NISTIR 5892

Electronics and Electrical Engineering Laboratory

J. M. Rohrbaugh
Compiler

Technical Publication Announcements

48

Covering Laboratory Programs,
January to March 1996,
with 1996 EEEL Events Calendar

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

NIST

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

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August 1996

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U.S. DEPARTMENT OF COMMERCE
Michael Kantor, Secretary
TECHNOLOGY ADMINISTRATION
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INTRODUCTION TO THE EEEL TECHNICAL PUBLICATION ANNOUNCEMENTS

This is the forty-eighth 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). This issue of the EEEL Technical Publication Announcements covers the fourth quarter of calendar year 1995.

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 year 1996 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 18.

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 16.

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.

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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 ***Measurements for Competitiveness in Electronics*** and ***EEEL 1995 Technical Accomplishments, Advancing Metrology for Electrotechnology to Support the U.S. Economy***. The first presents selected technical accomplishments of the Laboratory for the period October 1, 1994 through September 30, 1995. 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 1995 Technical Accomplishments, Advancing Metrology for Electrotechnology to Support the U.S. Economy, NISTIR 5818 (December 1995).

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 1995 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.

This document is a successor to NISTIR 90-4260, *Emerging Technologies in Electronics ... and their measurement needs* [Second Edition].
[Contact: Ronald M. Powell, (301) 975-2220]

FUNDAMENTAL ELECTRICAL MEASUREMENTS

Kautz, R.L., and Benz, S.P., **Metallic-Barrier Junctions for Programmable Josephson Voltage Standards**, Proceedings of the European Conference on Applied Superconductivity, Edinburgh, Scotland, July 3-6, 1995, pp. 1407-1410.

The current amplitudes of Shapiro steps are studied in large-area metallic-barrier Josephson junctions by simulation and experiment. In the absence of a ground plane, simulations show that junctions larger than about four times the Josephson penetration depth are of limited utility because the microwave power required to induce Shapiro steps increases rapidly with junction size. Experimentally, step amplitudes as large as 7 mA are observed in Nb-PdAu-Nb sandwich junctions.
[Contact: Richard L. Kautz, (303) 497-3391]

SEMICONDUCTOR MICROELECTRONICS

Silicon Materials

Rennex, B.G., Ehrstein, J.R., and Scace, R.I., **Methodology for the Certification of Reference Specimens for Determination of Oxygen Concentration in Semiconductor Silicon by Infrared Spectrophotometry**, Journal of the Electrochemical Society, Vol. 143, No. 1, pp. 258-263 (1996).

The methodology and experiment for certification of reference specimens for determining interstitial oxygen concentration in semiconductor silicon are reported. These reference specimens are intended for calibration of infrared spectrophotometers which measure the 1107 cm^{-1} oxygen peak in silicon to enable users to improve their measurement agreement. Based on an earlier international Grand Round Robin study, this measurement agreement is at best 5.4% (2σ). Industry requirements for measurement comparison are much more demanding, and a methodology to satisfy those requirements is described. The most important aspect of this methodology is to reduce interlaboratory variation by the use of a single infrared instrument for certification. The certification uncertainty depends primarily on the improved repeatability of this instrument. Other sources of uncertainty were nonuniformity in both oxygen concentration and thickness over the specimen area, and variations in residual oxygen among the float-zone specimens which provided zero-oxygen reference for the reference sets. These various sources were combined in quadrature to arrive at 2σ estimates of uncertainty under 0.2% at three oxygen levels.
[Contact: Brian G. Rennex, (301) 975-2108]

Compound Materials

Bennett, H.S., **Report on Workshop on Planning for Compound Semiconductor Technology**, NIST Journal of Research, Vol. 101, pp. 89-94 (1996).

This report describes the motivation for and the results of the Workshop on Planning for Compound Semiconductor Technology. This Workshop, sponsored by NIST and Semiconductor Equipment and Materials International, was held at Gaithersburg, Maryland on February 3, 1995, in conjunction with the International Workshop on Semiconductor Characterization: Present Status and Future Needs, January 30—February 2, 1995. The purposes of the Workshop on Planning for Compound Semiconductor Technology were to: (1) assess whether agreement exists in the compound semiconductor industry for the need of a consensus-based planning effort to support its future goals for materials, processes, devices, interconnects, and packages, and (2) foster the free exchange of information and ideas that might be used to create a more competitive compound semiconductor industry by a mutual understanding of its common problems and of ways to solve them. Without some consensus-based planning on the part of the North American compound semiconductor industry, future economic opportunities in this industry may be limited.
[Contact: Herbert S. Bennett, (301) 975-2079]

Burnett, J.H., Amirtharaj, P.M., Cheong, H.M., Paul, W., Koteles, E.S., and Elman, B., **Use of Pressure for Quantum-Well Band Structure Characterization**, Semiconductor Characterization: Present Status and Future Needs, W.M. Bullis D.G. Seiler, and A.C. Diebold, Eds. (AIP, New York, 1996), pp. 634-638.

[See Analysis and Characterization Techniques.]

Chandler-Horowitz, D., Berning, D.W., Pellegrino, J.G., Burnett, J.H., Bour, D.P., and Treat, D.W., **Double-Modulation and Selective Excitation Photoreflectance for Wafer-Level Characterization of Quantum-Well Laser Structures**, Semiconductor Characterization: Present Status and Future Needs, W.M. Bullis, D.G. Seiler, and A.C. Diebold, Eds. (AIP, New York, 1996), pp. 639-643.

[See Analysis and Characterization Techniques.]

Richter, C.A., Seiler, D.G., Pellegrino, J.G., Tseng, W.F., and Thurber, W.R., **Novel Magnetic Field Characterization Techniques for Compound Semiconductor Materials and Devices**, Semiconductor Characterization: Present Status and Future Needs, W.M. Bullis, D.G. Seiler, and A.C. Diebold, Eds. (AIP, New York, 1996), pp. 673-677.

[See Analysis and Characterization Techniques.]

Sha, W., Smirl, A.L., and Tseng, W.F., **Coherent Plasma Oscillations in Bulk Semiconductors**, Physical Review Letters, Vol. 74, No. 21, pp. 4273-4276 (22 May 1995).

Coherent subpicosecond electron-hole charge oscillations that result from ballistic transport in the presence of a constant built-in field are observed in a bulk GaAs p-i-n sample by using differential electroabsorption techniques.
[Contact: Wen F. Tseng, (301) 975-5291]

Analysis and Characterization Techniques

Burnett, J.H., Amirtharaj, P.M., Cheong, H.M., Paul, W., Koteles, E.S., and Elman, B., **Use of Pressure for Quantum-Well Band Structure Characterization**, Semiconductor Characterization: Present Status and Future Needs, W.M. Bullis, D.G. Seiler, and A.C. Diebold, Eds. (AIP, New York, 1996), pp. 634-638.

We present a technique to determine unambiguously the origin of the peaks in absorption spectra (and related spectra) of semiconductor heterostructures, using external hydrostatic and uniaxial pressure. This technique depends on the different effective mass dependencies of the various types of heterostructure energy levels involved in absorption transitions, such as electron, heavy hole, light hole, exciton, and defect levels, and the dissimilar pressure dependencies of the various masses. Measurements of the hydrostatic or uniaxial pressure dependencies of the spectral peaks, thus, distinguish peaks associated with these different types of energy levels. The approach is demonstrated for GaAs/AlGaAs quantum wells and HgTe/HgCdTe superlattices using hydrostatic pressure. Heavy- and light-hole-related peaks have large differences in external uniaxial pressure coefficients, so not only is externally applied uniaxial pressure a convenient and reliable method to distinguish heavy- and light-hole levels, but also the heavy-hole/light-hole splitting can be used to determine quantitatively the amount of built-in uniaxial strain in the heterostructure layers.
[Contact: John H. Burnett, (301) 975-5974]

Chandler-Horowitz, D., Berning, D.W., Pellegrino, J.G., Burnett, J.H., Bour, D.P., and Treat, D.W., **Double-Modulation and Selective Excitation Photoreflectance for Wafer-Level Characterization of Quantum-Well Laser Structures**, Semiconductor Characterization: Present Status and Future Needs, W.M. Bullis, D.G. Seiler, and A.C. Diebold, Eds. (AIP, New York, 1996), pp. 639-643.

