NISTIR 6078

Electronics and Electrical Engineering Laboratory

J. M. Rohrbaugh
Compiler

Technical Publication Announcements

52

Covering Laboratory Programs,
January to March 1997,
with 1997-1998 EEEL Events Calendar

U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Institute of Standards
and Technology

NIST

NISTIR 6078

Electronics and Electrical Engineering Laboratory

J. M. Rohrbaugh
Compiler

Electronics and Electrical
Engineering Laboratory
Semiconductor Electronics Division
Gaithersburg, MD 20899-0001

Technical Publication Announcements

October 1997

52

Covering Laboratory Programs,
January to March 1997,
with 1997-1998 EEEL Events Calendar

U.S. DEPARTMENT OF COMMERCE
William M. Daley, Secretary
TECHNOLOGY ADMINISTRATION
Gary Bachula, Acting Under Secretary
for Technology
NATIONAL INSTITUTE OF STANDARDS
AND TECHNOLOGY
Robert E. Hebner, Acting Director

INTRODUCTION TO THE EEEL TECHNICAL PUBLICATION ANNOUNCEMENTS

This is the fifty-second issue of a publication providing information on the technical work of the National Institute of Standards and Technology Electronics and Electrical Engineering Laboratory (EEEL). This issue of the EEEL Technical Publication Announcements covers the first quarter of calendar year 1997.

Organization of Bulletin: This issue contains citations and abstracts for Laboratory publications published in the quarter. Entries are arranged by technical topic as identified in the Table of Contents and alphabetically by first author within each topic. 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 years 1997 and 1998 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 five technical research Divisions: the Semiconductor Electronics and the Electricity Divisions in Gaithersburg, Md., and the Electromagnetic Fields, Electromagnetic Technology Divisions, and the newly formed Optoelectronics Division in Boulder, Colo. The Office of Law Enforcement Standards conducts research and provides technical services to the U.S. Department of Justice and State and local governments, and other agencies in support of law enforcement activities. In addition, the Office of Microelectronics Programs (OMP) coordinates 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 inside 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 20.

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 17.

Certain commercial equipment, instruments, or materials are identified in this paper in order to specify adequately the experimental procedures. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

Internet Access (World Wide Web): http://www.eeel.nist.gov

TO LEARN MORE ABOUT THE LABORATORY...

Two general documents are available that may be of interest. These are ***EEEL 1996 Technical Accomplishments, Advancing Metrology for Electrotechnology to Support the U.S. Economy*** and ***Measurements for Competitiveness in Electronics.*** The first presents selected technical accomplishments of the Laboratory for the period October 1, 1995 through September 30, 1996. A brief indication of the nature of the technical achievement and the rationale for its undertaking are given for each example. The second identifies measurement needs for a number of technical areas and the general importance of measurements to competitiveness issues. The findings of each chapter dealing with an individual industry have been reviewed by members of that industry. A longer description of both documents follows:

EEEL 1996 Technical Accomplishments, Advancing Metrology for Electrotechnology to Support the U.S. Economy, NISTIR 5941 (December 1996).

The Electronics and Electrical Engineering Laboratory, working in concert with other NIST Laboratories, is providing measurement and other generic technology critical to the competitiveness of the U.S. electronics industry and the U.S. electricity-equipment industry. This report summarizes selected technical accomplishments and describes activities conducted by the Laboratory in FY 1996 in the field of semiconductors, magnetics, superconductors, low-frequency microwaves, lasers, optical fiber communications and sensors, video, power, electromagnetic compatibility, electronic data exchange, and national electrical standards. Also included is a profile of EEEL's organization, its customers, and the Laboratory's long-term goals.

EEEL is comprised of five technical divisions, Electricity and Semiconductor Electronics in Gaithersburg, Maryland, and Electromagnetic Fields, Electromagnetic Technology, and Optoelectronics in Boulder, Colorado. Through two offices, the Laboratory manages NIST-wide programs in microelectronics and law enforcement.
[Contact: JoAnne Surette, (301) 975-5267]

Measurements for Competitiveness in Electronics, NISTIR 4583 (April 1993).

Measurements for Competitiveness in Electronics identifies for selected technical areas the measurement needs that are most critical to U.S. competitiveness, that would have the highest economic impact if met, and that are the most difficult for the broad range of individual companies to address. The document has two primary purposes: (1) to show the close relationship between U.S. measurement infrastructure and U.S. competitiveness and show why improved measurement capability offers such high economic leverage, and (2) to provide a statement of the principal measurement needs affecting U.S. competitiveness for given technical areas, as the basis for a possible plan to meet those needs, should a decision be made to pursue this course.

The first three chapters, introductory in nature, cover the areas of: the role of measurements in competitiveness, NIST's role in measurements, and an overview of U.S. electronics and electrical-equipment industries. The remaining nine chapters address individual fields of electronic technology: semiconductors, magnetics, superconductors, microwaves, lasers, optical-fiber communications, optical-fiber sensors, video, and electromagnetic compatibility. Each of these nine chapters contains four basic types of information: technology review, world markets and U.S. competitiveness, goals of U.S. industry for competitiveness, and measurement needs. Three appendices provide definitions of the U.S. electronics and electrical-equipment industries.
[Contact: Ronald M. Powell, (301) 975-2220]

TABLE OF CONTENTS

FUNDAMENTAL ELECTRICAL MEASUREMENTS

Cage, M.E., and Jeffery, A.-M., **Intrinsic Capacitances and Inductances of Quantum Hall Effect Devices**, Journal of Research of the National Institute of Standards and Technology, Vol. 101, No. 6, pp. 733-744 (November–December 1996).

Analytic solutions are obtained for the internal capacitances, kinetic inductances, and magnet inductances of quantum Hall effect devices to investigate whether or not the quantized Hall resistance is the only intrinsic impedance of importance in measurements of the ac quantum Hall effect. The internal capacitances and inductances are obtained by using results of Cage and Lavine, who determined the current and potential distributions across the widths of quantum Hall effect devices. These intrinsic capacitances and inductances produce small out-of-phase impedance corrections to the quantized Hall resistance and the longitudinal resistance.
[Contact: Marvin E. Cage, (301) 975-4224]

SEMICONDUCTOR MICROELECTRONICS

Compound Materials

Anderson, G.W., Kub, F.J., Carruthers, T.F., Papanicolaou, N.A., Frankel, M.Y., Katzer, D.S., Modolo, J.A., and Tseng, W.F., **Planar, $Al_{0.3}Ga_{0.7}As$-Passivated-Base, Heterojunction Bipolar Phototransistors**, Applied Optics, Vol. 36, No. 4, pp. 760-764 (1 February 1997).

New planar GaAs heterojunction bipolar phototransistors have been designed and demonstrated. The devices use a $GaAs/Al_{0.3}Ga_{0.7}As$ molecular-beam-epitaxy materials system with an $Al_{0.3}Ga_{0.7}As$ passivated, 10 nm thick base; a depleted, high-low emitter; and a low emitter-base capacitance. Electrical contact to the emitter is made by a set of parallel, ohmic fingers and to the collector by an ohmic contact formed in a large $\sim$1.48 μm deep via. Rise times in response to impulse optical excitation at 810 nm measured at 810 nm and 850 nm were 0.67-19, depending on experimental conditions. These devices are promising for use in heterodyne photodetector arrays for coherent optical processing channelizers requiring a 100 MHz bandwidth.
[Contact: Wen F. Tseng, (301) 975-5291]

Tseng, W.F., Chandler-Horowitz, D., Papanicolaou, N.A., and Boos, J.B., **Interdigitated Hetero InGaAs/GaAs n-i-p-i Modulators**, Materials Letters, Vol. 29, pp. 249-253 (December 1996).

Interdigitated hetero InGaAs n-i-p-i InGaAs/GaAs modulators have been grown and fabricated by a shadow mask technique for selectively making contacts to n- and p-layers. Manipulations of exciton peak positions and intensities by external electrical bias and incident optical power have been demonstrated.
[Contact: Wen F. Tseng, (301) 975-5291]

Device Physics and Modeling

Adams, V.H., Blackburn, D.L., Joshi, Y., and Berning, D.W., **Issues in Validating Package Compact Thermal Models for Natural Convection Cooled Electronic Systems**, Proceedings of the Thirteenth Annual IEEE Semiconductor Thermal Measurement and Management Symposium - SEMITHERM XIII, Austin, Texas, January 28-30, 1997, pp. 10-23.

[See Packaging.]

Microfabrication Technology

Cavicchi, R.E., Semancik, S., DiMeo Jr., F., Suehle, J.S., Tea, N., Kreider, K.G., Chaparala, P., and Gaitan, M., **Temperature-Modulated Micro-Hotplate Gas Sensors**, Proceedings of the Sixth International Meeting on Chemical Sensors, Gaithersburg, Maryland, July 22-25, 1996 (unpaged).

A considerable body of sensor research has been devoted to the miniaturization of the Taguchi or tin oxide solid state gas sensor into a thin film device. The motivations are threefold, 1) to improve the poor selectivity of this device by fabricating arrays in which the array elements are either different in composition or in fixed operating temperature; 2) to reduce the power consumption so that small portable devices become possible; and 3) to reduce cost by using the batch fabrication techniques of this film processing. A fourth key advantage has

emerged from work on microsensors: the rapid thermal time constant (~1 ms) associated with small size allows rapid temperature modulation during operation. Temperature modulation can be used to change the time-constants for desorption, adsorption, and reaction of detected species during sensor operation. The temperature-dependence of the time-constants are different for different species. This produces a time-dependent response pattern which is characteristic of the species being detected.
[Contact: John S. Suehle, (301) 975-2247]

DeGroot, D.C., Rudman, D.A., Zhang, K., Ma, Q.Y., Kato, H., and Jaeger, N.A.F., **Planar Microwave Devices Fabricated by Ion-Implantation Patterning of High-Temperature Superconductors**, Applied Physics Letters, Vol. 69, No. 14, pp. 2119-2121 (30 September 1996).

[See Microwave and Millimeter-Wave Metrology.]

