NISTIR 5231

Electronics and Electrical Engineering Laboratory

Technical Publication Announcements

J. M. Rohrbaugh
Compiler

July 1993

Covering Laboratory Programs,
January to March, 1993
with 1993/1994 EEEL Events Calendar

36

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

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U.S. DEPARTMENT OF COMMERCE
Ronald H. Brown, Secretary

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
Arati Prabhakar, Director

INTRODUCTION TO THE EEEL TECHNICAL PUBLICATION ANNOUNCEMENTS

This is the thirty-sixth 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 first quarter of calendar year 1993.

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 1993/1994 and a list of sponsors of the work.

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

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

Key contacts in the Laboratory are given on the 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 12.

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 9.

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 are necessarily the best available for the purpose.

TABLE OF CONTENTS

SEMICONDUCTOR MICROELECTRONICS

Silicon Materials

Conley, J.F., Lenahan, P.M., and Roitman, P., **Electron Traps, Structural Change, and Hydrogen-Related SIMOX Defects**, Extended Abstract, Proceedings of the 1992 IEEE International SOI Conference, Ponte Vedra Beach, Florida, October 6-8, 1992, pp. 26-27.

Evidence for structural changes in SIMOX buried oxides is presented. We show that deep electron traps may be created in SIMOX buried oxides; these electron traps could compensate for some positively charged E′ centers. In addition, we report observation of relatively high densities of hydrogen-related defects in VUV illuminated oxides. We suggest that this short range disorder may be responsible for the differences between the response of ordinary thermal oxide and SIMOX buried oxides.
[Contact: Peter Roitman, (301) 975-2077]

Krause, S.J., Park, J.C., Lee, J.D., El-Ghor, M., and Roitman, P., **Effect of Thermal Ramping Conditions on Defect Formation in Oxygen Implanted Silicon-On-Insulator Material**, Extended Abstract, 1992 IEEE International SOI Conference, Ponte Vedra Beach, Florida, October 6-8, 1992, pp. 80-81.

SIMOX (Separation by IMplanted OXygen) is a leading technology for providing SOI material for complementary metal-oxide-semiconductor (CMOS) circuits which have increased radiation hardness and higher operating speed. Defects in the top Si layer affect CMOS device yield, operation, and reliability. Defects in annealed SIMOX form from oxide precipitation and dissolution during thermal ramping and annealing. These defects include dislocations, stacking faults, stacking fault pairs, and stacking fault tetrahedra. Multiple cycles of implantation and annealing and higher temperature implantation, above 600 °C, have been used to reduce the defect density. Thermal ramping rate and annealing ambient can significantly affect precipitation processes and defect formation during thermal ramping. In this work, the effect of thermal ramping conditions, including oxide capping, on defect formation was studied.
[Contact: Peter Roitman, (301) 975-2077]

Mayo, S., Suehle, J.S., and Roitman, P., **Charge Trapping and Breakdown Mechanism in SIMOX**, Extended Abstract, Proceedings of the 1992 IEEE International SOI Conference, Ponte Vedra Beach, Florida, October 6-8, 1992, pp. 28-29.

We have studied the charge build-up mechanism in SIMOX (Separation by IMplanted OXygen) capacitors injected with electrons from the gate or substrate. The breakdown voltage corresponds to electric fields of 1×10^7 V cm^{-1} for electron injection from the gate, or 7.5×10^6 V cm^{-1} for electron injection from the substrate. These field values, comparable to breakdown fields in capacitors fabricated with thermally grown oxides, are reported here for the first time in SIMOX buried oxides. This breakdown voltage asymmetry in the SIMOX structure is determined by differences in interface morphology at the gate or substrate. Injection from the substrate yields higher current under equal bias and results in lower breakdown fields.
[Contact: Santos Mayo, (301) 975-2045]

Roitman, P., Krause, S.J., Seraphin, S., Simons, D.S., and Cordts, B.F., **Effect of Annealing Ambient on the Removal of Oxide Precipitates in High-Dose Oxygen Implanted Silicon**, Applied Physics Letters, Vol. 59, No. 23, pp. 3003-3005 (December 1991).

The effect of annealing ambient on the precipitate removal processes in high-dose oxygen-implanted silicon [Separation by IMplanted OXygen] has been studied with transmission electron microscopy, electron energy-loss spectroscopy, and secondary ion mass spectroscopy. The rate of removal of oxide precipitates from the top silicon layer in SIMOX is higher during annealing in argon than in nitrogen. The removal is reduced in nitrogen due to the formation of an oxynitride complex at the precipitate surface which inhibits oxygen diffusion across the interfaces. Similar effects have been observed for oxide precipitation during nitrogen ambient annealing in bulk silicon.
[Contact: Peter Roitman, (301) 975-2077]

Compound Materials

Littler, C.L., Maldonado, E., Song, X.N., Yu, Z., Elkind, J.L., Seiler, D.G., and Lowney, J.R., **Investigation of Mercury Interstitials in $Hg_{1-x}Cd_xTe$**

Alloys Using Resonant Impact-Ionization Spectroscopy, Journal of Vacuum Science Technology B, Vol. 10, No. 4, pp. 1466-1470 (July/August 1992).