A double-modulation photoreflectance (PR) procedure is presented, where both the probe and pump beams are modulated, and the photoreflectance signal can be isolated from the luminescence and the scattered pump beam signals. The PR signal is separated from the other two signals through detection at the sum frequency. A careful choice of frequencies and specially designed filters and tuned amplifiers were needed to achieve optimum operation. A complete system, along with the necessary circuits, is presented and applied to the characterization of a highly luminescent quantum-well laser structure. The freedom allowed by such a system to easily accommodate any pump wavelength is an important feature. We have exploited this added versatility, and the ordering of the bandgap of the multiple layers required in complex laser structures, to extract the bandgap and alloy composition of each

of the constituent regions as well as the built-in strain in the pseudomorphic quantum-well.
[Contact: Deane Chandler-Horowitz, (301) 975-2084]

Diebold, A.C., Kump, M.R., Kopanski, J.J., and Seiler, D.G., **Characterization of Two-Dimensional Dopant Profiles: Status and Review**, Journal of Vacuum Science and Technology B, Vol. 14, No. 1, pp. 196-201 (January/February 1996).

The National Technology Roadmap for Semiconductors calls for development of two- and three-dimensional dopant profiling methods for calibration of technology computer-aided design process simulators. We have previously reviewed 2D dopant profiling methods. In this article, we briefly review methods used to characterize etched transistor cross sections by expanding our previous discussion of scanned probe microscopy methods. We also mention the need to participate in our ongoing comparison of analysis results for test structures that we have provided the community.
[Contact: Joseph J. Kopanski, (301) 975-2089]

Kopanski, J.J., Marchiando, J.F., and Lowney, J.R., **Scanning Capacitance Microscopy Measurements and Modeling: Progress Towards Dopant Profiling of Silicon**, Journal of Vacuum Science and Technology B, Vol. 14, No. 1, pp. 242-247 (January/February 1996).

A scanning capacitance microscope (SCM) has been implemented by interfacing a commercial contact-mode atomic force microscope with a high-sensitivity capacitance sensor. The SCM has promise as a next-generation dopant-profiling technique because the measurement is inherently two dimensional, has a potential spatial resolution limited by tip diameter of at least 20 nm, and requires no current-carrying metal-semiconductor contact. Differential capacitance images have been made with the SCM of a variety of bulk-doped samples and in the vicinity of pn junctions and homojunctions. Also, a computer code has been written that can numerically solve Poisson's equation for a model SCM geometry by using the method of collocation of Gaussian points. Measured data and model output for similar structures are presented. How data and model output can be combined to achieve an experimental determination of dopant profile is discussed.
[Contact: Joseph J. Kopanski, (301) 975-2089]

Neubauer, G., Erickson, A., Williams, C.C., Kopanski, J.J., Rodgers, M., and Adderton, D., **2D-Scanning Capacitance Microscopy Measurements of Cross-Sectioned VLSI Teststructures**, Semiconductor Characterization: Present Status and Future Needs, W.M. Bullis, D.G. Seiler, and A.C. Diebold, Eds. (AIP, New York, 1996), pp. 318-321.

We have developed a setup which uses scanning capacitance microscopy (SCM) to obtain electrical data of cross-sectioned samples while simultaneously acquiring conventional topographical atomic force microscopy data. The results presented here include 2D SCM maps of cross-sections of blanket implanted, annealed Si wafers as well as test structures on Si. We found the technique to be sensitive over several orders of magnitude of carrier density concentrations $<10^{15}$ to 10^{20} atoms/cm^3, with a lateral resolution of 20 nm to 150 nm, depending on probe tip and dopant level. We find excellent agreement of total implant depth obtained from SCM signals of cross-sectioned samples with conventional Secondary Ion Mass Spectrometry profiles of the same sample.
[Contact: Joseph J. Kopanski, (301) 975-2089]

Neubauer, G., Erickson, A., Williams, C.C., Kopanski, J.J., Rodgers, M., and Adderton, D., **Two Dimensional Scanning Capacitance Microscopy Measurements of Cross-Sectioned Very Large Scale Integration Test Structures**, Journal of Vacuum Science and Technology B, Vol. 14, No. 1, pp. 426-432 (January/February 1996).

Scanning probe technology, with its inherent two-dimensionality, offers unique capabilities for the measurement of electrical properties on a nanoscale. We have developed a setup which uses scanning capacitance microscopy (SCM) to obtain electrical information of cross-sectioned samples while simultaneously acquiring conventional topographical atomic force microscopy (AFM) data. In an extension of our work on very large scale integration cross sections, we have now obtained one-dimensional and two-dimensional SCM data of

cross sections of blanket-implanted, annealed Si wafers, as well as special test structures on Si. We find excellent agreement of total implant depth obtained from SCM signals of these cross-sectioned samples with conventional secondary ion mass spectrometry (SIMS) profiles of the same samples. Although no modeling for a direct correlation between signal output and absolute concentration has yet been attempted, we have inferred quantitative dopant concentrations from correlation to SIMS depth profiles obtained on the same sample. By these means of indirect modeling, we have found that our SCM technique is sensitive to carrier density concentrations varying over several orders of magnitude, i.e., $<1 \times 10^{15}$ to 1×10^{20} atoms/cm^3, with a lateral resolution of 20 nm to 150 nm, depending on tip and dopant level.
[Contact: Joseph J. Kopanski, (301) 975-2089]

Nguyen, N.V., Chandler-Horowitz, D., Pellegrino, J.G., and Amirtharaj, P.M., **High-Accuracy Principal-Angle Scanning Spectroscopic Ellipsometry of Semiconductor Interfaces**, Semiconductor Characterization: Present Status and Future Needs, W.M. Bullis, D.G. Seiler, and A.C. Diebold, Eds. (AIP, New York, 1996), pp. 438-442.

A high-performance spectroscopic ellipsometer has been custom built, in-house at NIST, based on the commonly used rotating-analyzer configuration. The data accuracy was highly enhanced by using the principal-angle scanning technique. This technique requires an accurate setting of the angle of incidence which is accomplished by an interferometer and high-precision goniometers for the sample stage and the polarizer. For each wavelength, the principal angle of incidence was automatically searched to obtain a 90° phase shift of the polarized light upon reflection, i.e., $\boldsymbol{\Delta} = 90°$, and the polarizer azimuth was set to $\boldsymbol{\Psi}$. At this condition, the ac component of detected intensity is near a null. With zone averaging, systematic errors such as the detector nonlinearity, and the analyzer and polarizer calibration constants are minimized. To illustrate the use and capability of this system, we use the results of a recent study of the optical properties of SiO_2/Si system and, in particular, the transitional region, defined as an interlayer between the thermally grown SiO_2 film and the Si substrate. In this study, the complex dielectric function and the thickness of the interlayer was determined. From the dielectric function, the existence of both strain and microroughness at this region was inferred, and the strain was seen to induce a redshift of 0.042 eV of the critical point E_1.
[Contact: Nhan V. Nguyen, (301) 975-2044]

Perkowitz, S., Seiler, D.G., Bullis, W.M., **Optical Characterization of Materials and Devices for the Semiconductor Industry: Trends and Needs**, Semiconductor Characterization: Present Status and Future Needs, W.M. Bullis, D.G. Seiler, and A.C. Diebold, Eds. (AIP, New York, 1996), pp. 422-424.