Gaitan, M., **Microheating Elements in CMOS Technology**, Proceedings of the 1996 IEEE International Symposium on Circuits and Systems, Atlanta, Georgia, May 12-15, 1996, pp. 5-8.

The miniaturization of heating elements offers two distinct advantages over conventional heaters: their small size allows the rapid temperature transient control of a small surface, on the order of 1 ms, and array integration, enabling the configuration of a temperature programmable surface. Since many physical, biological, and chemical phenomena can be controlled by temperature, microheating elements have many interesting and potential applications. Integration of microheating elements with CMOS technology allows the monolithic circuit integration with the heaters for control, sensing, and signal processing. This paper is an overview of CMOS-based microheating elements realized by an anisotropic chemical etch after the full CMOS process is complete.
[Contact: Michael Gaitan, (301) 975-2070]

Li, H.Q., Ono, R.H., Vale, L.R., Rudman, D.A., and Liou, S.H., **A Novel Multilayer Circuit Process Using $YBa_2Cu_3O_x$/Sr TiO_3 Thin Films Patterned by Wet Etching and Ion-Milling**, Applied Physics Letters, Vol. 69, No. 18, pp. 2752-2754 (28 October 1996).

[See Cryoelectronic Metrology.]

Tseng, W.F., Chandler-Horowitz, D., Papanicolaou, N.A., and Boos, J.B., **Interdigitated Hetero InGaAs/GaAs n-i-p-i Modulators**, Materials Letters, Vol. 29, pp. 249-253 (December 1996).

[See Compound Materials.]

Plasma Processing

Bretagne, J., Šimko, T., Gousset, G., Rao, M.V.V.S., Van Brunt, R.J., Wang, Y., Olthoff, J.K., Peko, B.L., and Champion, R.L., **Distributions of H^+, H_2^+ H_3^+ Ions in Townsend Discharge and Determination of Their Collision Cross Sections**, Proceedings of the Thirteenth European Sectional Conference on the Atomic and Molecular Physics of Ionised Gases, Poprad, Slovakia, August 27-30, 1996, pp. 115-116.

[See Power Systems Metrology.]

Christophorou, L.G., Olthoff, J.K., and Rao, M.V.V.S., **Electron Interactions with CHF_3**, Journal of Physical and Chemical Reference Data, Vol. 26, No. 1, pp. 1-15 (1997).

In this paper, we assess and synthesize the available information on the cross sections and the rate coefficients for collisional interactions of trifluoromethane (CHF_3) with electrons in an effort to build up a database on electronic and ionic collision processes that will aid the understanding of the behavior of CHF_3 in its use in manufacturing semiconductor devices and other applications. The limited data on the total and partial electron impact ionization and dissociation cross sections, total and partial cross sections for electron impact dissociation of CHF_3 into neutral species, electron-impact-induced line and continuous light emission from CHF_3, negative ion states of CHF_3, and the energetics of ionization, dissociation, and attachment are summarized and discussed. To our knowledge, no measurements are available of the cross sections of any of the electron scattering processes (elastic, momentum, vibrational, inelastic, etc.) or the electron transport, attachment, and ionization coefficients. While the available information is meager, the synthesis of the existing knowledge and the background information provided

in the paper can be helpful for modeling plasma reactors. Clearly, more measurements and calculations are needed of the cross sections for virtually all fundamental electron impact processes for this plasma processing gas. Measurements of the transport, attachment, and ionization coefficients over wide ranges of the density-reduced electric field are also needed.
[Contact: Loucas Christophorou, (301) 975-2432]

Christophorou, L.G., Olthoff, J.K., and Rao, M.V.V.S., **Electron Interactions with CF_4**, Journal of Physical and Chemical Reference Data, Vol. 25, No. 5, pp. 1341-2388 (September 1996).

Carbon tetrafluoride (CF_4) is one of the most widely used components of feed gas mixtures employed for a variety of plasma-assisted material-processing applications. It has no stable excited states and, in a plasma environment, is an ideal source of reactive species, especially F atoms. To assess the behavior of CF_4 in its use in manufacturing semiconductor devices and other applications, it is necessary to have accurate information about its fundamental properties and reactions, particularly its electronic and ionic interactions and its electron collision processes at low energies (<100 eV).

In this article, we assess and synthesize the available information on the cross sections and/or the rate coefficients for collisional interactions of CF_4 with electrons. Assessed information is presented on: (i) cross sections for electron scattering (total, momentum, elastic, differential, inelastic), electron impact ionization (total, partial, multiple, dissociative), electron impact dissociation (total, and for dissociative excitation), and electron attachment (total, and for specific anions); (ii) coefficients for electron transport (electron drift velocity, transverse and longitudinal electron diffusion coefficients), electron attachment, and electron impact ionization; and (iii) cross-section sets derived from analyses of electron transport data. The limited ionization data on CF_4 radicals are also presented, and references are given to measurements of electron transport properties of CF_4 gas mixtures. Based upon the assessment of published experimental data, recommended values for various cross sections and coefficients are generated which are presented in graphical and tabular form.
[Contact: Loucas Christophorou, (301) 975-2432]

Packaging

Adams, V.H., Blackburn, D.L., Joshi, Y., and Berning, D.W., **Issues in Validating Package Compact Thermal Models for Natural Convection Cooled Electronic Systems**, Proceedings of the Thirteenth Annual IEEE Semiconductor Thermal Measurement and Management Symposium - SEMITHERM XIII, Austin, Texas, January 28-30, 1997, pp. 10-23.

A methodology is proposed for the validation of compact thermal models of electronic packages which utilizes data and simulations obtained from a simple, but realistic system containing the package. The test system is the enclosure specified by the JEDEC Subcommittee, JC15.1 for thermal measurements in a natural convection environment. Simulations for a detailed model and several different compact models for a 88-pin plastic quad flat-package in the enclosure are in good agreement with experimental measurements of junction temperature. The study shows that the system must be well characterized, including accurate knowledge of circuit board thermal conductivity and accurate simulation of radiation heat transfer, to serve for validation purposes. For the package used in this study, system level considerations can outweigh package level considerations for predicting junction temperature. Given that the system is accurately modeled, the JEDEC enclosure can serve as a viable experimental validation tool for compact models.
[Contact: David L. Blackburn, (301) 975-2068]

Harman, G.G., **Wire Bonding to Multichip Modules and Other Soft Substrates**, Chapter in Multichip Modules with Integrated Sensors, W.K. Jones and G. Harsanyi, Eds. (Kluwer Academic Publishers, Dordrecht, The Netherlands, 1996), pp. 47-62.

Several classes of "soft substrates" can be difficult to wire bond. These include MCM-Ds, MCM-Ls, flex substrates, some complex IC chips with multilevel polymer-insulated metallization, and microwave hybrids made on PTFE substrates. The bonding solutions include: increasing the bond-pad metal thickness and area and applying a hard metal

under-layer, a hard metal top-layer, or some combination of these, capped with a highly bondable metal. A summary is given of the bond-pad metallurgy and bonding machine parameters that have produced successful wire bonding to a wide variety of MCMs and other "soft substrates." Wire bonding yield is also generally correlated to the elastic modulus and T_g of the polymer or laminate, and to the yield strength of the metal pads. Thus, the choice of material properties for the substrate and bond pads is at least as important as the actual bonding machine setup in achieving high-yield wire bonding. Other considerations, such as the possible use of high-frequency ultrasonic bonding and high-clock-rate skin-effect losses on the multilayer bond pads, are discussed.
[Contact: George G. Harman, (301) 975-2097]

Reliability

Suehle, J.S., and Chaparala, P., **Low Electric Field Breakdown of Thin SiO_2 Films Under Static and Dynamic Stress**, IEEE Transactions on Electron Devices, Vol. 44, No. 5, pp. 801-808 (May 1997).

A comprehensive study of Time-Dependent Dielectric Breakdown (TDDB) of 6.5, 9, 15, and 22 nm SiO_2 films under dc and pulsed bias has been conducted over a wide range of electric fields and temperatures. Very high temperatures were used at the wafer level to accelerate breakdown so tests could be conducted at electric fields as low as 4.5 MV/cm. New observations are reported for TDDB that suggest a consistent electric field and temperature dependence for intrinsic breakdown and a changing breakdown mechanism as a function of electric field. The results show that the logarithm of the median-test-time-to-failure log (t_{50}) is described by a linear electric field dependence, with a field acceleration parameter that is not dependent on temperature. It has a value of approximately 1 decade/MV/cm for the range of oxide thicknesses studied and shows a slight decreasing trend with decreasing oxide thickness. The thermal activation E_a ranged between 0.7 and 0.95 eV for electric fields below 9.0 MV/cm for all oxide thicknesses. TDDB tests conducted under pulsed bias indicate that increased dielectric lifetime is observed under unipolar and bipolar pulsed stress conditions, but diminishes as the stress electric field and oxide thickness are reduced. This observation provides new evidence that low electric field aging and breakdown is not dominated by charge generation and trapping.
[Contact: John S. Suehle, (301) 975-2247]

SIGNAL ACQUISITION, PROCESSING AND TRANSMISSION

Cryoelectronic Metrology

Li, H.Q., Ono, R.H., Vale, L.R., Rudman, D.A., and Liou, S.H., **A Novel Multilayer Circuit Process Using $YBa_2Cu_3O_x$/Sr TiO_3 Thin Films Patterned by Wet Etching and Ion-Milling**, Applied Physics Letters, Vol. 69, No. 18, pp. 2752-2754 (28 October 1996).

A process combining hydrofluoric acid (HF) and Ar^+ ion-milling has been used to make $YBa_2Cu_3O_x/SrTiO_3/YBa_2Cu_3O_x$ (YBCO/STO/YBCO) multilayer test circuits. Low-angle steps can be readily etched in STO and YBCO films with this process. YBCO lines crossing 5^o steps have about the same critical temperature T_c (89 K to 90 K) and critical current density J_c (>1 x 10^6 A/cm^2 at 86 K) as lines on planar surfaces. Via connections have the same T_c as other circuit components and adequate critical currents for most circuit designs.
[Contact: Ronald H. Ono, (303) 497-3762]

Antenna Metrology

Will, J.E., Norgard, J.D., Sega, R.M., Seifert, M., Pesta, A., Cleary, J., Stubenrauch, C.F., and MacReynolds, K., **Near-Field to Far-Field Antenna Pattern Measurements Using Infrared Imaging and Fourier Iterative Plane-To-Plane Techniques**, Proceedings of the 1996 Sixth Annual Dual-Use Technologies and Applications Conference, Syracuse, New York, June 3-6, 1996, pp. 266-271.