A new technique for studying low concentrations of trap levels in narrow-gap $Hg_{1-x}Cd_xTe$ has been combined with the deliberate introduction of impurities to determine the activation energies of these impurities in this ternary material. In this investigation, mercury (Hg) interstitials, believed to be responsible for dark current in metal insulator-semiconductor devices, were deliberately introduced into samples with $x = 0.22$ and $x = 0.24$. Each sample was divided into two parts, with the second part of each slice used as a control. The results from the interstitially doped samples provide direct evidence that Hg interstitials create trap levels near 45 and 60 meV above the valence band edge for these x-value samples.
[Contact: David G. Seiler, (301) 975-2074]

Integrated-Circuit Test Structures

Marshall, J.C., Cresswell, M.W., Ellenwood, C.H., Linholm, L.W., Roitman, P., and Zaghloul, M.E., **The Design Guide for CMOS-On-SIMOX Test Chips NIST3 and NIST4**, NISTIR 4889 (January 1993).

The design guidelines for test chips NIST3 and NIST4 are specified in this manual. These chips were designed for process monitoring and device parameter extraction for a CMOS (Complementary Metal-Oxide-Semiconductor)-on-SOI (Silicon-On-Insulator) process. The chips contain structures which are common to a standard CMOS process as well as structures specifically designed for a SIMOX (Separation by IMplanted OXygen) process. In order to facilitate the CAD process, a unique "technology file" was created for the Magic VLSI layout editor used on a Sun-3/280 system running Sun Version 3.5. This SIMOX technology file is very general and can be used to build CMOS as well as SIMOX chips.

NIST3 is 6380 μm x 4780 μm and contains several large-geometry MOSFETs, resistors, and capacitors. NIST4 is 1 cm x 1 cm and contains approximately 300 small-geometry test structures. The SIMOX specific structures found on these chips include MOSFETs, capacitors, interconnects, and pads.

The test guide for the test structures on NIST3 and NIST4 is included in a separate manual (NISTIR 4890).
[Contact: Janet C. Marshall, (301) 975-2049]

Marshall, J.C., Cresswell, M.W., Ellenwood, C.H., Linholm, L.W., Roitman, P., and Zaghloul, M., **The Test Guide for CMOS-on-SIMOX Test Chips NIST3 and NIST4**, NISTIR 4890 (January 1993).

A test chip set has been designed for process monitoring and device parameter extraction for a CMOS (Complementary Metal-Oxide-Semiconductor)-on-SOI (Silicon-On-Insulator) process. The chips contain structures which are common to a standard CMOS process as well as structures specifically designed for a SIMOX (Separation by Implanted OXygen) process.

NIST3 is 6380 μm x 4780 μm and contains several large-geometry MOSFETs, resistors, and capacitors. NIST4 is 1 cm x 1 cm and contains approximately 300 small-geometry test structures. The SIMOX specific structures found on these chips include MOSFETs, capacitors, interconnects, and pads. This report presents the information necessary to test NIST3 and NIST4.

Design guidelines, technology file modifications, and data output specifications for NIST3 and NIST4 are discussed in a separate manual (NISTIR 4889).
[Contact: Janet C. Marshall, (301) 975-2049]

Microfabrication Technology

Suehle, J.S., and Gaitan, M., **Application of CMOS-Compatible Micro-Hotplates for *In-Situ* Process Monitors**, IEEE Electron Device Letters, Vol. 14, No. 3, pp. 118-120 (March 1993).

A CMOS-compatible micromechanical structure that can be used as an *in-situ* sensor for monitoring and controlling the deposition of films is reported. This micro-hotplate structure is fabricated by the micromachining of commercial CMOS-technology wafers or chips and the deposition of additional films. This device is comprised of a polysilicon resistor for heating, an aluminum plate for temperature sensing, and four top aluminum contacts that provide electrical connection to sensing materials or to films that are being deposited.

Arrays of micro-hotplates have been fabricated and used to study film growth at several substrate temperatures. A matrix of experiments can be performed during one deposition cycle using such an array of structures. Examples are presented using the micro-hotplate: to monitor substrate temperature during aluminum sputtering to monitor film resistivity during deposition, and to sense the presence of gas species.
[Contact: John S. Suehle, (301) 975-2247]

SIGNAL ACQUISITION, PROCESSING, AND TRANSMISSION

DC and Low-Frequency Metrology

Chang, Y.M., **NIST Capacitance Measurement Assurance Program (MAP)**, Proceedings of the 1993 Measurement Science Conference, Anaheim, California, January 21-22, 1993 (unpaged).

This paper describes the recently developed capacitance Measurement Assurance Program service at the National Institute of Standards and Technology (NIST). Using a commercial digital capacitance meter as the transport standard, two separate pilot programs for the capacitance MAP have been performed for standards at both the 1000-pF and 100-pF levels. The first was carried out as a single transfer with a government standards laboratory, and the second was designed for round-robin measurements as a multiple transfer by three industrial standards laboratories. As a contrast to the normal MAP, where the transport standards are measured by the client laboratory, the capacitance MAP involves measurements performed on "dummy" standards by both the meter and the laboratory capacitance measuring systems. Results from these two pilot programs are presented. Also included are requirements and procedures for laboratories interested in participating in the capacitance MAP service.
[Contact: Y. May Chang, (301) 975-4237]

Antenna Metrology

Guerrieri, J.R., Tamura, D.T., and Repjar, A.G., **Accurate Planar Near-Field Probe Correction Using Dual-Port Circularly Polarized Probes**, Proceedings of the Antenna Measurement Techniques Association Symposium, Columbus, Ohio, October 19-23, 1992, pp. 10-17—10-25.