Contactless, nondestructive optical methods are used to characterize materials, processes, and devices in the semiconductor industry. In response to industrial needs, the Semiconductor Electronics Division of the National Institute of Standards and Technology conducted a survey of the needs for and use of optical characterization methods within the semiconductor industry. Data from forty-two firms were analyzed to show the impact of the methods, what they measure, their range and precision, and their cost. A significant finding of the study is the need expressed by many industrial users for improved standards and test methods for optical characterization.
[Contact: David G. Seiler, (301) 975-2054]

Richter, C.A., Seiler, D.G., Pellegrino, J.G., Tseng, W.F., and Thurber, W.R., **Novel Magnetic Field Characterization Techniques for Compound Semiconductor Materials and Devices**, Semiconductor Characterization: Present Status and Future Needs, W.M. Bullis, D.G. Seiler, and A.C. Diebold, Eds. (AIP, New York, 1996), pp. 673-677.

Quantum-mechanical effects observed in the magnetoresistance of semiconductor devices and materials give important information such as carrier density, scattering rates, and band structure parameters. However, the small size of these effects often limits their observation and subsequently their practical use. The purpose of this paper is to show how these quantum mechanical effects can be more easily observed and used as characterization tools by modulating the applied magnetic field, which can increase the

sensitivity of magnetotransport measurements.
[Contact: Curt A. Richter, (301) 975-2082]

Shaffner, T.J., Diebold, A.C., McDonald, R.C., Seiler, D.G., and Bullis, W.M., **Business and Manufacturing Motivations for the Development of Analytical Technology and Metrology for Semiconductors**, Semiconductor Characterization: Present Status and Future Needs, W.M. Bullis, D.G. Seiler, and A.C. Diebold, Eds. (AIP, New York, 1996), pp. 1-10.

Semiconductor characterization is an indispensable enabler of all modern microelectronics and optoelectronic circuits, and is in the critical path for maintaining the steady decline in cost-per-function of silicon integrated circuit technology. It is also driving new developments in compound semiconductor materials and devices (III-V and II-VI). In this overview, we present a perspective on measurement technology relative to business and economic challenges of the semiconductor industry, and illustrate the key role metrology plays in modern process development and manufacturing. We also describe how new characterization techniques evolve for semiconductor applications.
[Contact: David G. Seiler, (301) 975-2054]

Insulators and Interfaces

Nguyen, N.V., Chandler-Horowitz, D., Pellegrino, J.G., and Amirtharaj, P.M., **High-Accuracy Principal-Angle Scanning Spectroscopic Ellipsometry of Semiconductor Interfaces**, Semiconductor Characterization: Present Status and Future Needs, W.M. Bullis, D.G. Seiler, and A.C. Diebold, Eds. (AIP, New York, 1996), pp. 438-442.

[See Analysis and Characterization Techniques.]

Dimensional Metrology

Drapela, T.J., Franzen, D.L., and Young, M., **Optical Fiber, Fiber Coating, and Connector Ferrule Geometry: Results of Interlaboratory Measurement Comparisons**, NIST Technical Note 1378 (November 1995).

[See Optical Fiber/Waveguide Sensors.]

Integrated-Circuit Test Structures

Allen, R.A., Cresswell, M.W., Ellenwood, C.H., and Linholm, L.W., **The Enhanced Voltage-Dividing Potentiometer for High-Precision Feature Placement**, IEEE Transactions on Instrumentation and Measurement, Vol. 45, No. I, pp. 136-141 (February 1996).

Enhancements to the voltage-dividing potentiometer, an electrical test structure for measuring the spatial separations of pairs of conducting features, are presented and discussed. These enhancements reduce or eliminate systematic errors which can otherwise lead to uncertainties as large as several hundred nanometers. These systematic errors, attributed by modeling to asymmetries at certain intersections of conducting features in the test structure, are eliminated by modifications to the test structure and test procedures.
[Contact: Richard A. Allen, (301) 975-5026]

Plasma Processing

Hwang, H.H., Olthoff, J.K., Van Brunt, R.J., Radovanov, S.B., and Kushner, M.J., **Evidence for Inelastic Processes for N_3^+ and N_4^+ from Ion Energy Distributions in He/N_2 Radio Frequency Glow Discharges**, Journal of Applied Physics, Vol. 79, No. 1, pp. 93-98 (1 January 1996).

The ion energy distributions (IEDs) striking surfaces in rf glow discharges are important in the context of plasma etching during the fabrication of microelectronics devices. In discharges sustained in molecular gases or multicomponent gas mixtures, the shape of the IED and the relative magnitudes of the ion fluxes are sensitive to ion-molecule collisions which occur in the presheath and sheath. Ions which collisionlessly traverse the sheaths or suffer only elastic collisions arrive at the substrate with a measurably different IED than do ions which undergo inelastic collisions. In this article, we present measurements and results from parametric calculations of IEDs incident on the grounded electrode of a rf glow discharge sustained in a HeN_2 gas mixture while using a Gaseous Electronics Conference Reference Cell (33.3 Pa, 13.56 MHz). We found that the shape of the IEDs for H_3^+ and H_4^+ provide evidence for inelastic ion-molecule reactions

which have threshold energies of <10 eV.
[Contact: James K. Olthoff, (301) 975-2431]

Power Devices

Adams, V.H., Joshi, Y., and Blackburn, D.L., **Natural Convection from an Array of Electronic Packages Mounted on a Narrow Aspect Ratio Enclosure**, Proceedings of the Thirteenth National Heat and Mass Transfer Conference, Surathkal, India, December 28-30, 1995, pp. 911-917.

Three-dimensional natural convection flow and heat transfer were numerically studied for a 3 x 3 array of discretely heated electronic packages mounted on a horizontal circuit board in an air-filled, narrow aspect ratio rectangular enclosure with length, width, and height ratio of 6:6:1. The governing equations for natural convection in air, coupled with conjugate conduction within the electronic packages surfaces and maximum chip temperatures for Rayleigh numbers of 10^4, 10^6, and 10^7 were compared with corresponding results from an analysis involving only heat conduction. It was found that conduction-only analysis underpredicts heat transfer from the top surfaces of the electronic packages by a factor of 1.5 to 4.4, with a resultant overprediction of the maximum chip to ambient temperature difference of 235%.
[Contact: David L. Blackburn, (301) 975-2068]

Reliability

Chaparala, P., Suehle, J.S., Messick, C., and Roush, M., **Time-Dependent Dielectric Breakdown of Intrinsic SiO_2 Films under Dynamic Stress**, Final Report of the IEEE 1995 Integrated Reliability Workshop, Lake Tahoe, California, October 22-25, 1995, pp. 104-112 (1996).

We present time-dependent dielectric breakdown (TDDB) characteristics for 9, 15, and 22 nm silicon dioxide films stressed under dc, unipolar, and bipolar pulsed bias conditions. Our results indicate that the increased lifetime observed under pulsed stress conditions diminishes as the stress electric-field and oxide thickness are reduced. TDDB data under pulse bias conditions exhibit similar field and temperature dependencies as under static stress. C-V measurements indicate that lifetime enhancement only occurs for electric fields and thickness where charge trapping is significant.
[Contact: John S. Suehle, (301) 975-2247]

Erhart, D.L., Schafft, H.A., and Gladden, W.K., **On the Road to Building-In Reliability**, Final Report of the IEEE 1995 International Integrated Reliability Workshop, Lake Tahoe, California, October 22-25, 1995, pp. 5-10 (1996).