This paper describes the application of the "plane-to-plane" (PTP) iterative Fourier processing technique to infrared thermographic images of microwave fields to calculate the near-field and far-field patterns of radiating antennas. A resistive sheet is positioned in a radiating field, and a thermal "picture" is then taken of the heat pattern. Each pixel of this thermal image represents a measurement of the intensity (magnitude) of the field at the pixel location on the resistive sheet.

The PTP technique allows recovery of the phase by combining measurements made on two planes, both in the radiating near field of the antenna under test. Starting with an estimate of the phase and the measured magnitudes, Fourier processing techniques are used to iteratively "propagate" between the planes to determine the correct phase distribution at each plane. We describe the technique and show comparisons made between the predicted results and results from measured IR thermograms of the field of a 36-element patch array antenna operating at 4 GHz using the University of Colorado Springs (UCCS) Thermal Camera.
[Contact: Carl F. Stubenrauch, (303) 497-3927]

Will, J.E., Norgard, J., Stubenrauch, C.F., MacReynolds, K., Seifert, M., and Sega, R., **Phase Measurements of Electromagnetic Fields Using Infrared Imaging Techniques and Microwave Holography**, Proceedings of the SPIE, (The international Society for Optical Engineering, P.O. Box 10, Bellingham, Washington 98227-0010), Thermosense XVIII, Vol. 2766, pp. 323-333 (1996).

Complex (magnitude and phase) measurements of the near field of a radiating antenna over a known surface (usually a plane, cylinder, or sphere) can be used to determine its far-field radiation pattern using near-field to far-field Fourier transformations. Standard gain horn antennas are often used to probe the near field. Experimental errors are introduced into the near-field measurements by mechanical probe position inaccuracies and electrical probe interactions with the antenna under test and probe correction errors.

A minimally perturbing infrared (IR) imaging technique can be used to map the near fields of the antenna. This measurement technique is much simpler and easier to use than the probe method and eliminates probe position errors and probe correction errors. Current IR imaging techniques, which have been successfully used to rapidly map the relative magnitude of a radiating field at many locations (mXn camera pixels per image captured) over a surface, however, suffer from an inability to determine phase information.

Absolute magnitude and relative phase data can be obtained by empirical or theoretical calibration of the IR detector screens (used to absorb the radiated energy over the measurement plane) and by using techniques from microwave holography. For example, magnitude only measurements of the radiating field of an antenna at two different locations (over two different surfaces) in the near field of the antenna can be used to determine its complex (magnitude and phase) far-field radiation pattern using plane-to-plane iterative transformations.

This paper discusses the progress made to date in determining both magnitude and phase information from IR imaging data (IR Thermograms), thus, enabling near-field and far-field measurements of antenna patterns using IR thermal imaging techniques.
[Contact: Carl F. Stubenrauch, (303) 497-3927]

Microwave and Millimeter-Wave Metrology

DeGroot, D.C., Rudman, D.A., Zhang, K., Ma, Q.Y., Kato, H., and Jaeger, N.A.F., **Planar Microwave Devices Fabricated by Ion-Implantation Patterning of High-Temperature Superconductors**, Applied Physics Letters, Vol. 69, No. 14, pp. 2119-2121 (30 September 1996).

We have applied ion-implantation inhibit patterning as a new method of fabricating low-loss microwave transmission lines in high-temperature superconductor thin films. To determine the effectiveness of this technique, we fabricated coplanar waveguide transmission lines in $YBa_2Cu_3O_{7-\delta}$ thin films that had been deposited on $LaAlO_3$ substrates using pulsed laser deposition. Microwave characterizations of these lines are compared to a reference line fabricated with conventional ion milling. At 76 K and 12 GHz, the attenuation constants of the ion-implanted transmission lines are approximately 0.02 dB/mm, and the overall loss response is indistinguishable from that of the ion-milled device.
[Contact: Donald C. DeGroot (303) 497-7212]

DeGroot, D.C., Walker, D.F., and Marks, R.B., **Impedance Mismatch Effects on Propagation Constant Measurements**, Proceedings of the IEEE 5th Topical Meeting on Electrical

Performance of Electronic Packaging, Napa, California, October 28-30, 1996, pp. 141-143.

By measuring propagation constants of coplanar waveguide transmission lines, we show the significant systematic errors of common measurement techniques when the characteristic impedance of the lines does not match the reference impedance of the instrument.
[Contact: Donald C. DeGroot, (303) 4978-7212]

Ginley, R.A., **Dual 6-Port ANA Calibration with a Single Impedance Standard**, Digest of the 1996 Conference on Precision Electromagnetic Measurements, Braunschweig, Germany, June 17-20, 1996, pp. 532-533.

A newly developed method allows dual 6-port ANAs to be calibrated with a single, known one-port termination instead of air line standards. This technique is especially useful for low-frequency calibrations below 30 MHz where air lines cannot be adequately characterized.
[Contact: Ronald A. Ginley, (303) 497-3634]

Huang, D.-X., Rebuldela, G., and Harper, J., **RF-DC Differences of Micropotentiometers**, Digest of the 1996 Conference on Precision Electromagnetic Measurements, Braunschweig, Germany, June 17-20, 1996, pp. 460-461.

Various sources of rf-dc differences of a micropotentiometer (μpot) are analyzed and calculated, and the results agree well with the experiments. A new design reduces the rf-dc differences of μpot significantly. Observations show good stability over a long period, which makes μpots suitable as primary rf and audio standards in the microvolt and millivolt ranges.
[Contact: Gregorio Rebuldela, (303) 497-3561]

Marks, R.B., Jargon, J.A., and Juroshek, J.R., **Calibration Comparison Method for Vector Network Analyzers**, Proceedings of the 48th Automatic Radio Frequency Techniques Group, Clearwater, Florida, December 5-6, 1996, pp. 38-45.

We present a technique for comparing the scattering parameter measurements made with respect to two vector network analyzer calibrations. This method determines the worst-case measurement error bounds on any calibration from a benchmark calibration, assuming the two are similar to first order. We illustrate our method by examining the differences between an open-short-load-thru and a sliding load calibration, both of which are available commercially on a variety of vector network analyzers.
[Contact: Roger B. Marks, (303) 497-3037]

Williams, D.F., **Calibration in Multiconductor Transmission Lines**, Proceedings of the 48th Automatic Radio Frequency Techniques Group, Clearwater, Florida, December 5-6, 1996, pp. 46-53.

This paper presents a calibration and measurement method for circuits embedded in lossy printed multiconductor transmission lines. The experimental results illustrate the complexity of the modal representation and the utility of the conductor representation for circuit design.
[Contact: Dylan F. Williams, (303) 497-3138]

Williams, D.F., and Olyslager, F., **Modal Cross Power in Quasi-TEM Transmission Lines**, IEEE Microwave and Guided Letters, Vol. 6, No. 11, pp. 413-415 (November 1996).

This letter examines modal cross power in electromagnetic transmission lines. It shows that the cross powers of nearly degenerate modes may be large in quasi-TEM multiconductor transmission lines typical of modern electronic circuits at moderate and low microwave frequencies. The letter develops simple expressions to estimate the magnitude of these cross powers from the "power-normalized" conductor impedance and admittance matrices of the lines.
[Contact: Dylan F. Williams, (303) 497-3138]

Electromagnetic Properties

Jones, C.A., Kantor, Y., and Grosvenor, J.H., **Permittivity Measurements of Low-Loss Dielectric Materials at 60 GHz**, Proceedings of the SPIE (The International Society for Optical Engineering, P.O. Box 10, Bellingham, Washington 98227-0010), Millimeter and Submillimeter Waves and Applications III, Vol. 2842, pp. 263-273 (1996).

The National Institute of Standards and Technology is developing a Fabry-Perot resonator to measure the permittivity of materials at 60 GHz. The system is designed to operate in a semi-confocal configuration with the ability to adapt the system for high-temperature measurements. This talk will focus on design of the system, mode, identification, and measurements of permittivity for three low-loss materials.
[Contact: Chriss A. Jones, (303) 497-5958]

Krupka, J., Geyer, R.G., Baker-Jarvis, J., and Ceremuga, J., **Measurements of the Complex Permittivity of Microwave Circuit Board Substrates Using Split Dielectric Resonator and Reentrant Cavity Techniques**, Proceedings of the Seventh International Conference on Dielectric Materials Measurements and Applications, University of Bath, United Kingdom, September 23-26, 1996, pp. 21-24.

Dielectric properties of microwave circuit board materials are usually measured with stripline or microstripline resonator techniques. These techniques have two disadvantages. First, it is difficult to measure dielectric loss tangent of low-loss materials, because conductor losses in such resonators are large and are usually not known accurately. Second, it is difficult to measure particular tensor components of anisotropic materials. We propose a split dielectric resonator technique for measurements of the complex permittivity of isotropic materials and a combination of this method and the re-entrant cavity for characterization of the complex permittivity of anisotropic materials.
[Contact: Richard G. Geyer, (303) 497-5852]

Lewis, R.L., **Relative Permittivity Measurement of Square Copper-Laminated Substrates Using the Full-Sheet Resonance Technique**, NISTIR 5053 (January 1997).