When the planar near-field method for antenna characterization is used, two probes are required to measure an antenna under test (AUT). The receiving patterns (both amplitude and phase) of these probes must be determined and utilized to accurately determine the far-field of the AUT from planar near-field measurements. This process is commonly called planar near-field probe correction. When the antenna to be tested is nominally circularly polarized (CP), the measurements are more accurate and efficient if nominally circularly polarized probes are used. Further efficiency is obtained when only one probe which is dual-polarized is used to allow for simultaneous measurements of both components. However, when using dual-port circularly-polarized probes to measure the antenna, the probe correction can be important even for on-axis measurements.

The most accurate method to determine the probe coefficients is to measure the dual-port probes on a spherical probe pattern range at each frequency and then compute the coefficients. This can be costly in terms of time and resources, but is routinely done at the National Institute of Standards and Technology. A second method is to approximate the probe patterns at each frequency using theoretical techniques. Before attempting to do this, one should thoroughly evaluate the effects of the probe on the antenna measurements. This is done by examining the planar near-field coupling equations for on-axis and off-axis pattern calculations, assuming a low side-lobe AUT and state-of-the-art CP probes. Results are shown at several frequencies, and problems associated with theoretically obtaining probe coefficients are discussed.
[Contact: Jeffrey R. Guerrieri, (303) 497-3863]

MacReynolds, K., Repjar, A.G., Kremer, D.P., and Canales, N., **Phased-Array Testing and Diagnostics Using Planar Near-Field Scanning**, Proceedings of the Antenna Measurement Technology Association Symposium, Columbus, Ohio, October 19-23, 1992, pp. 8-24—8-30.

The Antenna Metrology Group of the National

Institute of Standards and Technology, working in cooperation with McClellan Air Force Base, Sacramento, California, have examined measurement techniques to test a large phased-array antenna using planar near-field (PNF) scanning. It was necessary to find methods that would be useful in both field and production testing and could provide gain and diagnostic information in a simple and timely manner. This paper discusses several aspects of the PNF measurement cycle that impact effective testing of the antenna array. These aspects include the use of a polarization-matched probe, the effect of scan truncation both on the transform to the far-field and the inverse transform to the aperture plane, and use of gain prediction curves as a diagnostic tool.
[Contact: Katherine MacReynolds, (303) 497-3471]

Wittmann, R.C., Newell, A.C., Stubenrauch, C.F., MacReynolds, K., and Francis, M.H., **Simulation of the Merged Spectrum Technique for Aligning Planar Phased-Array Antennas, Part I**, NISTIR 3981 (October 1992).

This report describes the initial phase of a NIST study of the merged-spectrum technique for determining the element excitations from planar scanning near-field measurements of phased-array antennas. Excitation data are used in adjusting phase shifters to meet design specifications. Measurement uncertainties, steering errors, and various analytic approximations will all introduce errors into the alignment. The study is ultimately directed to quantify the effect of these errors, to more fully understand the merged-spectrum technique, and to recommend possible improvements. The present report covers theory developed to support evaluation of the merged-spectrum technique and gives simulation examples illustrating calculation of near fields from array factor and element patterns.
[Contact: Ronald C. Wittmann, (303) 497-3326]

Microwave and Millimeter-Wave Metrology

Marks, R.B., and Williams, D.F., **A General Waveguide Circuit Theory**, Journal of Research of the National Institute of Standards and Technology, Vol. 97, No. 5, pp. 533-562 (September-October 1992).

This work revises, updates, and extends classical circuit theory of electromagnetic waveguides. Unlike the conventional theory, the present formulation applies to all waveguides, even those involving lossy conductors and hybrid mode fields, in a fully rigorous way. Special attention is given to distinguishing the traveling waves, constructed with respect to a well-defined characteristic impedance, from a set of pseudo-waves, defined with respect to an arbitrary reference impedance. Matrices describing a linear junction are defined, and relationships among them, some newly discovered, are derived. New ramifications of reciprocity are developed. Measurement of the various network parameters is given extensive treatment.
[Contact: Roger B. Marks, (303) 497-3037]

Marks, R.B., and Williams, D.F., **Accurate Experi mental Characterization of Interconnects: A Discussion of "Experimental Electrical Characterization of Interconnects and Discontinuities in High-Speed Digital Systems,"** IEEE Transactions on Components, Hybrids, Manufacturing Technology, Vol. 15, No. 4, pp. 601-604 (August 1992).

This letter discusses two issues concerning the accuracy of electrical characterizations of interconnect transmission lines, particularly in regard to a recently published paper. The error in the characteristic impedance may be reduced through an alternative approximation to the capacitance of the transmission line. Furthermore, measurements of both the propagation constant and characteristic impedance, which are the two primary parameters characterizing the line, may be improved by the use of a well-conditioned algorithm.
[Contact: Roger B. Marks, (303) 497-3037]

Williams, D., **Comments on "Characterization of Resistive Transmission Lines by Short-Pulse Propagation,"** IEEE Microwave and Guided Wave Letters, Vol. 2, No. 8, p. 346 (August 1992).