The cycle-time pressures to reduce the time required to introduce new products, and the continued demands for decreasing product failure rates are pushing our existing reliability risk management methodology to its limits. These issues have stimulated the reassessment of our strategy and the development of an alternate approach. In this presentation, we explore the implementation of building-in-reliability (BIR). We develop working definitions for BIR and the present reliability risk assessment methodology, testing-in reliability (TIR). We contrast the TIR and BIR approaches in the context of a new product introduction process, as well as in the context of day-to-day manufacturing. We examine the TIR and BIR approaches to metallization reliability, and develop a strawman proposal for the implementation of BIR.
[Contact: Harry A. Schafft, (301) 975-2234]

Martin, A., Suehle, J.S., Chaparala, P., O'Sullivan, P., Mathewson, A., and Messick, C., **Assessing MOS Gate Oxide Reliability on Wafer Level with Ramped/Constant Voltage and Current Stress**, Final Report of the IEEE 1995 Integrated Reliability Workshop, Lake Tahoe, California, October 22-25, 1995, pp. 81-91 (1996).

In this study, time-to-breakdown distributions are compared for MOS gate oxides which were stressed with a constant voltage (or current) stress or a pre-stressing voltage (or current) ramp followed by a constant voltage (or current) stress. Results show clearly that a pre-stress can increase time-to-breakdown. This increase is discussed, and it is shown that it is dependent on oxide thickness, pre-stressing ramp rate and the processing conditions. The current-time (or voltage-time) characteristics of the constant stress are investigated, and it is observed that charge trapping in the oxide is the reason for the time-to-breakdown increase. The

pre-stressed oxide clearly shows a different initial charge trapping characteristic than the nonpre-stressed oxide. The measurement results are discussed, and it is demonstrated that the common understanding of oxide breakdown cannot explain the observed results. Therefore, a new parameter is proposed which is related to oxide degradation and breakdown and which has to be considered in combined ramped/constant stress measurements.
[Contact: John S. Suehle, (301) 975-2247]

Schlund, B., Suehle, J.S., Messick, C., and Chaparala, P., **A New Physics-Based Model for Time-Dependent-Dielectric Breakdown**, Final Report of the IEEE 1995 Integrated Reliability Workshop, Lake Tahoe, California, October 22-25, 1995, pp. 72-80 (1996).

A new, physics-based model for time-dependent-dielectric breakdown has been developed, and is presented along with test data obtained by NIST on oxides provided by an industrial firm. Testing included fields from 5.6 MV/cm to 12.7 MV/cm, and temperatures ranging from 60 °C to 400 °C. The physics, mathematical model, and test data all confirm a linear, rather than an inverse field dependence. The primary influence on oxide breakdown was determined to be due to the dipole interaction energy of the field with the orientation of the molecular dipoles in the dielectric. The resultant failure mechanism is shown to be the formation and coalescence of vacancy defects, similar to that proposed by Dumin et al.
[Contact: John S. Suehle, (301) 975-2247]

Other Semiconductor Metrology Topics

Shaffner, T.J., Diebold, A.C., McDonald, R.C., Seiler, D.G., and Bullis, W.M., **Business and Manufacturing Motivations for the Development of Analytical Technology and Metrology for Semiconductors**, Semiconductor Characterization: Present Status and Future Needs, W.M. Bullis, D.G. Seiler, and A.C. Diebold, Eds. (AIP, 1996), pp. 1-10.

[See Analysis and Characterization Techniques.]

SIGNAL ACQUISITION, PROCESSING, AND TRANSMISSION

Cryoelectronic Metrology

Booi, P.A.A., and Benz, S.P., **Design of High-Frequency, High-Power Oscillators Using Josephson-Junction Arrays**, Proceedings of the European Conference on Applied Superconductivity, Edinburgh, Scotland, July 3-7, 1995, pp. 1479-1482.

We analyze the limitations imposed by junction capacitance and the parasitic inductance associated with shunt resistors, on the performance of Nb/Al-AlO_x/Nb-junction-array oscillators. We use wide junctions that are in-situ deposited on top of PdAu resistor films (to minimize inductance) and are situated above Nb ground planes to ensure uniform current injection. From the measured parasitics, we infer the maximum power and frequency that can be obtained for critical-current densities $J_c \leq 100$ kA/cm^2. We illustrate these findings with experimental results of 1,968-junction arrays having $J_c \approx 10$ kA/cm^2 that was found to couple 0.1 to 0.8 mW to a 56-Ω load in the range 100 to 300 GHz.
[Contact: Peter A. A. Booi, (303) 497-5910]

Kautz, R.L., and Benz, S.P., **Metallic-Barrier Junctions for Programmable Josephson Voltage Standards**, Proceedings of the European Conference on Applied Superconductivity, Edinburgh, Scotland, July 3-6, 1995, pp. 1407-1410.

[See Fundamental Electrical Measurements.]

Roshko, A., Goodrich, L.F., Rudman, D.A., Moerman, R., and Vale, L.R., **Magnetic Flux Pinning in Epitaxial $YBa_2Cu_3O_{7-\delta}$ Thin Films**, Journal of Electronic Materials, Vol. 24, No. 12, pp. 1919-1922 (1995).

The influence of microstructure on the critical current density of laser ablated $YBa_2Cu_3O_{7-\delta}$ thin films has been examined. Scanning tunneling microscopy was used to examine the morphologies of $YBa_2Cu_3O_{7-\delta}$ films and the morphology data were then correlated with measurements of the critical current density. The films were found to grow by an island nucleation and growth mechanism. The critical current densities of the films are similar to those of films with screw dislocation growth, indicating that screw dislocation

growth is not necessary for good pinning. The data suggest that the critical current density in applied magnetic field may be higher in films with higher densities of growth features.
[Contact: Alexana Roshko, (303) 497-5420]

Antenna Metrology

Guerrieri, J., Canales, N., MacReynolds, K., and Tamura, D., **Planar Near-Field Measurements and Microwave Holography for Measuring Aperture Distribution on a 60 GHz Active Array Antenna**, Proceedings of the 17th Annual Meeting and Symposium, Antenna Measurement Techniques Association, Williamsburg, Virginia, November 13-17, 1995, pp. 295-299.

This paper discusses results of a recent attempt to measure aperture distribution of a small active steerable array antenna at 60 GHz using planar near-field measurements and the back transform. Using a procedure which exercises every phase shifter without steering the antenna beam, it is possible to isolate problems with individual bits in the phase shifters. From calculation of the aperture fields for each case, we hope to infer the individual phase shifter bit loss. We also discuss problems which arose in the measurement because of the short wavelength, signal-to-noise ratio and small number of elements.
[Contact: Jeffrey J. Guerrieri, (303) 497-3863]

Microwave and Millimeter-Wave Metrology

Marks, R.B., Jargon, J.A., Pao, C.K., and Wen, C.P., **Microwave Characterization of Flip-Chip MMIC Components**, Proceedings of the 45th Electronic Components & Technology Conference, Las Vegas, Nevada, May 21-24, 1995, pp. 343-350.

We apply custom calibration standards and software to the accurate on-wafer measurement of metal-insulator-metal capacitors and spiral inductors on flip-chip coplanar-waveguide MMICs. We suggest equivalent circuit models and document their deficiencies. The results are applicable to the development of an accurate CAD database.
[Contact: Roger B. Marks, (303) 497-3037]

Marks, R.B., Jargon, J.A., Pao, C.K., and Wen, C.P., **Microwave Characterization of Flip-Chip MMIC Interconnections**, Proceedings of the IEEE 1995 International Microwave Symposium, Orlando, Florida, May 14-19, 1995, Vol. 3, pp. 1463-1466.