A measurement program has been undertaken at NIST to evaluate the full-sheet resonance (FSR) technique from which consistent relative permittivity values have been obtained. Here, we present an analysis of the theory underlying the FSR technique, along with a theoretical formulation correcting full two-port scattering-matrix measurements of a resonant cavity for the effects of coupling between the external measurement circuit and the cavity. A circuit analysis modeling the resonant cavity and its external circuit is presented, along with a least-squares solution for the resonant cavity's primary resonance parameters. The least-squares analysis features a slight rearrangement of an earlier formulation leading to a more numerically stable solution. An even earlier solution for a resonant cavity's unloaded quality factor also using a least-squares solution to obtain a coupling correction is presented for comparison. The application of these coupling correction formulations to the FSR technique is discussed, and results from these two correction formulations are compared with uncorrected results for two sample FSR panels. Computed least-squares data-scatter uncertainties are obtained for each FSR permittivity measurement, which are then used to obtain overall uncertainty estimates for each panel's measured permittivity, including a repeatability uncertainty estimate. These overall uncertainty estimates are compared to our earlier uncorrected FSR uncertainty estimate, showing a tightening of the uncertainty interval for corrected measurements. Finally, our measured FSR permittivities are compared with re-entrant cavity substrate permittivity measurements, showing agreement within expected uncertainty limits between the two techniques.
[Contact: Richard L. Lewis, (303) 497-5196]

Paulter, N.G., **A Fast and Accurate Method for Measuring the Dielectric Constant of Printed Wiring Board Materials**, IEEE Transactions on Components, Packaging, and Manufacturing Technology, Part C, Vol. 19, No. 3, pp. 214-225 (June 1996).

A new time-domain-reflectometry measurement method is described that provides accurate measurements of the average high-frequency (0.1 GHz to 5 GHz) dielectric constant of printed wiring board materials and that is suitable for "factory-floor" usage. A parallel-plate transmission line is used for the sample geometry. A model is developed that describes the electrical behavior of the transmission line, thereby allowing the dielectric constant to be extracted from the observed signal. The data analysis and the sample preparation are both simple to accomplish.
[Contact: Nicholas G. Paulter, (301) 975-2405]

Weil, C.M., Janezic, M.D., and Vanzura, E.J., **Intercomparison of Permeability and Permittivity Measurements Using the Transmission/Reflection Method in 7 and 14 mm Coaxial Air Lines**, NIST Technical Note 1386 (March 1997).

We discuss a measurement intercomparison, designed as a follow-up to that reported by Vanzura et al. In this effort, 13 participants performed broadband (3 MHz to 10 GHz) measurements of the magnetic and dielectric properties of five different ferrite samples using the transmission/reflection (T/R) method in 7 and 14 nm diameter coaxial air lines. Agreement within ±5 percent was obtained for the measured permeability data for frequencies between 50 and 100 MHz. However, consistent with the findings of the earlier study, significant variability (±15 percent) was found to exist in the permittivity data, due to air-gap effects.
[Contact: Claude M. Weil, (303) 497-5305]

OPTOELECTRONICS

Amin, A.J., Aust, J.A., and Sanford, N.A., **Stable CW Operating Waveguide lasers at Room-Temperature in Rare-Earth-Diffused Lithium Niobate**, Proceedings of the SPIE (The International Society for Optical Engineering, P.O. Box 10, Bellingham, Washington 98227-0010), Rare-Earth-Doped Devices, Vol. 2996, pp. 166-170 (1997).

A means of reproducibly fabricating stable cw-channel waveguide lasers in rare-earth-doped Ti:$LiNbO_3$ is demonstrated, through careful choice of the light propagation direction. Z-propagating waveguides have been fabricated in Nd:Ti$LiNbO_3$ and room-temperature cw laser operations has been obtained by pumping in the 800 nm band with greatly reduced photorefractive instability. The reduced photorefractive damage susceptibility in this waveguide configuration has been used to our advantage in the realization, for the first time, of a 980 nm-pumped laser Er:Ti:$LiNbO_3$. The device showed a lasing threshold of 10.5 mW of absorbed pump power and a slope efficiency of 8.5%.
[Contact: Andrew J. Amin, (303) 497-3289]

Amin, A.J., Veasey, D.L., Sanford, N.A., and Hayden, J.S., **Waveguide Lasers by Ion-Edge in Er-Doped Glass**, Proceedings of the SPIE (The International Society for Optical Engineering, P.O. Box 10, Bellingham, Washington 98227-0010), Rare-Earth-Doped Devices, Vol. 2996, pp. 135-142 (1997).

Erbium and erbium/ytterbium co-doped silicate glass waveguide lasers have been fabricated by silver ion-exchange and their characteristics analyzed. We report on measurements and comparisons made in the lasing properties of these devices, including thresholds, slope-efficiencies, and pump tuning ranges. The results presented show that through proper choice of host glass, it is possible to make low-threshold lasers both in singly and co-doped devices.
[Contact: Andrew J. Amin, (303) 497-3289]

Knopp, K.J., Christensen, D.H., and Hill, J.R., **Vertical-Cavity Surface-Emitting Lasers with Low-Ripple Optical Pump Bands**, Applied Physics Letters, Vol. 69, No. 26, pp. 3987-3989 (23 December 1996).

We have used multilayer mirror optimization methods to enhance the coupling of pump light into vertical-cavity surface-emitting lasers (VCSELs). With previously reported devices, pump light was coupled into VCSEL cavities through interference notches in the mirror reflectance spectrum. This approach is sensitive to temperature-dependent reflectance spectrum shifts. We have created devices with a wide pump-band window of low reflectanyce. We report the simulation, growth, and optically pumped lasing of such optimized low-ripple VCSELs. Further, broadband pump windows open the possibility of spectrally broad optical pumps, and they eliminate the need for costly tunable pump lasers.
[Contact: David H. Christensen, (303) 497-3354]

Knopp, K.J., Christensen, D.H., Hill, J.R., and Masterson, K.D., **Thin-Film Design for Enhanced Stability of Optically Pumped Vertical-Cavity Surface-Emitting Lasers (VCSELs)**, Proceedings of the International Conference on Metallurgical Coatings and Thin Films, San Diego, California, April 22-26, 1996, pp. 783-787.

We have employed a novel approach to enhance the optical pump-coupling stability of vertical-cavity

surface-emitting lasers (VCSELs). These structures are composed of thin-film semiconductor multilayers and are manufactured entirely by thin-film deposition. In the past, pump light was coupled into VCSEL cavities through the short wavelength interference notches in the reflectance spectrum. However, the steep slope and narrow width of the notches inherently makes pump-coupling sensitive to device temperature. We have employed traditional thin-film optimization to the multilayer etalon to create a low ripple, wideband pump region of low reflectance while maintaining cavity-mode field overlap at the quantum wells. We demonstrate a factor of 2.5 times better stability across a 35 nm spectral range.
[Contact: David H. Christensen, (303) 497-3354]

Rochford, K.B., Rose, A.H., and Day, G.W., **Magneto-Optic Sensors Based on Iron Garnets**, Proceedings of the 9th Annual IEEE Lasers and Electro-Optics Society 1996 Annual Meeting, Boston, Massachusetts, November 18-19, 1996, pp. 242-243. [Also published in IEEE Transactions on Magnetics, Vol. 32, No. 5, pp. 4113-4117 (September 1996).]

Large magneto-optic coefficients make iron garnets attractive transducers for magnetic field sensors. A typical response curve can be idealized as a Faraday rotation that is linear with applied field H up to a field that causes saturation, H_{sat}. Applying H_{sat} yields a saturation rotation Θ_{sat}. For sensor operation over the range of linear response, the slope, or magneto-optic sensitivity S, can be approximated by $S = \Theta_{sat}/H_{sat}$. The Faraday rotation Θ is equal to S•H in this approximation.
[Contact: Kenneth B. Rochford, (303) 497-5170]

Schaafsma, D.T., and Christensen, D.H., **Cavity Coupling in Vertical-Cavity Semiconductor Lasers**, NISTIR 5047 (January 1997).

The growing sophistication of vertical-cavity surface-emitting lasers, or VCSELs, has fostered questions which have previously lacked a certain relevance. In particular, the gain medium in the laser can now be confined to a very small region of space and moved about within the cavity, and the mode volume of the cavity itself can be reduced to a scale where coupling between the source medium and the emitted radiation and even the quantum nature of light can become significant. This work explores two types of coupling in planar cavities: emitter coupling, a light-matter interaction; and mode coupling, a light-only interaction. Technological applications of coupling effects are discussed, along with novel metrology designed for devices such as VCSELs. A novel experimental technique for probing the side-emission from VCSELs is also described and is used both to probe for coupling effects and to serve as a metrological tool.

Experiments designed to probe for emitter coupling in VCSELs are described, and their results show that the effect of the cavity on the emitter can, indeed, be seen in side emission studies. The results of this experiment show side emission to be a versatile tool, not only for examining cavity effects, but also for basic metrology and modeling of optical response.

The general effects of mode coupling are illustrated in a simplified experiment designed to show the strong redistribution of energy from a dipole inside an etalon, which is much more pronounced than the normal etalon redistribution effects for light originating outside the cavity. These tests also show that redistribution of intensity patterns does not indicate feedback to an emitter from its own radiation. This type of coupling to cavity modes is then examined in VCSEL structures and shown to be potent enough for device applications.
[Contact: David H. Christensen, (303) 497-3354]

Schaafsma, D.T., and Christensen, D.H., **Mode Splitting in Side Emission from Vertical-Cavity Surface-Emitting Lasers**, Physical Review B, Vol. 54, No. 20, 14 618-14 622 (15 November 1996).

We present side-emission (luminescence) data from vertical-cavity surface-emitting lasers which show cavity-induced effects on the emission spectrum. In particular, the heavy-hole luminescence spectrum contains two peaks when pumped in such a way as to excite electron-hole pairs well inside the cavity region, where coupling to free-space modes is minimized, and only one peak when pumped near the edge of the cavity (near a cleaved facet), where coupling to free-space modes is maximized. This splitting can be distinguished as a cavity-induced effect with little ambiguity from other factors present in semiconductor quantum-well radiation, such as

the light- and heavy-hole splitting. A fit to the data using Lorentzian line shapes gives a vacuum-field Rabi splitting of roughly 34 meV, which is consistent with theoretical calculations and with other reports on this phenomenon. We, therefore, conclude that the two peaks in the spectrum are due to Rabi oscillation in the cavity, and that they represent an actual change in the energy configuration of the quantum well.
[Contact: David H. Christensen, (303) 497-3354]

Schlager, J.B., Mechels, S.E., and Franzen, D.L., **Zero-Dispersion Wavelength Uniformity and Four-Wave Mixing in Optical Fiber**, Proceedings of the IEEE Laser and Electro-Optics Society Meeting (LEOS'96), Boston, Massachusetts, November 18-19, 1996, pp. 166-167.