Comments on the paper "Characterization of Resistive Transmission Lines by Short-Pulse Propagation" are presented. The accuracy of the measurement technique reported in the paper is discussed.
[Contact: Dylan Williams, (303) 497-3138]

Electromagnetic Properties

Tofani, S., Ondrejka, A.R., Kanda, M., and Hill, D.A, **Bistatic Scattering of Absorbing Materials from 30 to 1000 MHz,** IEEE Transactions on Electromagnetic Compatibility, Vol. 34, No. 3, pp. 304-307 (August 1992).

A wideband time-domain reflectometer has been used to evaluate the bistatic performance of the scattering coefficient of rf/microwave absorbers. The scattering coefficient has been measured inside an anechoic chamber in the 30- to 1000-MHz frequency range in the case of specular reflection. The scattering coefficient increases with incidence angle, and the measurement accuracy is ±2 dB.
[Contact: Arthur R. Ondrejka, (303) 497-3309]

ELECTRICAL SYSTEMS

Power Systems Metrology

Fenimore, C., and Zhang, Y.X., **Summary of 1989 Panel Session Paper on Robust Estimation in Parameter Extraction,** IEEE Transactions on Power Delivery, Vol. 7, No. 4, pp.1800-1804 (October 1992).

This paper presents a method of evaluating high voltage test parameters from digital records. It considers the problem of evaluating the parameters of the step response of an impulse measuring system. The method used should be robust: that is, the estimates should not be sensitive to noise or small variations in the input. Using cubic splines to fit the waveform provides an objective interpretation of "the mean curve" and "the steepest tangent line" and of the derived time parameters of the step response. Direct application of the standard definitions gives estimates which are sensitive to the small changes in the data. Redefining the tangent as the best fitting straight line along the rising portion of the step gives robust estimates of the parameters.
[Contact: Charles Fenimore, (301) 975-2428]

Martzloff, F.D. and Samotyj, M., **An Important Link in Whole-House Protection: Surge Reference Equalizers**, Proceedings of the EMC Zurich Symposium, Zurich, Switzerland, March 9-11, 1993 pp. 395-398.

The increasing use of electronics in residential applications has been paralleled by a realization that surge protection may be necessary for this type of equipment. Installing a surge-protective device on the power-line port as well as on the communications-line port of a piece of equipment such as a computer might appear sufficient to ensure this protection. However, the normal operation of one of the protective devices during a surge event can create differences in the voltages of the references of the two ports. This difference in voltages, applied across the equipment or across a communication link between two pieces of equipment, can result in permanent damage as well as upset. Equalizing these voltages can be achieved by proper routing of the two lines through a single device, called *Surge Reference Equalizer,* and, thus, avoid the risk of damage.
[Contact: Francois D. Martzloff, (301) 975-2409]

Rebuldela, G., and Jargon, J.A., **High Power CW Wattmeter Calibration at NIST**, Journal of Research of the National Institute of Standards and Technology, Vol. 97, No. 6, pp. 673-687 (November-December 1992).

The National Institute of Standards and Technology has established a measurement capability to support high power systems and devices. The automated wattmeter calibration system operates at power levels of 1 to 1000 W for frequencies from 1 to 30 MHz and 1 to 500 W from 30 to 400 MHz. A cascaded coupler technique is used to extend power measurements to high levels which are traceable to a 10-mW standard thermistor mount. This technique uses an arrangement of nominal 10-, 20-, 30-, 40-, and 50-dB couplers with sidearm power meters. The initial step transfers the calibration of the 10-mW standard to the 10-dB coupler/power meter. The standard is then replaced with a wattmeter to be calibrated. RF power is increased 10 dB, and the calibration is transferred to the adjacent 20-dB coupler/power meter. This sequence is repeated with the remaining coupler/power meters until the wattmeter is calibrated at the desired power levels and frequencies. Power ratios calculated from simultaneous power measurements made at each transfer are used to calculate the incident power at the wattmeter. Due to nonideal components, corrections are made for nonlinearities, mismatch, and other errors. Two

types of wattmeters have been evaluated at selected frequencies and power levels. Total uncertainties are based on the random and systematic components.
[Contact: Gregorio Rebuldela, (303) 497-3561]

Wan, H.-X., Moore, J.H., Olthoff, J.K., and Van Brunt, R.J., **Electron Scattering and Dissociative Attachment by SF_6 and Its Electrical-Discharge By-Products**, Plasma Chemistry and Plasma Processing, Vol. 13, No. 1, pp. 1-16 (March 1993).

Discrete electron-molecule processes relevant to SF_6 etching plasmas are examined. Absolute, total scattering cross sections for 0.2- to 12-eV electrons on SF_6, SO_2, SOF_2, SO_2F_2, SOF_4, and SF_4, as well as cross sections for negative-ion formation by attachment of 0.2- to 8-eV electrons have been measured. These are used to calculate dissociative-attachment rate coefficients as a function of E/N for SF_6 by-products in SF_6.
[Contact: James K. Olthoff, (301) 975-2431]

Superconductors

Goldfarb, R.B., Cross, R.W., Goodrich, L.F., and Bergren, N.F., **Magnetic Measurement of Transport Critical Current Density of Granular Superconductors**, Cryogenics, Vol. 33, No. 1, pp. 3-7 (1993).