We report accurate on-wafer measurements of transmission lines on flip-chip coplanar-waveguide MMICs. The effects are difficult to predict theoretically, and without custom standards and unique calibration software, measurements would be intractable. The results are applicable to the development of an accurate CAD database. We also report and apply a new technique for the measurement of transmission line capacitance.
[Contact: Roger B. Marks, (303) 497-3037]

Weidman, M.P., **Direct Comparison Transfer of Microwave Power Sensor Calibrations**, NIST Technical Note 1379 (January 1996).

This report describes a basic, but potentially accurate, transfer technique for comparing microwave power sensors. The technique is not new, but the specific applications are. This report is written to supplement the existing literature. The method transfers the effective efficiency of a standard power sensor to an unknown (uncalibrated) power sensor. The power sensors may be bolometric (thermistor mounts), thermoelectric, or diode types, and each type will have inherent limitations. The technique can be implemented with a variety of commercial coaxial and rectangular waveguide components. Measurement uncertainty is discussed in this report so that a potential user can quantify transfer uncertainties.
[Contact: Manly P. Weidman, (303) 497-3516]

Williams, D.F., and Schappacher, J.B., **Line Reflect-Match Calibrations with Nonideal Microstrip Standards**, Proceedings of the 46th Automatic Radio Frequency Techniques Group, Scottsdale, Arizona, November 30—December 1, 1995, pp. 35-38.

We apply a previously developed Line-Reflect-Match calibration that compensates for the nonideal electrical behavior of the match standard to microstrip transmission lines and investigate impedance definitions, standard parasitics, and

calibration accuracy.
[Contact: Dylan F. Williams, (303) 497-3138]

Electromagnetic Properties

Baker-Jarvis, J., and Grosvenor, J.H., **Dielectric and Magnetic Measurements from -50 °C to 200 °C and in the Frequency Band 50 MHz to 2 GHz**, NISTIR 5045 (March 1996).

This is an overview of techniques for dielectric and magnetic measurements of low-loss through high-loss materials in the frequency range from 50 MHz to 2 GHz and over a temperature range of -50 °C to 200 °C. We conclude that a single fixture is not adequate to satisfy the measurement objectives. The necessary measurements can be met using a combination of reentrant cavity, coaxial line, and dielectric resonator fixtures. In order to minimize heat loss, the coaxial line fixture should be milled from stainless steel stock and then gold plated. The reentrant cavity and split post resonator fixtures should be fitted with high-temperature coaxial cables and temperature control obtained from an environmental furnace.
[Contact: James Baker-Jarvis, (303) 497-5621]

Baker-Jarvis, J., and Janezic, M.D., **Analysis of a Two-Port Flanged Coaxial Holder for Shielding Effectiveness and Dielectric Measurements of Thin Films and Thin Materials**, IEEE Transactions on Electromagnetic Compatibility, Vol. 38, No. I, pp. 67-70 (February 1996).

A two-port flanged coaxial probe for measuring the dielectric and magnetic properties of thin material sheets is analyzed. Closed form solutions for the two-port scattering parameters are presented. The solution assumes an incident TEM wave together with evanescent TM_{0n} modes. Numerical results are obtained for both the forward and inverse problem. Computations indicate that at low frequencies the incident waves are almost totally reflected. As the frequency is increased, transmission through the sample increases. Experimental results compare closely with theory. The inverse solution yielded good permittivity determination for the cases tested. The technique should prove useful for nondestructive testing of circuit boards or substrates.
[Contact: James-Baker Jarvis, (303) 497-5621]

Mantese, J.V., Micheli, A.L., Dungan, D.F., Geyer, R.G., Baker-Jarvis, J., and Grosvenor, J., **Applicability of Effective Medium Theory to Ferroelectric/Ferrimagnetic Composites with Composition and Frequency-Dependent Complex Permittivities and Permeabilities**, Journal of Applied Physics, Vol. 79, No. 3, pp. 1655-1660 (February 1996).

High-frequency (1 MHz to 1 GHz) transmission line measurements were used to determine the composition and frequency-dependent complex permittivities and complex permeabilities of ferroelectric/ferrimagnetic (barium titanate and a magnesium-copper-zinc ferrite) composites. The effective medium rules of Maxwell-Garnett give both lower and upper bounds for the effective permittivities and permeabilities and yield accurate estimates of the bulk electric and magnetic properties at low volume fill fraction of either component provided the proper host matrix is chosen. Bruggeman theory yielded the best predictive values for the permittivity and permeability over the entire composition range. In all cases, these complex quantities were shown to be constrained by Bergman-Milton bounds.
[Contact: Richard G. Geyer, (303) 497-5852]

Laser Metrology

Vayshenker, I., Yang, S., Li, X., and Scott, T.R., **Automated Measurements of Nonlinearity of Optical Fiber Power Meters**, Proceedings of SPIE (The International Society for Optical Engineering, P.O. Box 10, Bellingham, Washington 98227-0010), Photodetectors and Power Meters II, Vol. 2550, pp. 12-19 (1995).

[See Optical Fiber Metrology.]

Optical Fiber Metrology

Vayshenker, I., Yang, S., Li, X., and Scott, T.R., **Automated Measurements of Nonlinearity of Optical Fiber Power Meters**, Proceedings of SPIE (The International Society for Optical Engineering, P.O. Box 10, Bellingham, Washington 98227-0010), Photodetectors and Power Meters II, Vol. 2550, pp. 12-19 (1995).

We have developed a system for measuring the

nonlinearity of optical power meters or detectors over a dynamic range of more than 60 dB at telecommunications wavelengths. This system uses optical fiber components and is designed to accommodate common optical power meters and optical detectors. It is based on the triplet superposition method. The system also measures the range discontinuity between neighboring power ranges or scale settings of the optical power meter. We have developed an algorithm to treat both the nonlinearity and the range discontinuity in a logically consistent manner. Measurements with this system yield correction factors for powers in all ranges. The measurement system is capable of producing results which have standard deviations as low as 0.02%. With slight modification, the system can operate over a 90 dB dynamic range at telecommunications wavelengths. This measurement system provides accurate determination of optical power meter or detector nonlinearity; the characterized detectors then can be used for such applications as absolute power and attenuation measurements.
[Contact: Thomas R. Scott, (303) 497-3651]

Optical Fiber/Waveguide Sensors

Deeter, M.N., **Fiber-Optic Faraday-Effect Magnetic-Field Sensor Based on Flux Concentrators**, Applied Optics, Vol. 35, No. 1, pp. 154-157 (1 January 1996).

[See Magnetic Materials and Measurements.]

Drapela, T.J., Franzen, D.L., and Young, M., **Optical Fiber, Fiber Coating, and Connector Ferrule Geometry: Results of Interlaboratory Measurement Comparisons**, NIST Technical Note 1378 (November 1995).

Interlaboratory measurement comparisons, dealing with geometrical parameters of optical fibers, fiber coating, and fiber connector ferrules (including steel pin gages used to determine ferrule inside diameter), have been coordinated by NIST. The international fiber (glass) geometry comparison showed better agreement among participants, for all measured parameters, than in previous comparisons. Many participants' test sets were calibrated for fiber cladding diameter measurements by means of calibration artifacts from NIST or other national standards laboratories; there was significantly better agreement among those participants than among participants who were not calibrated. In the other comparisons, some parameters showed large systematic offsets between participants' data; accurate calibration, for those parameters, would lead to better interlaboratory agreement. NIST is developing ferrule, pin gage, and coating calibration artifacts.
[Contact: Timothy J. Drapela, (303) 497-5858]

Rose, A.H., and Wyss, J.C., **Self Calibrating Optical Thermometer**, Proceedings of SPIE (The International Society for Optical Engineering, P.O. Box 10, Bellingham, Washington 98227-0010), Self-Calibrated Intelligent Optical Sensors and Systems, Vol. 2594, pp. 142-148 (1996).