Frequency-domain phase shift measurements of zero-dispersion wavelength in optical fibers cut from a single spool are compared with the maximum four-wave mixing efficiency wavelength. A 1.2 nm change in zero-dispersion wavelength over 10 km affects four-wave mixing behavior.
[Contact: John S. Schlager, (303) 497-3542]

Veasey, D.L., Gary, J.M., and Amin, J., **Rigorous Scalar Modeling of Er and Er/Yb-Doped Waveguide Lasers**, Proceedings of the SPIE (The International Society for Optical Engineering, P.O. Box 10, Bellingham, Washington 98227-0010), Rare-Earth-Doped Devices, Vol. 2996, pp. 109-120 (1997).

A rigorous scalar model for predicting the characteristics of rare-earth-doped waveguide lasers has been developed. The model consists of two nonhomogeneous wave equations: one for the forward-propagating laser signal power, the other for the backward-propagating laser signal. These equations are coupled with one forward-propagating nonhomogeneous wave equation representing the pump signal. The three wave equations are coupled with the space dependent laser rate equations to form a system of time-dependent differential equations. This large system of equations is solved, using appropriate initial and boundary conditions, by the method of lines using collocation for the spatial approximation. The solutions to this system yield data which predict the time- and position-dependent laser signal power, pump power, and population densities in a waveguide laser cavity supporting an arbitrary guided mode. The assumptions made in this new model are that the transverse field maintains the same shape as a function of longitudinal position in the laser cavity and that the effects of spatial hole burning and standing waves are neglected. We have used this model to predict continuous wave and Q-switched laser performance for Er and Er/Yb-doped lasers. We have achieved favorable comparisons with actual laboratory operation of cw Yb/Er-co-doped waveguide lasers. Results from simulations of Er-doped and Yb/Er-doped Q-switched lasers are presented which show that high-peak powers on the order of 500 W and 1 ns pulse widths can be achieved.
[Contact: David L. Veasey, (303) 497-5952]

Williams, P.A., **Accuracy in Polarization Mode Dispersion Measurements**, Proceedings of the IEEE Laser and Electro-Optics Society Meeting (LEOS'96), Boston, Massachusetts, November 18-19, 1996, pp. 170-171.

A description is given of ongoing work toward accuracy statements for polarization mode dispersion measurements. The work described here includes theoretical comparisons of methods, experimental and simulated accuracies, and round-robin comparison results.
[Contact: Paul A. Williams, (303) 497-3805]

ELECTRICAL SYSTEMS

Power Systems Metrology

Bachl, H., Martzloff, F., and Nastasi, D., **Using Incandescent Lamp Failure Levels for Assessment of the Surge Environment**, Proceedings of the 1997 International Zurich Symposium on Electromagnetic Compatibility, Zurich, Switzerland, February 18-20, 1997, pp. 579-584.

This paper reports a joint investigation of the failure modes and levels of incandescent lamps ("light bulbs") exposed to surges occurring in low-voltage ac power systems. Tests were performed in one European laboratory and in one U.S. laboratory on typical 100 W bulbs used in the two environments, the North American 120 W systems, and the 230 V

European systems. Through complementary tests and high-speed video observation of the flashes, more detailed understanding of the parameters has been obtained. Having determined what it takes to fail a light bulb by a surge, this information can be used to assess the surge environment by noting that frequent bulb failure does not occur; therefore, surges above the failure threshold must be infrequent.
[Contact: François Martzloff, (301) 975-2409]

Bretagne, J., Šimko, T., Gousset, G., Rao, M.V.V.S., Van Brunt, R.J., Wang, Y., Olthoff, J.K., Peko, B.L., and Champion, R.L., **Distributions of H^+, H_2^+ H_3^+ Ions in Townsend Discharge and Determination of Their Collision Cross Sections**, Proceedings of the Thirteenth European Sectional Conference on the Atomic and Molecular Physics of Ionised Gases, Poprad, Slovakia, August 27-30, 1996, pp. 115-116.

Experimental and theoretical investigations of hydrogen discharges are complicated by coexistence of three dominant ionic species (H^+, H_2^+ and H_3^+) and their mutual interconversion by collisions with neutral gas molecules. A recent cross-section set for collisions of H_n^+ and ions (n = 1,2,3) with H_2 based on extrapolations to low energies is highly uncertain, especially for H_3^+/H_2 and with moderate collision energies (10 to 1000 eV), and this uncertainty can be reflected in predicted ion-energy distributions.

In this work, an attempt is made to deduce a consistent set of H_n^+/H_2 cross sections by comparing experimental and theoretical investigations of ion-energy distributions and fluxes in low-pressure Townsend discharges.
[Contact: Richard J. Van Brunt, (301) 975-2425]

Lindes, G., Mansoor, A., Martzloff, F.D., and Vannoy, D., **Surge Recordings that Make Sense**, Proceedings of the Electrical Power Research Institute PQA'97 Conference, Columbus, Ohio, March 3-6, 1997, pp. 1-11.

This paper offers a rationale for avoiding attempts to characterize the surge environment in low-voltage end-user power systems by a single number – the "energy in the surge" – derived from a simple voltage measurement. Numerical examples illustrate the fallacy of this concept. Furthermore, based on the proliferation of surge-protective devices in low-voltage end-user installations, the paper draws attention to the need for changing focus from surge voltage measurements to surge current measurements.
[Contact: François Martzloff, (301) 975-2409]

Mansoor, A., Nastaski, D., and Martzloff, F.D., **Applying Reality Checks to Standards on the Surge Environment**, Proceedings of the 23rd International Conference on Lightning Protection, Florence, Italy, September 23-27, 1996, Vol. II, pp. 749-754.

The paper identifies several realities of surge environment and equipment survival that are sometimes ignored in surge-protection practices. It questions the quest for what could be overly conservative requirements for surge immunity or surge mitigation by presenting "reality checks" based on field experience or laboratory data. A first check focuses on the fact that some recent field recordings of surges may be misleadingly low in today's surge environment. Additional checks, aimed at moderating the overly conservative requirements, include the case history of a proposed high-stress 100/1300 μs surge test, data on failure levels of clock motors and light bulbs that can serve as benchmarks for severity levels, and measurements, validated by parametric modeling, showing that large currents cannot propagate into long cables without causing a flashover of the wiring devices at the beginning of the cable, effectively limiting the energy-delivery capability of a surge at the end of the cable.
[Contact: François D. Martzloff, (301) 975-2409]

Martzloff, F.D., **Surge Recordings that Make Sense: Shifting Focus from Voltage to Current Measurements**, Proceedings of the 1996 International Symposium on Electromagnetic Compatability, Rome, Italy, September 17-20, 1996, pp. 311-314.

The paper proposes to establish a program for characterizing surge events according to the capability of a surge event to deliver a surge current through the power system in end-user facilities. This characterization would replace the conventional, and by now misleading, monitoring of

surge voltages. The new approach will use a current transducer including a silicon-avalanche diode with the lowest possible voltage to "attract" surges away from other surge-protective devices connected within the facility. The voltage signal from the current transducer will then be recorded using any power-quality-monitoring instrument available to the individual researchers, providing complete current waveform parameters.
[Contact: François D. Martzloff, (301) 975-2409]

Misakian, M., and Fenimore, C., **Distributions of Measurement Errors for Single-Axis Magnetic Field Meters During Measurements near Appliances**, Bioelectromagnetics, Vol. 18, pp. 273-276 (1997).

Comparisons are made between the average magnetic flux density as it would be measured with a single-axis coil probe and the flux density at the center of the probe, assuming that the probe is oriented to measure the maximum field at that point. Probability distributions of the differences between the two quantities are calculated assuming a dipole magnetic field and are found to be asymmetric. The distributions are used to estimate the uncertainty for maximum magnetic field measurements at distances that are large compared with the dimensions of the field source.
[Contact: Martin Misakian, (303) 497-2426]

Van Brunt, R.J., and von Glahn, P., **Improved Monte-Carlo Simulator of Partial Discharge**, Proceedings of the 1996 Conference on Electrical Insulation and Dielectric Phenomena, San Francisco, California, October 20-23, 1996, pp. 504-509.

A previous introduced Monte-Carlo simulator of partial discharge (PD) has been extended and made more versatile to allow simulation of a wider range of observed discharge behavior. The version of the simulator described here allows simulation of pulsating PD that can be represented as a point process and covers such properties as nonstationary behavior associated with PD-induced modifications of the discharge site and statistical characteristics of multi-site discharges. In the present work, it is shown how the simulator can be applied to gain insight into the physical basis for the previously reported anomalous stochastic behavior of PD generated by applying low-frequency alternating voltages to point electrodes that touch the surface of pure Al_2O_3.
[Contact: Richard Van Brunt, (301) 975-2425]

Van Brunt, R.J., Olthoff, J.K., Firebaugh, S.L., and Sauers, I., **Production of S_2F_{10}, S_2OF_{10}, and $S_2O_2F_{10}$ from Spark and Negative-Corona Discharges in SF_6 and SF_6/O_2 Gas Mixtures**, Transactions of the IEE of Japan, Vol. 116-A, No. 11, pp. 1014-1024 (November 1996).

