NISTIR 5435

Electronics and Electrical Engineering Laboratory

Technical Publication Announcements

J. M. Rohrbaugh
Compiler

June 1994

Covering Laboratory Programs,
October to December 1993
with 1994/1995 EEEL Events Calendar

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U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Institute of Standards
and Technology
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U.S. DEPARTMENT OF COMMERCE
Ronald H. Brown, Secretary

TECHNOLOGY ADMINISTRATION
Mary L. Good, Under Secretary for Technology

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
Arati Prabhakar, Director

TABLE OF CONTENTS

SEMICONDUCTOR MICROELECTRONICS

Silicon Materials

Korman, C.E., Mayergoyz, I.D., Gaitan, M., Tai, G.C., **An Efficient Method to Compute the Maximum Transient Drain Current Overshoot In Silicon On Insulator Devices**, Journal of Applied Physics, Vol. 73, No. 6, pp. 2611-2616 (March 15, 1993).

We present an efficient method to compute the maximum transient drain current overshoot in silicon-on-insulator metal-oxide silicon field effect transistors. The method is based on the physical idea that the number of majority carriers remains unchanged immediately after a change in the applied gate bias. The maximum overshot is computed by solving the Poisson and the stationary minority carrier transport equations under the constraint that the number of majority carriers is conserved. Hence, the novel aspect of the method is that it allows one to compute the maximum drain current overshoot without resorting to a computationally costly transient simulation. The accuracy of the method is verified by comparing the value of the drain current computed by this method with the maximum value of the drain current computed by transient simulations. The comparisons show that, with this method, the maximum transient drain current overshoot can be computed quite accurately for fast changes in the gate bias.
[Contact: Michael Gaitan, (301) 975-2070]

Compound Materials

Friedman, D.J., Zhu, J.G., Kibbler, A.E., Olson, J.M., and Moreland, J., **Surface Topography and Ordering-Variant Segregation in GaInP$_2$**, Applied Physics Letters, Vol. 63, No. 13, pp. 1774-1776 (September 27, 1993).

Using transmission electron diffraction dark-field imaging, atomic force microscopy (AFM), and Nomarski microscopy, we demonstrate a direct connection between surface topography and cation site ordering in GaInP$_2$. We study epilayers grown by organometallic vapor-phase epitaxy on GaAs substrates oriented 2° off (100) towards (110). Normarski microscopy shows that, as growth proceeds, the surface of ordered material forms faceted structures aligned roughly along [011]. A comparison with the dark-field demonstrates that the $[1\bar{1}1]$ and $[11\bar{1}]$ ordering variants are segregated into complementary regions corresponding to opposite-facing facets of the surface structures. This observation cannot be rationalized with the obvious but naive model of the surface topography as being due to faceting into low-index planes. However, AFM reveals that the facets are, in fact, *not* low-index planes, but rather are tilted 4° from (100) towards $(111)_B$. This observation explains the segregation of the variants: the surface facets act as local $(111)_B$- misoriented growth surfaces which select only one of the two variants.
[Contact: John Moreland, (303) 497-3641]

Lowney, J.R., Seiler, D.G., Thurber, W.R., Yu, Z., Song, X.N., and Littler, C.L., **Heavily Accumulated Surfaces of Mercury Cadmium Telluride Detectors: Theory and Experiment**, Journal of Electronic Materials, Vol. 22, No. 8, pp. 985-991, January 4, 1993.

Some processes used to passivate *n*-type mercury-cadmium-telluride photoconductive infrared detectors produce accumulation layers at the surfaces which result in 2D electron gases. The dispersion relations for the electric subbands that occur in these layers have been calculated from first principles. Poisson's equation for the built-in potential and Schroedinger's equation for the eigenstates have been solved self-consistently. The cyclotron effective masses and Fermi energies have been computed for each subband density for 12 total densities between 0.1 to 5.0 × 10^{12} cm^{-2}. The agreement with Shubnikov-de Haas measurements is very good at lower densities with possible improvement if band-gap narrowing effects were to be included. At higher densities larger differences occur. The simple 2D description is shown to break down as the density increases because the wave functions of the conduction and valence bands cannot be well separated by the narrow band gap of long-wavelength detectors. These results provide a basis for characterizing the passivation processes, which greatly affect device performance.
[Contact: Jeremiah R. Lowney, (301) 975-2048]

Device Physics and Modeling

Lowney, J.R., Seiler, D.G., Thurber, W.R., Yu, Z., Song, X.N., and Littler, C.L., **Heavily Accumulated Surfaces of Mercury Cadmium Telluride Detectors: Theory and Experiment**, Journal of Electronic Materials, Vol. 22, No. 8, pp. 985-991, January 4, 1993.

[See Compound Materials.]

Dimensional Metrology

Allen, R.A., Troccolo, P., Owen III, J.C., Potzick, J.E., and Linholm, L.W., **Comparisons of Measured Linewidths of Sub-Micrometer Lines Using Optical, Electrical, and SEM Metrologies**, Proceedings of SPIE (The International Society for Optical Engineering, P.O. Box 10, Bellingham, Washington 98227-0010), Integrated Circuit Metrology, Inspection, and Process Control VII, Vol. 1926, pp. 34-43 (1993).