A computer-controlled optical thermometer has been built to demonstrate a self-calibrating optical sensor. The self-calibrating thermometer records the temperatures with a fiber-optic polarimetric temperature sensor. The wavelength sensitivity of the polarimetric sensor is used to facilitate the recalibration. The system contains an optical source which can be tuned over approximately a 9 nm wavelength range, and a monochromator to measure any shifts in the wavelength of the laser. The monochromator is calibrated with the spectrum of a neon discharge lamp.
[Contact: Allen H. Rose, (303) 497-5599]

Integrated Optics

Kumar, A., Jindal, R., and Gallawa, R.L., **Bending Induced Phase Shifts in Arbitrarily Bent Rectangular-Core Dual-Mode Waveguides**, Journal of Lightwave Technology, Vol. 14, No. 2, pp. 196-201 (February 1996).

We examine the variation of the effective indexes of the two modes of an arbitrarily bent dual-mode rectangular-core waveguide. We find that under the large bending radius approximation, which is indeed the practical case for most of the devices, the waveguide bent with bending radius p in a plane at an angle Θ with the major axis is almost equivalent to bending it simultaneously in the plane of major and minor axes with bending radii $p \sec \Theta$ and $p \operatorname{cosec} \Theta$, respectively. The bending-induced phase difference between the two modes is found (a) to be

maximum when the waveguide is bent along the major axis, and (b) to decrease first and then increase in the opposite direction as the *V*-number is decreased. The results of our study can be used to improve the sensitivity of the dual-mode optical waveguide sensors and devices based on the bending of fiber.
[Contact: Robert L. Gallawa, (303) 497-3761]

Other Signal Topics

Young, M., and Hale, P.D., **Off-Axis Illumination and Its Relation to Partial Coherence**, American Journal of Physics, Vol. 63, No. 12, pp. 1136-1141 (1996).

We calculate the partially coherent of an edge in one dimension by the method of adding intensities, that is, by modeling the illumination as an array of mutually incoherent plane waves incident over a range of angles. In order to visualize the transition between coherent and incoherent imaging, we display images that result from such off-axis plane waves; these images change considerably as the angle of illumination changes. The calculations are easily carried out on a microcomputer with a high-level mathematics program. The results shed light on off-axis and dark-field illumination as well. Finally, we elucidate a distinction between imaging with the aperture stop in the transform plane and imaging with the aperture stop distant from the transform plane.
[Contact: Matt Young, (303) 497-3223]

ELECTRICAL SYSTEMS

Power Systems Metrology

Misakian, M., and Fenimore, C., **Distributions of Measurement Error for Three-Axis Magnetic Field Meters during Measurements near Appliances**, IEEE Transactions on Instrumentation and Measurement, Vol. 45, No. 1, pp. 244-249 (February 1996).

Comparisons are made between the average magnetic flux density as would be measured with a three-axis coil probe and the flux density at the center of the probe. Probability distributions of the differences between the two quantities are calculated assuming a dipole magnetic field and are found to be asymmetric. The distributions allow estimates of uncertainty for resultant magnetic field measurements made near some electrical appliances and other electrical equipment.
[Contact: Martin Misakian, (301) 975-2426]

Stricklett, K.L., and Altafim, R.A.C., **Electrohydrodynamic Instability and Electrical Discharge Initiation in Hexane**, Proceedings of the Conference on Electrical Insulation and Dielectric Phenomena, Virginia Beach, Virginia, October 22-25, 1995, pp. 163-166.

An experimental technique is described that tests the hydrodynamic stability of the fluid boundary in a fluid-insulated system: A quasi-uniform field configuration is used, and a pulsed, Nd:YAG laser is employed to create a micro-bubble at the surface of one electrode. The gap is pulse-charged, and the laser is synchronized with the time-of-application of the voltage pulse. Under appropriate experimental conditions of voltage and laser pulse energy, the bubble evolves to produce full electrical breakdown by the onset and propagation of instabilities in the bubble surface. Experimental data obtained in hexane are presented.
[Contact: Kenneth L. Stricklett, (301) 975-3955]

Magnetic Materials and Measurements

Crawford, T.M., Rogers, C.T., Silva, T.J., and Kim, Y.K., **Observation of the Transverse Second Magneto-Optic Kerr Effect from $Ni_{81}Fe_{19}$ Thin Film Structures**, Applied Physics Letters, Vol. 68, No. 11, pp. 1573-1575 (11 March 1996).

We report measurements of the second-harmonic magneto-optic Kerr measurements on air-exposed, polycrystalline $Ni_{81}Fe_{19}$ thin films, ranging from 1 nm to 2 μm, on Al_2O_3-coated Si (001). For samples thicker than 20 nm, in the transverse Kerr geometry, we observe a factor of four change in second-harmonic intensity upon magnetization reversal. For thin samples, we observe interference between second-harmonic fields from the various interfaces and deterioration of ferromagnetism in the 1 and 2 nm films. Modeling suggests that the $Ni_{81}Fe_{19}/Al_2O_3$ interface has a larger second-order susceptibility than the air/$Ni_{81}Fe_{19}$ surface.
[Contact: Thomas J. Silva, (303) 497-7826]

Deeter, M.N., **Fiber-Optic Faraday-Effect Magnetic-Field Sensor Based on Flux Concentrators**, Applied Optics, Vol. 35, No. 1, pp. 154-157 (1 January 1996).

The principles and performances of a fiber-optic Faraday-effect magnetic-field sensor designed around an yttriium-ion-garnet (YIG) sensing element and two-flux concentrators are described. The system design exploits the technique of polarization-rotated reflection in which a single polarization-maintaining optical fiber links the sensor head to the optical source and detection system. In the sensing head, ferrite flux concentrators are magnetically coupled to the YIG sensing element to achieve maximum sensitivity. The system exhibits a noise equivalent field of 6 pT/$\sqrt{}$Hz and a -3 dB bandwidth of ~10 MHz.
[Contact: Merritt N. Deeter, (303) 497-5400]

Misakian, M., and Fenimore, C., **Distributions of Measurement Error for Three-Axis Magnetic Field Meters during Measurements near Appliances**, IEEE Transactions on Instrumentation and Measurement, Vol. 45, No. 1, pp. 244-249 (February 1996).

[See Power Systems Metrology.]

Oti, J.O., Russek, S.E., Sanders, S.C., and Cross, R.W., **Models of Granular Giant Magnetoresistance Multilayer Thin Films**, IEEE Transactions on Magnetics, Vol. 32, No. 2, pp. 590-598 (March 1996).

Phenomenological micromagnetic and large-scale magnetization-dependent models of resistivity that produce giant magnetoresistance in granular multilayer magnetic thin films are described. Included in the models are intralayer and interlayer scattering components formulated explicitly in terms of the microstructural properties and characteristic transport lengths of the medium. The micromagnetic model provides insight into the influence of the magnetization distribution on the giant magnetoresistance response of the medium. The large-scale model, which is derived from the micromagnetic model, is useful for obtaining media transport parameters from experimental data. Both models are used to study a set of annealed NiFe/Ag multilayer films.
[Contact: John O. Oti, (303) 497-5557]

Superconductors

Recently Published

Roshko, A., Goodrich, L.F., Rudman, D.A., Moerman, R., and Vale, L.R., **Magnetic Flux Pinning in Epitaxial $YBa_2Cu_3O_{7-\delta}$ Thin Films**, Journal of Electronic Materials, Vol. 24, No. 12, pp. 1919-1922 (1995).