The rates for production of the compounds S_2F_{10}, S_2OF_{10}, and $S_2O_2F_{10}$ have been measured both in spark and continuous, constant-current negative glow corona discharges generated using point-to-plane electrode gaps in "pure" SF_6 and SF_6/O_2 gas mixture containing up to 10% oxygen by volume fraction. In the case of corona discharges in pure SF_6, the S_2F_{10} concentrations were measured as a function of time during discharge operation using a gas chromatograph-mass spectrometer for gas pressures in the range of 100 kPa to 500 kPa and at discharge currents between 2 μA and 80 μA. The charge rate-of-production of S_2F_{10} from negative corona is observed to drop with decreasing discharge current, and the yield curves exhibit nonlinearities in the early stages of the discharge associated with "conditioning" of the point electrode. The initial nonlinearities become more pronounced with increasing gas pressure. The absolute yields of S_2OF_{10} and $S_2O_2F_{10}$ were measured as a function of O_2 content in SF_6 for both negative glow corona (40 μA and 200 kPa) and spark discharge (80 J/spark and 100 kPa). The gas analysis in the case of spark discharges was performed after each spark using a cryogenic enrichment chromatographic technique. When O_2 is added to the gas, there is a dramatic drop in the $S_2O_2F_{10}$ yield from both types of discharges, with a corresponding increase in S_2OF_{10} yield from the spark and $S_2O_2F_{10}$ yield from the corona discharge. The results can be explained within the framework of a plasma-chemical model from considerations of the competition among the reactions of SF_5 radicals produced by dissociation of SF_6 in the discharge with SF_5 itself as well as with O_2 and O, and the relative degree of O_2 dissociation in the two types of discharges.
[Contact: Richard J. Van Brunt, (301) 975-2425]

Van Brunt, R.J., von Glahn, P., and Las, T., **Anomalous Stochastic Behavior of Partial Discharge on Aluminum Oxide Surfaces**, Journal of Applied Physics, Vol. 81, No. 2, pp. 840-854 (15 January 1997).

The stochastic properties of pulsating partial discharge (PD) generated by applying a low-frequency sinusoidal alternating voltage to a point electrode touching an aluminum oxide (Al_2O_3) surface in air have been investigated. The time dependence of such statistical characteristics as mean numbers of positive and negative PD pulses per half cycle and the amplitude and phase distributions of individual positive and negative PD pulses selected according to their order of occurrence in a cycle were extracted from records of the amplitudes and phases of all PD events that occurred while the voltage was applied for times up to 40 min. The discharge characteristics exhibit a dramatic sensitivity to the impurity content of Al_2O_3. In the case of high-purity (99.9%) Al_2O_3, the positive-PD pulses cease within 30 s after application of the voltage from which time the negative-PD pulses persist indefinitely in a relatively stationary pattern. The cessation of positive PD was not observed for Al_2O_3 samples of lower purity (96% or lower). A modified version of a previously developed Monte-Carlo simulator of ac-generated PD that includes effects of transport and decay of surface charge between PD events was used to gain insight into the conditions that could give rise to the observed long-term behavior of PD for high purity Al_2O_3.
[Contact: Richard J. Van Brunt, (301) 975-2425]

Magnetic Materials and Measurements

Crawford, T.M., Rogers, C.T., Silva, T.J., and Kim, Y.K., **Transverse and Longitudinal Second-Harmonic Magneto-Optic Kerr Effect Observed from $Ni_{81}Fe_{19}$ Thin Film Structures**, IEEE Transactions on Magnetics, Vol. 32, No. 5, pp. 4087-4089 (September 1996).

We report measurements of the second-harmonic magneto-optic Kerr effect in both transverse and longitudinal geometries from 100 nm thick $Ni_{81}Fe_{19}$ films. For the transverse geometry, we observe intensity changes of roughly a factor of 3 upon magnetization reversal. In the longitudinal geometry, the second harmonic Kerr angle is 32.6° for s-incidence and 6.8° for p-incidence. A simple theoretical treatment allows us to compare the relevant second-order susceptibility elements as measured in the two geometries: the element magnitudes and relative phase shifts agree within experimental error.
[Contact: Thomas J. Silva, (303) 497-7826]

Cross, R.W., Kim, Y.K., Oti, J.O., and Russek, S.E., **Magnetostatic Effects in Giant Magnetoresistive Spin-Valve Devices**, Applied Physics Letters, Vol. 69, No. 25, pp. 3935-3937 (16 December 1996).

We report on magnetotransport measurements of spin valve films that have been fabricated into rectangular stripes with Au current leads. The spin valve films consisted of two magnetic NiFe layers separated by a nonmagnetic Cu layer. The top NiFe layer was magnetically pinned by a FeMn layer with an effective pinning field of 12 kA/m (150 Oe). After device fabrication, the transport properties changed dramatically as the stripe-height of the device was decreased below 1 μm. Internal demagnetizing fields and magnetostatic interactions between the magnetic layers dominated the magnetic response. These interactions change the biasing point and the linearity, and cause a decrease in sensitivity to field changes. We have developed a simple single-domain rotation model that includes magnetostatic, anisotropy, and exchange interactions to describe the magnetic behavior, from which we calculate the transport response.
[Contact: Ralph W. Cross, (303) 497-5300]

Kirschenbaum, L.S., Rogers, C.T., Beale, P.D., Russek, S.E., and Sanders, S.C., **High Current Density Self-Field Effects and Low-Frequency Noise in NiFe/Ag Giant Magneto-Resistance Multilayers**, IEEE Transactions on Magnetics, Vol. 32, No. 5, pp. 4684-4686 (September 1996).

High current densities (10^6 to 10^7 A/cm^2) produce magnetic fields which can induce antiparallel magnetic alignment in large (16 μm and 8 μm) NiFe/Ag thin film multilayer devices. We induce Giant Magneto-Resistance (GMR) in unannealed devices which normally do not display GMR. We find multiple peaks in the magnetoresistance curves

of annealed and unannealed devices. Analysis of the positions and shapes of these magnetoresistance peaks provides a new set of tools for determining the micromagnetic structure of the multilayers. Our magneto-optical Kerr effect data and low frequency noise data correlate with the magnetoresistance peaks and may yield further information about layer-layer interactions and domain structure.
[Contact: Stephen E. Russek, (303) 497-5097]

Liou, S.H., Malhotra, S.S., Moreland, J., and Hopkins, P.F., **High Resolution Imaging of Thin-Film Recording Heads by Superparamagnetic Magnetic Force Microscopy Tips**, Applied Physics Letters, Vol. 70, No. 1, pp. 135-137 (6 January 1997).

We have used superparamagnetic force microscopy (MFM) tips to obtain high-spatial resolution MFM images of recording heads. Profiles of magnetic field gradient above a thin-film recording head under 3 mA bias current to the head and various tip-head distance conditions are presented. At a low tip-head distance, the gap width, gap location, and gap-field structure can be well resolved in these MFM images. Superparamagnetic tips show promise for the magnetic imaging of recording heads with gap widths below 200 nm.
[Contact: John Moreland, (303) 497-3641]

Misakian, M., and Fenimore, C., **Distributions of Measurement Errors for Single-Axis Magnetic Field Meters During Measurements Near Appliances**, Bioelectromagnetics, Vol. 18, pp. 273-276 (1997).

[See Power Systems Metrology.]

Rice, P., and Hoinville, J., **Correlating Magnetic Force Microscopy Images and Recording Head Output**, Data Storage Magazine, pp. 35-40 (January 1997).

The preferred instrument for studying magnetization on recording media has been the spin-stand. Although the magnetization on a disk exists in two dimensions, the read-back head reduces the two-dimensional magnetic signal to one dimension and outputs a one-dimensional electrical waveform. We have combined output from the spin-stand and images obtained from the Magnetic Force Microscopy (MFM), to provide a more complete picture of the magnetic fields read by the head. This technique allows us to study effects such as how transition shape is affected by media noise and the corresponding effect on the read-back waveform. We can also see features left behind from previous data which cannot be distinguished from media noise as read back by the recording head. We have demonstrated that the response of an MFM tip to the disk's magnetic fields is almost identical to the output signal from an inductive read-back head. This implies that the MFM can be used to measure the two-dimensional magnetization that a transition contains to more fully understand the response of the read head.
[Contact: Paul Rice, (303) 497-3841]

Rice, P., and Hoinville, J., **Spatial Correlation Between Magnetic Force Microscope Images and Recording Head Output**, IEEE Transactions on Magnetics, Vol. 32, No. 5, pp. 3563-3565 (September 1996).

We have developed a technique which directly compares magnetic force microscope (MFM) images and recording head read-back signals on longitudinal thin-film disks with exact spatial correlation. To get exact spatial correlation, we had to perform three important operations at the same position on the disk. We wrote data with an inductive recording head; we read back the data with the same head; and we imaged the data with an MFM. Using this technique, we show that MFM images are related directly to the read-back signal. As one of the examples of this technique, we saw a signal anomaly which could have been mistaken for media noise which from the MFM image was proven to be incomplete overwrite.
[Contact: Paul Rice, (303) 497-3841]

Rice, P., and Russek, S.E., **Magnetic Imaging Reference Sample**, IEEE Transactions on Magnetics, Vol. 32, No. 5, pp. 4133-4137 (September 1996).

We propose a reference sample for magnetic imaging. We have chosen a thin-film magnetic hard disk as a representative sample because the domains are very stable magnetically and thermally. This type of sample is also of fundamental interest

to the disk drive industry, currently the largest user of magnetic force microscopy. Disk samples are prepared by writing a special magnetic pattern consisting of various transition spacings designed to explore certain aspects of magnetic imaging. Disks are then cut into coupons, cleaned, and patterned with a reference grid of numbered 20 μm × 20 μm Au frames. These frames allow easy navigation around the sample. We believe a sample of this type can help define limits, expectations, and claims of resolution, as well as instrument sensitivity and ease of operation.
[Contact: Paul Rice, (303) 497-3841]

Rochford, K.B., Rose, A.H., and Day, G.W., **Magneto-Optic Sensors Based on Iron Garnets**, Proceedings of the 9th Annual IEEE Lasers and Electro-Optics Society 1996 Annual Meeting, Boston, Massachusetts, November 18-19, 1996, pp. 242-243. [Also published in IEEE Transactions on Magnetics, Vol. 32, No. 5, pp. 4113-4117 (September 1996).]

[See **OPTOELECTRONICS**.]

Superconductors

DeGroot, D.C., Rudman, D.A., Zhang, K., Ma, Q.Y., Kato, H., and Jaeger, N.A.F., **Planar Microwave Devices Fabricated by Ion-Implantation Patterning of High-Temperature Superconductors**, Applied Physics Letters, Vol. 69, No. 14, pp. 2119-2121 (30 September 1996).