An investigation was carried out to determine the ability of three methods of linewidth metrology to measure the dimensions of features to less than 0.5 μm. The three methods are transmitted-light optical microscopy, electrical test structure, and scanning electron microscopy (SEM). Electrical, SEM, and reflected-light microscopy techniques are widely used for linewidth metrology in VLSI fabrication. However, none of these widely-used techniques currently permits traceability to international standards of length. Transmitted-light optical microscopy allows traceability; however, this technique is applicable only to transparent substrates. To permit the inclusion of transmitted-light optical microscopy in this investigation, 100-nm thick Ti films were patterned using normal VLSI processing techniques on a 150-mm diameter quartz wafer. The cross-bridge resistor test structure was used since this structure has been widely used in industry, and it allows the results from all three metrological techniques to be compared. The design bridge widths of the test structures range from 0.4 μm to 1.0 μm. The results of these measurements show systematic and uniform offsets between the different techniques. In this paper, we discuss the different techniques and describe the observed results.
[Contact: Richard A. Allen, (301) 975-5026]

Postek, M.T., Lowney, J.R., Vladar, A.E., Keery, W.J., Marx, E., and Larrabee, R.D., **X-Ray Lithography Mask Metrology: Use of Transmitted Electrons in an SEM for Linewidth Measurement**, Journal of Research of the National Institute of Standards and Technology, Vol. 98, No. 4, pp. 415-445 (July/August 1993).

X-ray masks present a measurement object that is different from most other objects used in semiconductor processing because the support membrane is, by design, X-ray transparent. This characteristic can be used as an advantage in electron beam-based X-ray mask metrology since, depending upon the incident electron beam energies, substrate composition and substrate thickness, the membrane can also be essentially electron transparent. The areas of the mask where the absorber structures are located are essentially X-ray opaque, as well as electron opaque. This paper shows that excellent contrast and signal-to-noise levels can be obtained using the transmitted-electron signal for mask metrology rather than the more commonly collected secondary electron signal. Monte Carlo modeling of the transmitted electron signal was used to support this work in order to determine the optimum detector position and characteristics, as well as in determining the location of the edge in the image profile. The comparison between the data from the theoretically modeled electron-beam interaction and actual experimental data was shown to agree extremely well, particularly with regard to the wall slope characteristics of the structure. Therefore, the theory can be used to identify the location of the edge of the absorber line for linewidth measurement. This work provides one approach to improved X-ray masks in commercial instrumentation. This work also represents an initial step toward the first scanning electron microscope-based accurate linewidth measurement standard from NIST, as well as providing a viable metrology for linewidth measurement instruments of X-ray masks for the lithography community.
[Contact: Michael T. Postek, (301) 975-2299]

Integrated-Circuit Test Structures

Allen, R.A., and Schuster, C.E., **An Electrical Test Structure for Improved Measurement of Feature Placement and Overlay in Integrated**

Circuit Fabrication Processes, Proceedings of the Government Microcircuit Applications Conference 1993, New Orleans, Louisiana, November 1-5, 1993, pp. 159-161.

The modified voltage-dividing potentiometer has previously been demonstrated to have a resolution of under 10 nm when applied to short-loop, single-level processes. This test structure has recently been applied to several full cycle processes, which we are reporting here for the first time. In this paper, we describe the successful demonstration of test vehicle implementations and test results obtained from applying the new design to a GaAs Microwave/Millimeter Wave Monolithic Integrated Circuits process and a CMOS/Bulk process. The demonstrated success in these substantially different processes indicates that these results should apply to a wide range of semiconductor fabrication environments.
[Contact: Richard A. Allen, (301) 975-5026]

Plasma Processing

Olthoff, J.K., **Gaseous Electronics Conference RF Reference Cell Newsletter**, Vol. 5, No. 1, pp. 1-2 (May 1993).

This newsletter provides users of Gaseous Electronics Conference (GEC) rf Reference Cells with information on related research projects. This issue summarizes the research projects using GEC cells at 10 different laboratories and provides the first list of GEC-cell-related publications.
[Contact: James K. Olthoff, (301) 975-2431]

Packaging

Carpenter, J.A., Jr., Dickens, B., Kreider, K.G., Manning, J.R., Mattis, R.L., Piermarini, G.J., Read, D.T., and Evans, R.D., **NIST/NCMS Program on Electronic Packaging: First Update**, Ceramic Transactions, Materials in Microelectronic and Optoelectronic Packaging, Vol. 33, pp. 345-358 (1993).