[See Cryoelectronic Metrology.]

ELECTROMAGNETIC INTERFERENCE

Conducted EMI

Martzloff, F.D., Mansoor, A., Phipps, K.O., and Grady, W.M., **Surging the Upside-Down House: Measurements and Modeling Results**, Proceedings of the Fourth International Conference on Power Quality: Applications and Perspectives, New York, New York, May 9-11, 1995, unpaged.

Electronic equipment with two input ports, power and communications, can be exposed to damaging differences of voltage between the two ports during surge events. To demonstrate real-world scenarios, a replica of the wiring system in a typical residence was installed in the laboratory. This paper reports selected results from many measurements, and presents the corresponding numerical modeling, thereby leading to mutual validation of the two processes. Two exposure scenarios for producing differences of voltages between the power and data ports of appliances are illustrated. Additional measurements and parametric variations are reported here to characterize the impedance of the various components of the wiring system and the source impedance of the resulting overvoltages appearing between the ports.
[Contact: François D. Martzloff, (301) 975-2409]

Radiated EMI

Camell, D.G., and Ma, M.T., **Data Evaluation of a Linear System by a Second-Order Transfer Function**, Conference Record of the 1995 IEEE

Electro-Magnetic Compatibility Symposium, Atlanta, Georgia, August 14-18, 1995, pp. 511-515.

A recently developed technique for predicting the response of a linear system to an electromagnetic pulse, based only on the measured continuous-wave (cw) magnitude, is applied to a particular system as a case study. The measured magnitude representing the system's transfer function is deduced first from the measured response to a known cw source, supplied by the Naval Surface Warfare Center. Then, an analytic expression is derived for the magnitude square of the transfer function to approximate the measured data, and a system transfer function in terms of the complex frequency is obtained. Finally, the system's cw phase characteristics and its multiple solutions due to a given impulse source are predicted.
[Contact: Dennis G. Camell, (303) 497-3214]

Crawford, M.L., **Alternative Electromagnetic Compatibility Compliance Test Facilities**, Book Chapter in Handbook of Electromagnetic Compatibility Academic Press, San Diego, California (1995), pp. 681-710.

A number of test facilities exist that can be used as alternatives to open field sites or shielded anechoic chambers for electromagnetic compatibility (EMC) compliance testing. The most common include various transverse electromagnetic (TEM) transmission line facilities. These operate as TEM transducers to either establish a known test field for radiated immunity testing or they serve as a receptor for measuring the radiated emissions from the equipment under test. Another alternative facility is the mode-stirred or reverberating chamber. This facility is essentially a large microwave oven. Tests are performed by measuring appropriate input, output, and statistical test field parameters for either radiated immunity or emissions testing. Procedures for performing radiated immunity and emission tests using TEM and reverberation chamber facilities are described. Recent work to combine TEM cell EMC measurement technology with reverberating chamber EMC measurements into a single, hybrid facility is also described.
[Contact: Myron L. Crawford, (301) 975-5497]

Crawford, M.L., Riddle, B.F., and Camell, D.G., **TEM/Reverberating Chamber Electromagnetic Radiation Test Facility at Rome Laboratory**, NISTIR 5002 (January 1996).

This report summarizes the measurement and evaluation of a TEM/reverberating chamber. This chamber was developed as a single, integrated facility for testing radiated electromagnetic compatibility/vulnerability (EMC/V) of large systems of a large shielded enclosure configured as a transverse electromagnetic (TEM) transmission line-driven reverberating chamber. TEM mode test fields are generated at frequencies below multimode cutoff, and mode-stirred test fields are generated at frequencies above multimode cutoff. The report discusses the basis for such a development including the theoretical concepts, the advantages and limitations, the experimental approach for evaluating the operational parameters, and the procedures for using the chamber to perform EMC/V measurements. Both the chamber's cw and pulsed rf characteristics are measured and analyzed.
[Contact: Myron L. Crawford, (303) 497-5497]

Hill, D.A., Camell, D.G., Cavcey, K.H., and Koepke, G.H., **Radiated Emissions and Immunity of Microstrip Transmission Lines: Theory and Measurements**, NIST Technical Note 1377 (July 1995).

We analyze radiation from a microstrip transmission line and calculate total radiated power by numerical integration. Reverberation chamber methods for measuring radiated emissions and immunity are reviewed and applied to three microstrip configurations. Measurements from 200 to 2000 MHz are compared with theory, and excellent agreement is obtained for two configurations that minimize feed cable and finite ground plane effects. Emissions measurements are found to be more accurate than immunity measurements because the impedance mismatch of the receiving antenna cancels when the ratio of the microstrip and reference radiated power measurements is taken. The use of two different receiving antenna locations for emissions measurements illustrates good field uniformity within the chamber.
[Contact: David A. Hill, (303) 497-3472]

Kanda, M., **Methodology for Electromagnetic**

Interference Measurements, Book Chapter in Handbook of Electromagnetic Compatibility, Academic Press, San Diego, California (1995), pp. 599-625.

Establishing standards for electromagnetic (EM) field measurements is a multifaceted endeavor which requires measurements made (1) in anechoic chambers, (2) at open sites, and (3) within guided-wave structures and the means of transferring these measurements from one situation to another. The underlying principles of these standard measurements and transfer standards fall into one of two categories: measurements and theoretical modeling. That is, either a parameter or a set of parameters is measured, or a parameter is calculated by established physical and mathematical principles. The three measurement topics and field transfer standards are discussed, with the guided-wave structures restricted to the transverse electromagnetic cell and the waveguide chamber. Throughout the discussion, the interplay between measured quantities and predicted (modeled) quantities are seen. The frequencies considered here range from 10 kHz to 40 GHz (and upward) and are determined by our ability to make an actual measurement and the restrictions imposed by rigorous theoretical analysis of a given model.
[Contact: Motohisa Kanda, (303) 497-5320]

Kanda, M., **Standard Probes for Electromagnetic Field Measurements**, Book Chapter in Handbook of Electromagnetic Capability Academic Press, San Diego, California (1995), pp. 627-648.

This tutorial paper discusses various standard antennas for measuring radio-frequency electric and magnetic fields. A theoretical analysis of each antenna's receiving characteristics is summarized and referenced. The standard probes described are an electrically short dipole, a resistively-loaded dipole, a half-wave dipole, an electrically small loop, and a resistively-loaded loop. A single-turn loop designed for simultaneous measurement of the electric and magnetic components of near-fields and other complex electromagnetic environments is also described. Each type of antenna demonstrates a different compromise between broadband frequency response and sensitivity.
[Contact: Motohisa Kanda, (303) 497-5320]

ADDITIONAL INFORMATION

Announcements

Characterization Workshop Proceedings Published.

The Proceedings of the International Workshop on Semiconductor Characterization: Present Status and Future Needs is now available through AIP Press. The book *Semiconductor Characterization* covers the unique characterization requirements of both silicon IC development and manufacturing and compound semiconductor materials, devices, and the National Technology Roadmap for Semiconductors. Additional sections discuss technology trends and future requirements for compound semiconductor applications. Recent developments in characterization, including in-situ, in-FAB, and off-line analysis methods are also highlighted. The book provides useful insights on the capabilities of different characterization techniques, gives perspectives on industrial metrology requirements, and explores critical needs and issues in semiconductor metrology research. This book will serve as a base-line reference in this rapidly growing field for the next decade.

