 (Research Triangle Park, NC)

Third Workshop on Radiation-Induced and/or Process-Related Electrically Active Defects in Semiconductor-Insulator Systems. This workshop is sponsored by the Microelectronics Center of North Carolina (MCNC), North Carolina State University, and the University of North Carolina at Charlotte, in cooperation with the Semiconductor Research Corporation, the IEEE Electron Devices Society, and the National Institute of Standards and Technology.

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then compressively deforming the resulting notch until it is tightly closed. The next operation is to restore a flat finish to the block face, after which the block is heat treated to the original temper. The controlled flaw has been named the "CDF notch," after its inventors (listed on patent application) Thomas E. Capobianco (Electromagnetic Technology Division), William P. Dube (Division 832), and Ken Fizer (Naval Aviation Depot, NAS Norfolk, Virginia).

In the past, the challenge has been to manufacture artificial flaws that closely simulate the mechanical properties of fatigue cracks. Currently used artifacts include electrical-discharge-machined and saw-cut notches, both of which are relatively poor representations of fatigue cracks as their widths are too great. The Division-developed method provides notches that can be made controllably in a variety of geometries, have known dimensions, with widths that are narrow enough to provide an acceptable representation of fatigue cracks.

An NIST Research Material is not certified by NIST, but meets the International Standards Organization definition of "a material or substance one or more properties of which are sufficiently well established to be used in the calibration of an apparatus, the assessment of a measurement method, or for assigning values to materials." The documentation issued with RM 8458 is a "Report of Investigation." Contact: technical information — Fred Fickett, (303) 497-3785; order information — Standard Reference Materials Program, (301) 975-6776.

Emerging Technologies in Electronics ... and Their Measurement Needs, Second Edition

This report assesses the principal measurement needs that must be met to improve U.S. competitiveness in emerging technologies within several fields of electronics: semiconductors, superconductors, magnetics, optical fiber communications, optical fiber sensors, lasers, microwaves, video, and electromagnetic compatibility. The report seeks feedback from industry and Government agencies on the assessment. The feedback will guide the development of NIST programs that provide U.S. industry with new documented measurement methods, new national reference standards to assure the accuracy of those measurement methods, and new reference data for electronic materials. Copies may be obtained by ordering Report No. PB90-188087/AS ($23.00 hard copy, $11.00 microfiche) from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161, (703) 487-4650.

1991 EEEL CALENDAR

August 27-30 (Vail and Boulder, CO)

Laser Measurements Short Course. In cooperation with the University of Colorado and industry, NIST is offering a three-and-one-half day course emphasizing the concepts, techniques, and apparatus used in measuring laser parameters. Topics in the course syllabus include optics for laser measurements, attenuation techniques, laser operation, basic laser power/energy standards, laser power/energy measurement techniques, optical fiber power measurements, pulse measurements, transfer standards, beam-profile measurements, diode lasers, laser measurements for optical communications, statistics and error analysis, laser safety, and detectors. The course will incorporate a visit to the NIST laser measurement laboratories. [Contact: Thomas Scott, (303) 497-3651 for information on the technical content of the program; for all other information, Office of Conference Services, University of Colorado at Boulder, (303) 492-5151.]

September 5, 1991 (Gaithersburg, MD)

Ion Implant Users Group. Upgrades to ion implanters extend their useful life and expand their flexibility. At this meeting, a series of technical presentations on ion implanter upgrades is planned. The general topic for the meeting is *Retro-fits* and *Upgrades*. The Group is open to anyone who has an interest in ion implantation.
[Contact: John Albers, (301) 975-2075]

September 8-11, 1991 (Research Triangle Park, NC)

Third Workshop on Radiation-Induced and/or Process-Related Electrically Active Defects in Semiconductor-Insulator Systems. This workshop is sponsored by the Microelectronics Center of North Carolina (MCNC), North Carolina State University, and the University of North Carolina at Charlotte, in cooperation with the Semiconductor Research Corporation, the IEEE Electron Devices Society, and the National Institute of Standards and Technology.

Some areas of interest are: relationships between processing and electrically active defect densities, measurement methods, theoretical modeling of electrically active defects, process control of the sensitivity of insulators to ionizing radiation, removal of radiation damage, controlled radiation standard sources, and memory effects.
[Contact: Jeremiah R. Lowney, (301) 975-2048]

September 29 and October 1-2, 1991 (Scottsdale, AZ)

11th VLSI and GaAs Packaging Workshop. This 11th annual workshop is co-sponsored by the IEEE CHMT Society and the National Institute of Standards and Technology. Topics to be discussed include: VLSI package design, integrated package design, multichip module design, package thermal and electrical design, GaAs IC packaging, VLSI package interconnection options, VLSI package materials and die-attach solutions, and failure mechanism and quality of VLSI packages. Contact: George G. Harman, (301) 975-2097.