[See Microwave and Millimeter Wave Metrology.]

Wiejaczka, J.A., and Goodrich, L.F., **Interlaboratory Comparison on High-Temperature Superconductor Critical-Current Measurements**, Journal of Research of the National Institute of Standards and Technology, Vol. 102, No. 1, pp. 29-52 (January—February 1997).

An extensive interlaboratory comparison was conducted on high-temperature superconductor (HTS) critical-current measurements. This study was part of an international cooperative effort through the Versailles Project on Advanced Materials and Standards. The study involved six U.S. laboratories that are recognized leaders in the field of HTS. This paper includes the complete results from this comparison of critical-current measurements on Ag-sheathed $Bi_2Sr_2Ca_2Cu_3O_{10-x}$ (2223) tapes. The effects of sample characteristics, specimen mounting, measurement technique, and specimen damage were studied. The future development of a standard HTS measurement method is also discussed. Most of the evolution of this emerging technology has occurred in improvement of the performance of the conductors. The successful completion of this interlaboratory comparison is an important milestone in the evolution of HTS technology and marks a level of maturity that the technology has reached.
[Contact: Loren F. Goodrich, (303) 497-3143]

Other Electrical Systems Topics

Stricklett, R.L., and Vangel, M., **Electric Motor Efficiency Testing Under the New Part 431 of Chapter II of Title 10, Code of Federal Regulations: Enforcement Testing**, NIST Technical Note 1422 (January 1997).

The provisions for electric motor efficiency testing under the proposed new Part 431 of Chapter II of Title 10, Code of Federal Regulations, as published for public comment in the *Federal Register*, Vol. 61, No. 230, Wednesday, November 27, 1996, pp. 60439-60475, are discussed. The criteria for demonstration of compliance with the energy efficiency requirements established by Energy Policy and Conservation Act of 1975, as amended, are presented. The operating characteristics, i.e., the estimated probability of demonstrating compliance based on the mean efficiency, standard deviation, and number of units tested, of the Sampling Plan for Enforcement Testing recommended by the new Part 431 are evaluated by model calculations.
[Contact: Kenneth L. Stricklett, (301) 975-3955]

ELECTROMAGNETIC INTERFERENCE

Conducted EMI

Bachl, H., Martzloff, F., and Nastasi, D., **Using Incandescent Lamp Failure Levels for Assessment of the Surge Environment**, Proceedings of the 1997 International Zurich Symposium on Electromagnetic Compatibility, Zurich, Switzerland, February 18-20, 1997, pp. 579-584.

[See Power Systems Metrology.]

Lindes, G., Mansoor, A., Martzloff, F.D., and Vannoy, D., **Surge Recordings that Make Sense**, Proceedings of the Electrical Power Research Institute PQA'97 Conference, Columbus, Ohio, March 3-6, 1997, pp. 1-11.

[See Power Systems Metrology.]

Mansoor, A., Nastaski, D., and Martzloff, F.D., **Applying Reality Checks to Standards on the Surge Environment**, Proceedings of the 23rd International Conference on Lightning Protection, Florence, Italy, September 23-27, 1996, Vol. II, pp. 749-754.

[See Power Systems Metrology.]

Martzloff, F.D., **Surge Recordings that Make Sense: Shifting Focus from Voltage to Current Measurements**, Proceedings of the 1996 International Symposium on Electromagnetic Compatability, Rome, Italy, September 17-20, 1996, pp. 311-314.

[See Power Systems Metrology.]

ADDITIONAL INFORMATION

Announcements

Yaney, D.S., and Settle-Raskin, A.D., **National Semiconductor Metrology Program, Project Portfolio, FY 1996**, NISTIR 5851 (June 1996).

The National Semiconductor Metrology Program (NSMP) is a NIST-wide effort designed to meet the highest priority measurement needs of the semiconductor industry as expressed by the *National Technology Roadmap for Semiconductors* and other authoritative industry sources. The NSMP was established in 1994 with a strong focus on mainstream silicon CMOS technology and an ultimate funding goal of $25 million annually. Current annual funding of approximately $11 million supports the 23 internal projects which are summarized in this Project Portfolio booklet. The NSMP is operated by NIST's Office of Microelectronics Programs, which also manages NIST's relationships with the Semiconductor Industry Association (SIA), SEMATECH, and the Semiconductor Research Corporation. These include NIST's memberships on the SIA committees that develop the *Roadmap* and numerous SRC technical management committees. In addition, NIST is active in the semiconductor standards development activities of ASTM, Deutsches Institut für Normung, Electronic Industries Association, International Organization for Standardization, and Semiconductor Equipment and Materials International. <http://www.eeel.nist.gov/omp>
[Contact: Alice D. Settle-Raskin, (301) 975-4400]

Lists of Publications

Bradford, A.G., **Metrology for Electromagnetic Technology: A Bibliography of NIST Publications**, NISTIR 5051 (September 1996).

This bibliography lists the publications of the personnel of the Electromagnetic Technology Division of NIST during 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 also included. This edition of the bibliography is the first since the Electromagnetic Technology Division split into two Divisions, and it includes publications from the areas of cryoelectronic metrology and superconductor and magnetic measurements. The optical electronic metrology section found in earlier editions is now being produced separately by the new Optoelectronics Division of NIST. That companion bibliography to this publication is NISTIR 5052.
[Contact: Ann G. Bradford, (303) 497-3678]

Lyons, R.M., **A Bibliography of the NIST Electromagnetic Fields Division Publications**, NISTIR 5050 (August 1996).

This bibliography lists the publications by the staff of the National Institute of Standards and Technology's Electromagnetic Fields Division for the period January 1970 through July 1996. It supersedes NISTIR 5039 which listed the publications of the Electromagnetic Fields Division from January 1970 through July 1995. Selected earlier publications from the Division's predecessor organizations are

included.
[Contact: Ruth Marie Lyons, (303) 497-3132]

Schmeit, R.A., **Electrical and Electronic Metrology: A Bibliography of NIST Electricity Division's Publications, NIST List of Publication 94** (March 1997).

This bibliography covers publications of the Electricity Division (and predecessor organizational units), Electronics and Electrical Engineering Laboratory, National Institute of Standards and Technology, for the period of January 1968 through December 1996. A brief description of the Division's technical program is given in the introduction.
[Contact: Ruth A. Schmeit, (301) 975-2401]

Smith, A.J., **A Bibliography of Publications of the NIST Optoelectronics Division**, NISTIR 5052 (September 1996).

This bibliography lists publications of the staff of the Optoelectronics Division and its predecessor organizational units from 1970 through the date of this report.
[Contact: Annie J. Smith, (303) 497-5342]

Walters, E.J., **NIST List of Publications 103, National Semiconductor Metrology Program and the Semiconductor Electronics Division, 1990-1996**. (March 1997).

This List of Publications includes all papers relevant to semiconductor technology published by NIST staff, including work of the National Semiconductor Metrology Program and the Semiconductor Electronics Division, and other parts of NIST having independent interests in semiconductor metrology. Bibliographic information is provided for publications from 1990 through 1996. Indices by topic area and by author are provided. Earlier reports of work performed by the Semiconductor Electronics Division (and its predecessor divisions) during the period from 1962 through December 1989 are provided in NIST List of Publications 72.
[Contact: E. Jane Walters, (301) 975-2050]

<u>1997-1998 Calendar of Events</u>

July 14-16, 1997 (San Francisco, California)

SEMICON West 97, Moscone Center. The NIST National Semiconductor Metrology Program will continue its government-industry liaison support role by exhibiting at SEMICON West in 1997. NIST personnel has provided expertise on semiconductor-related issues to industry, government agencies, and academia at SEMICON West for 27 years.

Due to tremendous industry growth and exhibitors' need for more space, SEMICON West is expanding to San Jose. Wafer Processing (process equipment, chemicals, gases, gas handling equipment, and clean room and materials) exhibits are at the Moscone Center, July 14-16. Test Assembly and Packaging exhibits are at San Jose Convention Center, July 16-18.

NIST's booth is located in the Gateway Hall, Booth 3706, Moscone Center. Please stop by and see us!
[Contact: Alice Settle-Raskin, (301) 975-4400]

July 24, 1997 (Gaithersburg, Maryland)

Ion Implant Users Group Meeting. One of the topics to be discussed will be Charging, Charging Damage and Test Structures. Additional topics will be announced at a later date.
[Contact: John Albers, (301) 975-2075]

August 12-15, 1997 (Boulder, Colorado)

Laser Measurements Short Course. Co-sponsored by NIST and University of Colorado, the course will provide training on laser management theory and techniques. The course will emphasize the concepts, techniques, and apparatus used in measuring laser parameters and will include a visit to the NIST laser measurement laboratories.
[Contact: Thomas R. Scott, (303) 497-3651]

October 16, 1997 (Austin, Texas)

Ion Implant Users Group Meeting. The meeting is in conjunction with SEMICON South West 95. This meeting provides a forum for the informal exchange of information and ideas of ion-implant related issues, their future trends and applications. This year's meeting, "Opportunities and Challenges in Ion Implantation," is organized by the Ion Implant Users Group (East Coast), the Greater Silicon Valley Implant Users Group and the Greater

Southwest Implant/RTP Users Group. The topics for this meeting included Nitrogen Implants for Defect Engineering, High-Dose Hydrogen Implants for SOI Applications, the Use of Indium and Antimony as Alternatives to Boron, Phosphorus for Shallow- Junction Formation, Trends in Ultra-Low Energy Implantation, and High-Energy Implantation.