We describe two magnetic techniques that may be used to determine the transport critical current density J_{ct} of granular superconductors by measuring the intergranular magnetization of a sample. In the first method, magnetization critical current density J_{cm} is used to estimate J_{ct} by isolating the intergranular magnetization and applying the critical state model. In the second method, magnetic detection is used to measure J_{ct} directly: intergranular magnetization hysteresis loops are obtained while increasing a transport current through a sample. The critical current density J_{ct} is that value of transport current density which causes the intergranular magnetization to collapse at a given magnetic field and temperature. Both methods give values of J_{ct} in fair agreement with values obtained from conventional transport measurements of J_{ct}. Magnetization was measured with both extraction and Hall probe magnetometers.
[Contact: Ronald B. Goldfarb, (303) 497-3650]

ELECTROMAGNETIC INTERFERENCE

Radiated

Adams, J.W., **Measured Results of Two Methods of Measuring Electromagnetic Shielding of RF Gaskets**, Proceedings of the 1992 International Symposium on Electromagnetic Compatibility, Anaheim, California, August 17-21, 1992, pp. 154-157.

An evaluation of two techniques and sample holders for measuring the electromagnetic shielding effectiveness of RF gaskets is given. Measured data and suggestions for refinements are also presented.
[Contact: John W. Adams, (303) 497-3328]

Adams, J.W., Cruz, J., and Melquist, D., **Comparison Measurements of Currents Induced by Radiation and Injection**, IEEE Transactions on Electromagnetic Compatibility, Vol. 34, No., 3, pp. 360-362 (August 1992).

Measurements are reported that show significant differences between currents measured in individual wires of a bundle due to equal current excitations by external radiated fields or by bulk injection. This raises concern as to whether bulk current injection is a practical, reliable technique for EMC work.
[Contact: John W. Adams, (303) 497-3328]

Crawford, M.L., and Riddle, B.F., **A Reverberating Asymmetric TEM Cell for Radiated EMC/V and SE Testing, 10 kHz - 18 GHz**, Record of the IEEE EMC Symposium on Electromagnetic Compatibility Symposium Record, Los Angeles, California, August 17-21, 1992, pp. 206-213.

This paper describes work in progress at the National Institute of Standards and Technology to develop a single, integrated facility for electromagnetic compatibility/vulnerability (EMC/V) and shielding effectiveness (SE) testing over the frequency range of 10 kHz to 18 GHz. The facility consists of an asymmetric TEM cell, 1.01 m × 1.20 m × 2.98 m in size, with two tuners, configured as a TEM transmission line-driven, mode-stirred chamber. TEM test fields are generated in the chamber at frequencies below multimode cutoff (150 MHz), and mode-stirred test fields are generated at frequencies above multimode cutoff. The test volume in the cell

is 0.5 m × 0.6 m × 0.6 m. This paper discusses the cell design, advantages, and limitations for its use, the theoretical basis for its operation, and the experimental approach for its use in SE or EMC/V testing. Results are given of the evaluation of the cell's operational parameters.
[Contact: Myron L. Crawford, (303) 497-5497]

Hill, D.A., **Currents Induced on Multiconductor Transmission Lines by Radiation and Injection**, IEEE Transactions on Electromagnetic Compatibility, Vol. 34, No. 4, pp. 445-450 (November 1992).

Multiconductor transmission line theory is used to compare currents induced on individual wires within a bundle by injection and radiated excitation. Calculations show that the two types of excitation generally induce significantly different current distributions, but the differences are much smaller for electrically short lines. The results are relevant to the validity of using current injection testing to replace radiated immunity testing.
[Contact: David A. Hill, (303) 497-3472]

Hill, D.A., **Electromagnetic Scattering by a Periodic Surface with a Wedge Profile**, Electromagnetics, Vol. 12, pp. 247-264 (1992).

Two-dimensional scattering from a periodic surface with a wedge profile is treated for both TE and TM polarization. The interface can be either perfectly conducting or penetrable, and the extended boundary condition is used in both cases. The method results in simple matrix elements and is easy to apply, but it becomes numerically ill-conditioned for surface heights that are a significant fraction of the period or the wavelength. Numerical results are presented for conservation of power, and some comparisons are made with previous results for sinusoidal surfaces. Some applications to rf absorbers are also presented.
[Contact: David A. Hill, (303) 497-3472]

Koepke, G., Driver, L.D., Cavcey, K., Masterson, K., John, R., and Kanda, M., **A New Spherical Dipole Source**, Proceedings of the 1992 IEEE International Symposium on Electromagnetic Compatibility, Anaheim, California, August 17-21, 1992, pp. 98-105. [Also published as NIST Technical Note 1351 (December 1991).]

A spherical dipole was developed to provide a source that can be characterized both by theory and experiment and to be integrated into modern automated test systems. The frequency and amplitude of the radiated electromagnetic field are established remotely using a signal generator. This signal and all other control features are transmitted to and from the sphere using fiber optic cable. The field measurements show good agreement to predictions over much of the frequency band.
[Contact: Galen Koepke, (303) 497-5766]

Randa, J.P., **Correction Factor for Nonplanar Incident Field in Monopole Calibrations,** IEEE Transactions on Electromagnetic Compatibility, Vol. 35, No. 1, pp. 94-96 (February 1993).