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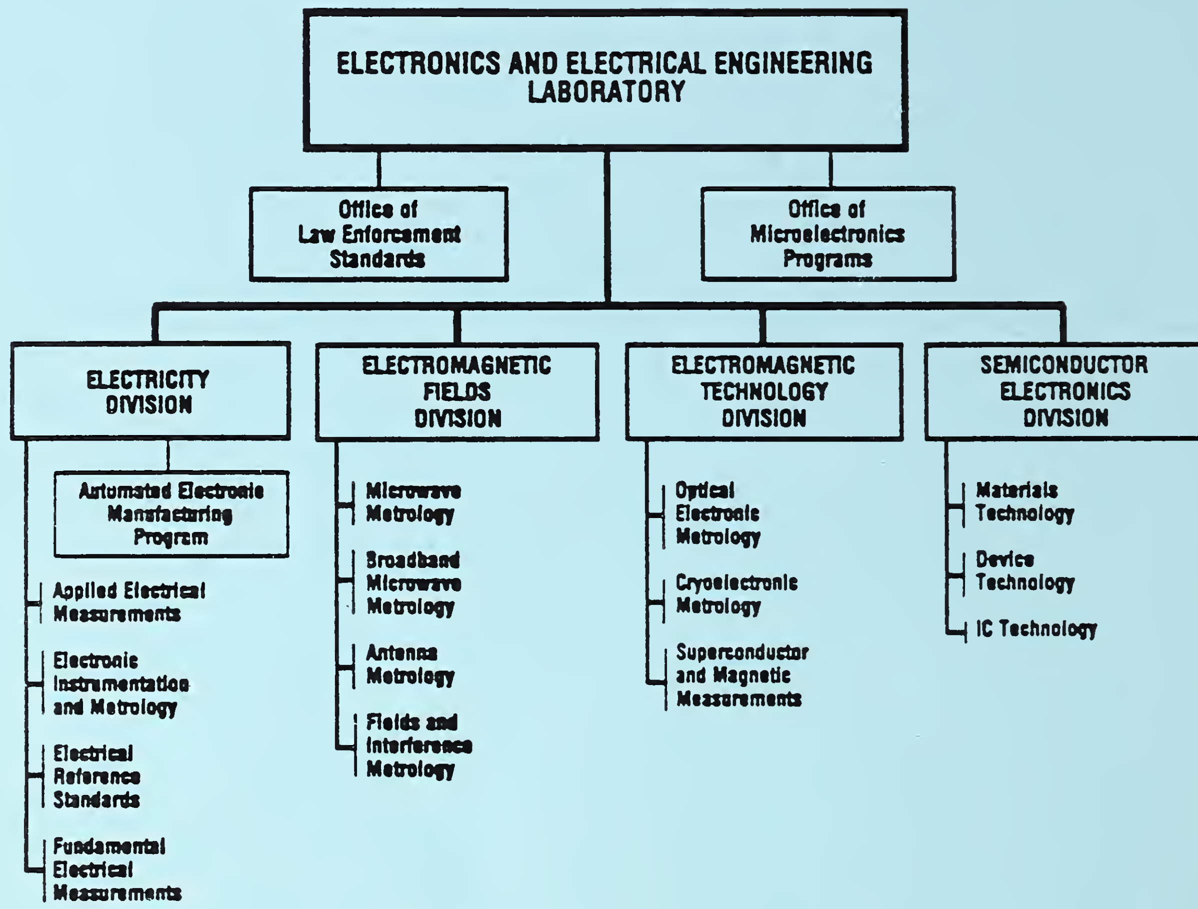

KEY CONTACTS

Laboratory Headquarters (810)	Director, Mr. Judson C. French (301) 975-2220
	Deputy Director, Dr. Robert E. Hebner (301) 975-2220
Office of Microelectronics Programs	Director, Mr. Robert I. Scace (301) 975-4400
Office of Law Enforcement Standards	Director, Mr. Lawrence K. Eliason (301) 975-2757
Electricity Division (811)	Chief, Dr. Oskars Petersons (301) 975-2400
Semiconductor Electronics Division (812)	Chief, Mr. Frank F. Oettinger (301) 975-2054
Electromagnetic Fields Division (813)	Chief, Dr. Ramon C. Baird (303) 497-3131
Electromagnetic Technology Division (814)	Chief, Dr. Robert A. Kamper (303) 497-3535

INFORMATION:

For additional information on the Electronics and Electrical Engineering Laboratory, write or call:

Electronics and Electrical Engineering Laboratory
National Institute of Standards and Technology
Metrology Building, Room B-358
Gaithersburg, MD 20899
Telephone: (301) 975-2220