[Contact: John Albers, (301) 975-2075]

October 30-31, 1997 (Gaithersburg, Maryland)

Workshop on Thin Dielectric Films. The Semiconductor Electronics Division of NIST will be conducting a two-day workshop on thin dielectric film metrology. This workshop will include invited speakers and discussion groups focused on issues pertinent to the setup and calibration for optical metrology tools (primarily ellipsometers and reflectometers), the use of standards, traceability of standards to NIST, and ways to address related evolving industry requirements for thin dielectric films. This workshop will be particularly beneficial for manufacturers of such optical metrology tools, those in integrated circuit manufacturers' calibration laboratories, and those involved with NIST-traceable or secondary thin dielectric film standards. The workshop will conclude with a round-table discussion of closely related issues such as metrology for developing thin-gate dielectrics, the relationship between optical, electrical, and other film characterization techniques, and what the projected necessary standards are for developing technologies.
[Contact: Barbara J. Belzer, (301) 975-2248]

November 4-7, 1997 (Shanghai, China)

International Conference on Materials and Process Characterization for VLSI, 1997 (ICMPC'97). Co-sponsored by NIST and Institute of Microelectronics in Singapore, this course will provide an international forum for the exchange of information on materials and process characterization for semiconductor and integrated circuit technology with emphasis on diagnostics and control of materials and processes, failure and reliability analysis, and new analytical methods. The Shanghai location will provide good opportunities to establish contacts with a large number of scientists and technologies from the Pacific Rim and China.
[Contact: David G. Seiler, (301) 975-2054]

March 10-12, 1998 (San Diego, California)

Fourteenth Annual IEEE Semiconductor Thermal Measurement and Management Symposium (SEMI-THERM) 1998. Co-sponsored by NIST and IEEE, the symposium will present papers on current thermal management, modeling and measurement work on electronic components and systems in the following areas: thermal characterization - component through system; analytical and computational modeling and simulation; experimental methods and applications; thermal design and testing for reliability; and thermal aspects of high temperature electronics.
[Contact: David L. Blackburn, (301) 975-2068]

March 23-27, 1998 (Gaithersburg, Maryland)

1998 International Conference on Characterization and Metrology for ULSI Technology. This workshop is to bring together scientists and engineers interested in all aspects of the technology and characterization techniques for semiconductor device research, development, manufacturing, and diagnostics: chemical and physical, electrical, optical, in-situ, and real-time control and monitoring.

The Workshop provides a forum to present and discuss critical issues; problems and limits; evolving requirements and analysis needs; future directions; and key measurement principles, capabilities, applications, and limitations. It will be comprised of formal invited presentation sessions and poster sessions for contributed papers. This Workshop is the second in a series. The first was held at NIST January 30 to February 2, 1995. Papers from that Workshop were published in *Semiconductor Characterization: Present Status and Future Needs* (AIP Press, New York, 1996), W. M. Bullis, D. G. Seiler, and A. C. Diebold, editors. This Workshop is sponsored by NIST, SEMATECH, Semiconductor Research Corporation, and American Vacuum Society - Manufacturing Science and Technology Group.
[Contact: David G. Seiler, (301) 975-2074]

EEEL Sponsors

National Institute of Standards and Technology
Executive Office of the President
U.S. Air Force
  Bolling Air Force Base; Newark Air Force Base; Patrick Air Force Base; CCG-Strategic Defense Command; CCG-Systems Command; Wright Patterson Air Force Headquarters, Pentagon
U.S. Army
  Aberdeen Proving Ground; Redstone Arsenal
Department of Defense
  Advanced Research Projects Agency; Defense Nuclear Agency; Combined Army/Navy/Air Force (CCG); Information Systems Agency; National Security Agency
Department of Energy
  Basic Energy Sciences; Building Energy R&D; Energy Systems Research; Fusion Energy
Department of Justice
  Law Enforcement Assistance Administration
U.S. Navy
  CCG, Seal Beach; Naval Air Systems Command; Naval Research Laboratory; Naval Ordnance Systems Command; Naval Surface Warfare Center; Office of Naval Research
National Science Foundation
National Aeronautics and Space Administration
  NASA Headquarters; Langley Research Center; John F. Kennedy Space Flight Center
Department of Transportation
  National Highway Traffic Safety Administration
Environmental Protection Agency
  Headquarters
MMIC Consortium
  Various Federal Government Agencies
  Various Industry Companies
Scanning Capacitance Consortium
U.S. Japan Joint Optoelectronics Project
Delmarva Power
Nuclear Regulatory Commission
Pacific Gas and Electric
Sandia Labs
Tennessee Center for Research & Development
IMRA America, Inc.
Hughes Aircraft Co.
Honeywell, Inc.
Science Applications International, Inc.
Allied Signal Aerospace
Astralux, Inc.

NIST SILICON RESISTIVITY SRMs

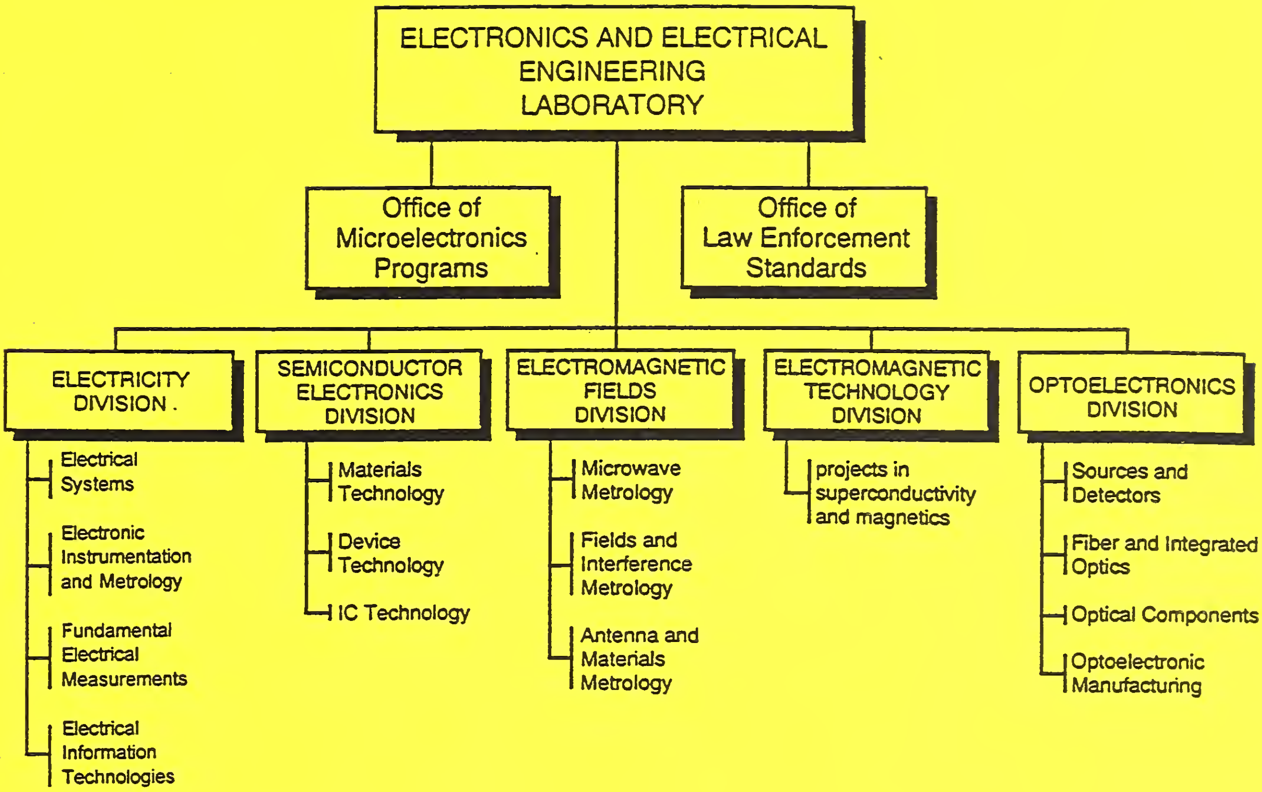
The Semiconductor Electronics Division of NIST provides Standard Reference Materials (SRMs) for bulk silicon resistivity through the NIST Standard Reference Materials Program. An improved set of resistivity SRMs, on 100 mm wafers, will be available according to the schedule in the table below. These wafer SRMs improve upon the earlier 50 mm diameter SRM sets 1521, 1522, and 1523.

The new SRMs have similar values of nominal resistivity as the earlier set, but offer improved uniformity and substantially reduced uncertainty of certified values due both to material and procedural improvements. The most significant feature of the new SRMs is in their certification, which is performed using a dual-configuration four-probe measurement procedure rather than the single-configuration measurements specified in ASTM F84. Extensive testing has shown that the dual-configuration procedure reduces random variations of measurement and probe-to-probe differences.

Technical insights presented by the rigorous certification process are available in NIST Special Publication 260-131, *Standard Reference Materials:* The Certification of 100 mm Diameter Silicon Resistivity SRMs 2541 through 2547 Using Dual-Configuration Four-Point Probe Measurements. Individual data for each wafer are supplied along with the SRM certificate.

NIST SILICON BULK RESISTIVITY STANDARD REFERENCE MATERIALS		
DATE UPDATED: 30 JUNE 1997		
NOMINAL RESISTIVITY (ohm·cm)	**NEW SRMs**	**AVAILABILITY**
0.01	2541	NOW!
0.1	2542	NOW!
1	2543	end of CY 97
10	2544	10/1/97
25	2545	NOW!
100	2546	NOW!
200	2547	NOW!

NIST sells SRMs on an as-available basis. For technical information, contact James R. Ehrstein, (301) 975-2060; for ordering information, call the Standard Reference Materials Program Domestic Sales Office: (301) 975-6776.



KEY CONTACTS

Laboratory Headquarters (810)	Director, Judson C. French (301) 975-2220
	Acting Deputy Director, Alan H. Cookson (301) 975-2220
	Acting Associate Director, Bruce F. Field (301) 975-2220
Office of Microelectronics Programs	Director, Robert I. Scace (301) 975-4400
Office of Law Enforcement Standards	Director, Kathleen M. Higgins (301) 975-2757
Electricity Division (811)	Chief, William E. Anderson (301) 975-2400
Semiconductor Electronics Division (812)	Chief, David G. Seiler (301) 975-2054
Electromagnetic Fields Division (813)	Chief, Allen C. Newell (303) 497-3131
Electromagnetic Technology Division (814)	Chief, Richard E. Harris (303) 497-3776
Optoelectronics Division (815)	Chief, Gordon W. Day (303) 497-5204

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