In calibrating large monopole antennas, the length of the antenna can be comparable to the separation distance. In that case, there is a significant variation in both the magnitude and the phase of the incident field along the length of the antenna being calibrated. This paper presents an expression for a correction factor to account for this effect. We evaluate the correction factor for some representative cases and present some guidelines for when this factor should be taken into account. The effect can exceed 1.0 dB in some practical cases.
[Contact: James P. Randa, (303) 497-3150]

Randa, J.P., Kanda, M., and Orr, R.D., **Optimized Thermo-Optic Electric-Field Probes for Microwaves and Millimeter Waves**, Record of the 1992 IEEE International Symposium on EMC, Anaheim, California, August 17-21, 1992, pp. 200-203.

We report the design and testing of electric-field probes for use at frequencies in the microwave and millimeter-wave range. The probes consist of a resistive element whose temperature rise is measured by an optically-sensed thermometer. Design parameters of the resistive element were optimized theoretically, with empirical confirmation. The optimized probe has a flat response above about 13 GHz and can measure fields as small as about 17 V/m.
[Contact: James P. Randa, (303) 497-3150]

ADDITIONAL INFORMATION

Lists of Publications

DeWeese, M.E., **Metrology for Electromagnetic Technology: A Bibliography of NIST Publications**, NISTIR 3994 (September 1992).

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

Lyons, R.M., and Gibson, K.A., **A Bibliography of the NIST Electromagnetic Fields Division Publications**, NISTIR 3993 (August 1992).

This bibliography lists publications by the staff of the National Institute of Standards and Technology's Electromagnetic Fields Division for the period from January 1970 through August 1992. Selected earlier publications from the Division's predecessor organizations are included.
[Contact: Kathryn A. Gibson, (303) 497-3132]

Meiselman, B., **Electrical and Electronic Metrology: A Bibliography of NIST Electricity Division's Publications, NIST List of Publications 94** (January 1993).

This bibliography covers publications of the Electricity Division, Electronics and Electrical Engineering, Laboratory, NIST, and of its predecessor sections for the period January 1968 to December 1992. A brief description of the Division's technical program is given in the introduction.
[Contact: Betty Meiselman, (301) 975-2401]

Walters, E.J., **Semiconductor Measurement Technology, 1990-1992, NIST List of Publications 103** (April 1993) and **Semiconductor Measurement Technology, 1962-1989, NIST List of Publications 72** (March 1990).

The bibliography provides information on technology transfer in the field of microelectronics at NIST for the calendar years 1990 and 1992. Publications from groups specializing in semiconductor electronics are included, along with NIST-wide research now coordinated by the NIST Office of Microelectronics Programs which was established in 1991. Indices by topic area and by author are provided. Earlier reports of work performed during the period from 1962 through December 1989 are provided in NIST List of Publications 72.
[Contact: E. Jane Walters, (301) 975-2050]

Availability of *Measurements for Competitiveness in Electronics* [First Edition], NISTIR 4583 (April 1993).

This document is the successor to NISTIR 90-4260, *Emerging Technologies in Electronics ...and their Measurement Needs* [Second Edition]. The new *Measurements for Competitiveness in Electronics* identifies 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 consensus on the principal measurement needs affecting U.S. competitiveness, as the basis for an *action plan* to meet those needs and to improve U.S. competitiveness.

Copies of this document are available as Order No. PB93-160588 from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161, at (800) 553-6847 or (703) 487-4650.

Abstract – Measurements are used to determine the values of hundreds of important quantities in the electronics industry. Representative quantities are the widths of the interconnections within semiconductor integrated circuits, the attenuation of lightwaves in optical fibers, and the signal power from microwave satellite antennas. Measurement capability is a fundamental tool used to build the nation's high-technology products. As such, it is part of the national infrastructure for the realization of these products.

Measurement capability is critical to research and development, manufacturing, marketplace entry, and after-sales support of products. Thus, measurement capability affects the performance, quality,

reliability, and cost of products. The result of this pervasive impact is that the level of U.S. measurement capability places an upper limit on the competitiveness of U.S. products.

At present, U.S. industry is experiencing a major shortfall in the measurement capability needed for competitiveness in electronic products. This document identifies 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 measurement needs are reviewed for nine important fields of electronics, including semiconductors, magnetics, superconductors, microwaves, lasers, optical-fiber communications, optical-fiber sensors, video, and electromagnetic compatibility. These fields of electronics underlie more than $300 billion of electronic and electrical products manufactured in the U.S. each year.

This assessment provides the framework for an action plan to correct the shortfall in U.S. measurement capability in electronics and to advance U.S. competitiveness.

<u>Guide</u> -- The compiler of the document provided an introductory guide to its organization and content. Because EEEL believes that a number of *TPB* readers will be interested in the information presented in the various chapters, the contents of this guide are reproduced below (page numbers of chapter summaries are included to provide a measure of the extent of the treatment):

This document contains 12 chapters, divided into two groups. The first three chapters are introductory in nature and are relevant to all of the following chapters. The remaining nine chapters address individual fields of electronic technology. Each chapter begins with a two-page summary that provides ready access to the major points made in the chapter. These short summaries are found on the pages identified below. By selecting from these summaries, you can quickly access information on the subjects of most interest to you.