In the foreword, **Craig Barrett**, Chief Operating Officer at Intel, and **Arati Prabhakar**, Director of NIST, stated that "characterization and modeling of semiconductors are increasingly becoming a crucial part of semiconductor manufacturing. This book provides a concise and effective portrayal of industry characterization needs and the problems that must be addressed by industry, government, and academia to continue the dramatic progress in semiconductor technology."

The work is based on papers given at the International Workshop, held the week of January 30, 1995 at NIST in Gaithersburg, Maryland. Sponsors were: The Advanced Research Projects Agency, SEMATECH, the National Institute of Standards and Technology, The Army Research Office, the U.S. Department of Energy, the National Science Foundation, Semiconductor Equipment and Materials International (SEMI), the Manufacturing Science and Technology Division of the American Vacuum Society, and the Working Group on Electronic Materials of the Committee on Civilian

Industrial Technologies.

To order the Proceedings, call the American Institute of Physics toll free at 1-800-809-2247.
[Contact: David G. Seiler, (301) 975-2054]

Lists of Publications

Bradford, A.G., **Metrology for Electromagnetic Technology: A Bibliography of NIST Publications**, NISTIR 5040 (September 1995).

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 4041.
[Contact: Ann G. Bradford, (303) 497-3678]

Lyons, R.M., **A Bibliography of the NIST Electromagnetic Fields Division Publications**, NISTIR 5039 (August 1995).

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 1995. It supersedes NISTIR 5028 which listed the publications of the Electromagnetic Fields Division from January 1970 through July 1994. 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** (July 1995).

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 1994. A brief description of the Division's technical program is given in the introduction.
[Contact: Ruth A. Schmeit, (301) 975-2401]

Smith, A.J., and Derr, L.S., **A Bibliography of Publications of the NIST Optoelectronics Division**, NISTIR 5041 (September 1995).

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, 1990-1995**. (March 1996).

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 1995. 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]

1996 Calendar of Events

August 19-23, 1996 (Boulder, Colorado)

Laser Measurements Short Course.
This meeting provides training on laser measurement 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 1-3, 1996 (Boulder, Colorado)

Symposium on Optical Fiber Measurements.

This Symposium, held at NIST in Boulder, provides a forum for reporting the results of recent measurement research in the area of lightwave communications, including optical fibers. Aspects of optical fiber metrology will be discussed, including attenuation, dispersion, geometry, reflectometry, and connectors; integrated optic devices; laser diode sources and detectors; and system measurements.
[Contact: Douglas L. Franzen, (303) 497-3346]

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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. The existing SRMs (on 50 mm wafers) shown in the table below will be augmented with an improved set (on 100 mm wafers) during CY 96-97. NIST efforts to produce the new SRMs have recently received increased emphasis. The earlier set will continue to be available until the supply is exhausted.

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. While it is expected that these wafers will offer considerable utility in calibrating contactless gauges, certification has been performed solely with four-point probe methods. Technical insights presented by the rigorous certification process will be presented in a NIST Special Publication. Individual data for each wafer will be supplied along with the SRM Certificate.

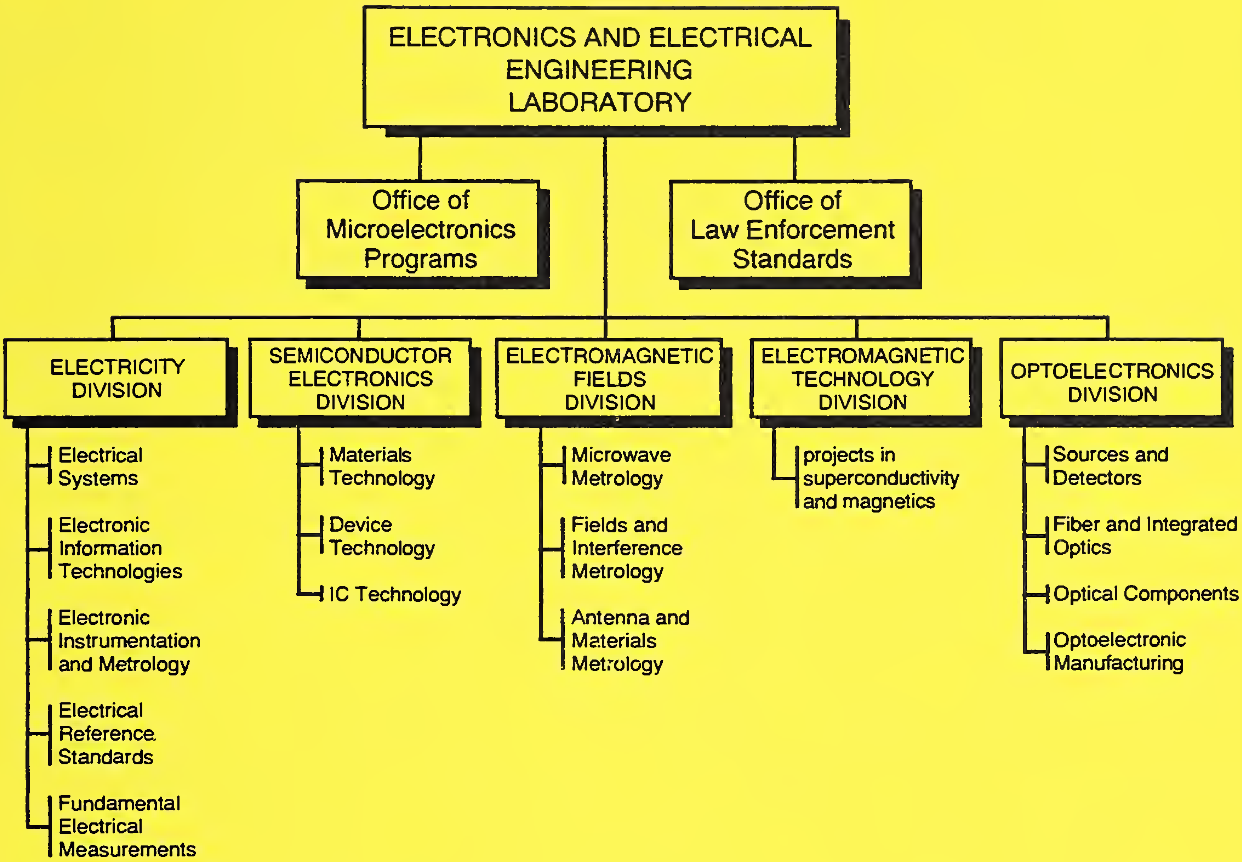
It is expected that the higher resistivity SRMs (2547, 2546) will be available first during CY 96 and be followed closely by SRM 2545. The low resistivity material (SRMs 2542, 2541) is expected to be available by year end. A limited number of SRM 2543 may also be available by year end, with the remainder in early CY 97. Technical issues associated with SRM 2544 will preclude its availability until CY 97.

NIST SILICON BULK RESISTIVITY STANDARD REFERENCE MATERIALS

DATE UPDATED: 23 JANUARY 1996

NOMINAL RESISTIVITY (ohm · cm)	OLD SRMs	AVAILABILITY	NEW SRMs (ohm · cm)	ANTICIPATED AVAILABILITY
0.01	1523 (one of set of two wafers)	limited supply	2541	CY 96
0.1	1521 (one of set of two wafers)	limited supply	2542	CY 96
1	1523 (one of set of two wafers)	limited supply	2543	CY 96-97
10	1521 (one of set of two wafers)	limited supply	2544	CY 97
25	1522	set of three wafers no longer available	2545	CY 96
75	1522		2546 (100)	CY 96
180	1522		2547 (200)	CY 96

The above table will be updated in future issues to reflect changes in availability. Every effort will be made to provide accurate statements of availability; 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.



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