<u>Introductory Information</u> -- Chapter 1, Role of Measurements in Competitiveness (page 3); Chapter 2, NIST's Role in Measurements (page 21); Chapter 3, Overview of U.S. Electronics and Electrical-Equipment Industries (page 31)

These three chapters introduce the subject of measurements and provide an overview of the products of the U.S. electronics and electrical-equipment industries.

Chapter 1, **Role of Measurements in Competitiveness**, shows why measurements are a fundamental part of the infrastructure of the nation. Chapter 1 also sets measurements in the context of the many other important factors that affect competitiveness.

Chapter 2, **NIST's Role in Measurements**, indicates the circumstances under which Government assistance to industry in the development of measurement capability is appropriate in pursuit of a strengthened national economy.

Chapter 3, **Overview of U.S. Electronics and Electrical-Equipment Industries**, introduces these industries through an overview of their major product lines. This chapter shows the various ways in which the products of these industries are commonly classified and how those classifications relate to the structure of this document.

<u>Fields of Technology</u> -- Chapter 4, Semiconductors (page 53); Chapter 5, Magnetics (page 95); Chapter 6, Superconductors (page 129); Chapter 7, Microwaves (page 147); Chapter 8, Lasers (page 183); Chapter 9, Optical-Fiber Communications (page 217); Chapter 10, Optical-Fiber Sensors (page 303); Chapter 11, Video (page 339); Chapter 12, Electromagnetic Compatibility (page 381)

Each of these chapters contains four basic types of information:

Technology Review: The field of technology is reviewed to highlight and explain the special capabilities that make the technology important. This review introduces the technical concepts that are necessary for understanding the sections that follow.

World Markets and U.S. Competitiveness: The economic significance of the field of technology is highlighted through use of national and international market data for major products that employ the technology. Available information on the U.S. competitiveness is described.

Goals of U.S. Industry for Competitiveness: The goals that U.S. industry is pursuing to improve its competitiveness are discussed so that they can be related to requirements for new measurement capability supportive of the goals.

Measurement Needs: The new measurement capability that U.S. industry will need to enable it to achieve its goals is described. This discussion emphasizes measurement capability that is needed widely in U.S. industry, that will have high economic impact if provided, and that is beyond the resources of the broad range of individual U.S. companies to provide.

[While the assessment of measurement needs in this document is wide ranging, not every field of technology important to the electronic and electrical-equipment industries has been covered. NIST plans to expand this assessment in future editions to include additional fields.]

The order in which chapters appear is intentional: the technologies on which most other technologies depend are introduced first. Thus, the chapter on semiconductors appears first because most electronic technologies depend on semiconductor materials. In contrast, the chapter on video is located near the end because it depends on nearly every other technology discussed earlier.

Chapters 4, 5, and 6 of this document describe the measurement needs arising from three important materials technologies that underlie current and emerging electronic and electrical products. These chapters also describe the measurement needs of components and equipment based on these materials and not discussed separately in other chapters.

Chapter 4, **Semiconductors**, addresses both silicon and compound semiconductors and their use in components, including individual (discrete) electronic and optoelectronic devices and integrated circuits. Semiconductor components are central to all modern electronic products from consumer products to supercomputers.

Chapter 5, **Magnetics**, focuses on both magnetic materials and the components made from them. Magnetic materials are second in importance only to semiconductor materials for electronic products and play a central role in electrical products. This chapter also addresses the measurement needs of selected equipment critically dependent on magnetic materials, including magnetic information storage equipment, electrical power transformers, and others.

Chapter 6, **Superconductors**, examines superconductor materials and addresses both present and emerging applications of these materials in electronic and electrical products.

Chapters 7 through 11 describe the measurement needs associated with selected technologies of importance to U.S. competitiveness for current and emerging products.

Chapter 7, **Microwaves**, describes the highest-information-capacity radio technology. Microwave electronics provide the basis for modern and emerging wireless communications systems and radar systems. Included are new personal communications services with both local and worldwide access, intelligent vehicle-highway systems, and advanced audio and video broadcasting systems, among others.

Chapter 8, **Lasers**, addressed the single most important component for emerging lightwave systems used for manufacturing, medicine, communications, printing, environmental sensing, and many other applications.

Chapter 9, **Optical-Fiber Communications**, describes the highest-information-capacity cable technology. It provides the basis for national and international information highways of unprecedented performance and broad economic impact. Optical-fiber systems will be linked with microwave systems to interconnect mobile and portable users and to backup cable systems.

Chapter 10, **Optical-Fiber Sensors**, focuses on an emerging class of sensors that offers outstanding performance for a broad spectrum of applications in manufacturing, aerospace, medicine, electrical power, and other areas.

Chapter 11, **Video**, emphasizes advanced, high-performance systems, such as high-definition television, which offer, for the first time, simultaneous access to high-resolution, smooth motion, and great color depth. The chapter notes the potential of full-power implementations of video technology in interactive networked environments. The chapter contains a special focus on flat-panel displays.

Chapter 12, **Electromagnetic Compatibility**, describes the special challenges that the U.S. faces in maintaining electromagnetic compatibility among the many new products of electronic and electrical technologies. Such compatibility is essential if the full potential of all of the above technologies is to be realized without debilitating mutual interference.

Appendices -- The three appendices provide definitions of the U.S. electronics and electrical-equipment industries. These definitions were used in preparing much of the economic information in the report.

Appendix 1 describes the Standard Industrial Classification System that the U.S. Government uses for collecting data about U.S. industry. This appendix also lists publications in which the U.S. Government reports data on U.S. shipments.

Appendix 2 provides a definition of the U.S. electronics industry in terms of the Standard Industrial Classification System.

Appendix 3 provides a definition of the U.S. electrical-equipment industry in terms of the Standard Industrial Classification System.

1993-1994 Calendar of Events

July 29, 1993 (Gaithersburg, Maryland)

Ion Implant Users Group Meeting. The 12th meeting of the Ion Implant Users Group will be held at NIST in July. General discussions of topics of interest to the group will be held.
[Contact: John Albers, (301) 975-2075]

October 11-13, 1993 (Yorktown Heights, New York)

IEEE CHMT VLSI Packaging Workshop. IEEE CHMT and NIST are sponsoring a workshop on VLSI packaging to be held at the T. J. Watson Research Center in Yorktown Heights. New developments or critical overviews in the following areas will be presented: VLSI package design; integrated package design; multichip module design; VLSI package materials and die attach solutions; VLSI package interconnection options: wire bonding, TAB, flip chip, and optical; failure mechanism and quality of VLSI packages; and silicon carrier MCMs. A tour of the IBM MLC line in East Fishkill and the TCM assembly and testing area in Poughkeepsie is included in the program.
[Contact: George G. Harman, (301) 975-2097]

October 28, 1993 (Gaithersburg, Maryland)

Ion Implant Users Group Meeting. The next regularly scheduled meeting of the Ion Implant Users Group will be held, as usual, at NIST in October. One of the topics scheduled for discussion is ion optics.
[Contact: John Albers, (301) 975-2075]

February 1-3, 1994 (San Jose, California)

10th Annual IEEE Semiconductor Thermal Measurement and Management Symposium (SEMI-THERM). Sponsored by IEEE CHMT and NIST, SEMI-THERM is the premier forum for the exchange of information on thermal management of electronics systems between the academic and industrial communities. The program will address the following topics: thermal characterization; analytical and computational thermal modeling; measurement techniques including temperature, fluid flow, and thermal-mechanical properties; and thermal reliability screening and testing. SEMI-THERM has a workshop atmosphere with single-session programs coupled with technical workshops, tutorials, vendor exhibits, and optional short courses.
[Contact: David L. Blackburn, (301) 975-2053]

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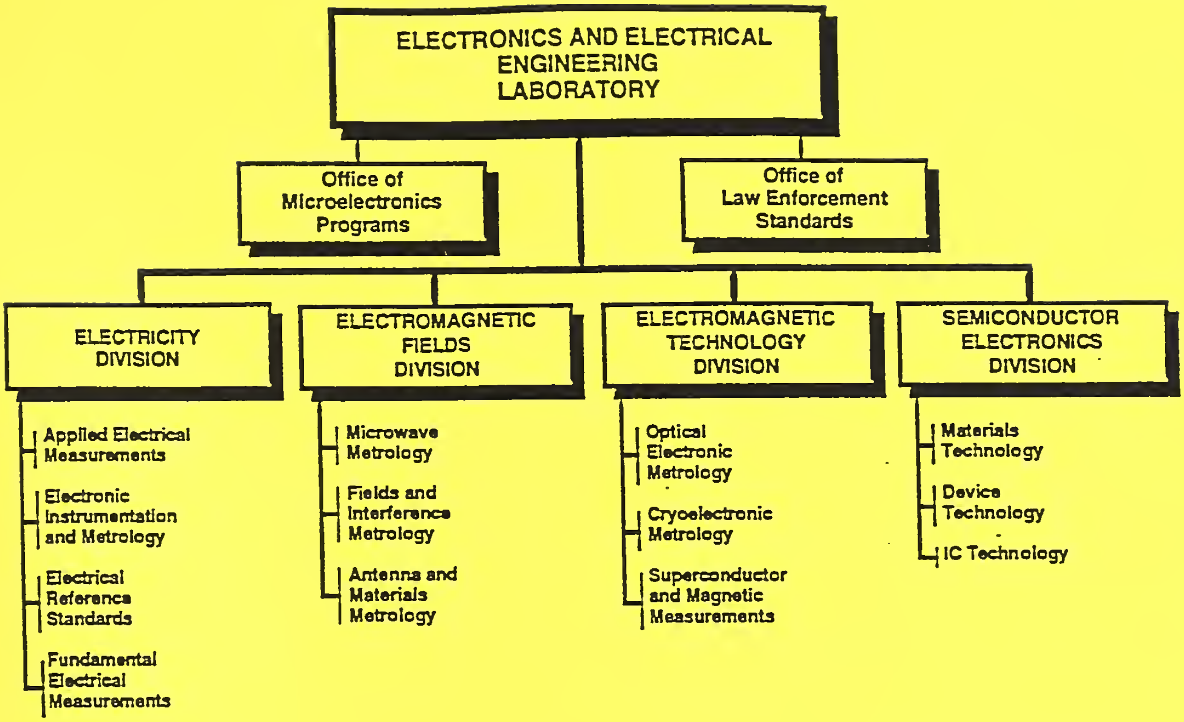

KEY CONTACTS

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

INFORMATION:

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

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