In 1992, the National Institute of Standards and Technology expanded its intermural efforts on development of metrology for microelectronics packaging and interconnection. The new intramural projects concentrate on development or refinement of metrology for measuring the properties of the materials as they actually exist in modern packaging and interconnection, and not as measured on idealized or bulk specimens. The metrology is intended for use in research, manufacturing, product quality control and failure analysis. Also, work begun in 1991 accelerated in a major consortium effort led by The National Center for Manufacturing Sciences and jointly supported by the consortium members and the NIST Advanced Technology Program to develop new materials and production technology for printed wiring boards. This is an update on the progress of those efforts.
[Contact: Richard L. Mattis, (301) 975-2235]

Photodetectors

Hale, P.D., and Franzen, D.L., **Accurate Characterization of High Speed Photodetectors**, Proceedings of SPIE (The International Society for Optical Engineering, P.O. Box 10, Bellingham, Washington 98227-0010), Photodetectors and Power Meters, Vol. 2022, pp. 218-227 (1993).

We designed a simple heterodyne system for frequency domain photodetector characterization which is intended to avoid many of the disadvantages of earlier characterization systems and to minimize errors due to intensity fluctuation, frequency calibration, and source impedance mismatch without using vector network analysis. A detailed uncertainty analysis for the system indicates 95% confidence intervals between ±0.25 and ±0.6 dB at 25 GHz, depending on the photodetector output impedance.
[Contact: Paul D. Hale, (303) 497-5367]

Lowney, J.R., Seiler, D.G., Thurber, W.R., Yu, Z., Song, X.N., and Littler, C.L., **Heavily Accumulated Surfaces of Mercury Cadmium Telluride Detectors: Theory and Experiment**, Journal of Electronic Materials, Vol. 22, No. 8, pp. 985-991, January 4, 1993.

Some processes used to passivate *n*-type mercury-cadmium-telluride photoconductive infrared detectors produce accumulation layers at the surfaces which result in 2D electron gases. The dispersion relations for the electric subbands that occur in these layers have been calculated from first principles. Poisson's equation for the built-in

potential and Schroedinger's equation for the eigenstates have been solved self-consistently. The cyclotron effective masses and Fermi energies have been computed for each subband density for 12 total densities between 0.1 to 5.0 × 10^{12} cm^{-2}. The agreement with Shubnikov-de Haas measurements is very good at lower densities with possible improvement if band-gap narrowing effects were to be included. At higher densities larger differences occur. The simple 2D description is shown to break down as the density increases because the wave functions of the conduction and valence bands cannot be well separated by the narrow band gap of long-wavelength detectors. These results provide a basis for characterizing the passivation processes, which greatly affect device performance.
[Contact: Jeremiah R. Lowney, (301) 975-2048]

SIGNAL ACQUISITION, PROCESSING, AND TRANSMISSION

DC and Low-Frequency Metrology

Avramov, S., and Oldham, N.M., **Automatic Calibration of Inductive Voltage Dividers for the NASA Zeno Experiment**, Review of Scientific Instruments, Vol. 64, No. 9, pp. 2676-2678 (September 1993).

Two inductive voltage dividers (IVDs) used for temperature measurements in NASA's zeno experiment were tested. In order to obtain the required resolution of 10 parts-per-billion, a 30-bit binary inductive voltage divider developed at the National Institute of Standards and Technology was used to measure the differential linearity of the Zeno IVDs. Automatic measurements were performed on the dividers in the Zeno experiment engineering model at frequencies of 266 Hz and 351 Hz over a ratio range of 0.55 to 0.56. The measured differential linearity limits the temperature resolution to 5 μK.
[Contact: Nile M. Oldham, (301) 975-2408]

Cryoelectronic Metrology

Booi, P.A., Livingston, C.A., and Benz, S.P., **Intrinsic Stress in dc Sputtered Niobium**, IEEE Transactions on Applied Superconductivity, Vol. 3, No. 2, pp. 3029-3031 (June 1993).

The intrinsic mechanical stress of dc magnetron-sputtered Nb films is characterized as a function of sputtering parameters and target erosion. The zero-stress point shifts to lower cathode voltages as the target erodes. The zero-stress point was always characterized by the same cathode current-Ar pressure relationship.
[Contact: Peter A. Booi, (303) 497-5910]

Ekin, J.W., **Preparation of Low Resistivity Contacts for High-T_c Superconductors**, in Processing and Properties of High-T_c Superconductors, Vol. 1, Chapter 9 (World Scientific Publishing Company, Singapore, 1993), pp. 371-407.

Methods for preparing practical contacts to high-T_c superconductors are described, including quick, easy techniques for attachment of voltage-taps, and detailed descriptions of how to fabricate high-quality contacts for current connections. Methods for soldering and lead attachment that preserve the low resistivity of high-quality contacts are also presented.
[Contact: John W. Ekin, (303) 497-5448]

Moreland, J., **Tunneling Spectroscopy of Thallium-Based High Temperature Superconductors**, Chapter in Thallium-Based High-Temperature Superconductors, A.M. Hermann and J.V. Yakhmi, Eds. (Marcel Dekker, Inc., New York, NY, 1994), pp. 569-577.

This chapter focuses on electron tunneling spectroscopy of the thallium-based high-temperature superconductor materials. A summary of published results is included with comments regarding interpretations of each measurement. Other phenomena that may have subsequent bearing on the interpretation of tunneling spectra are addressed briefly including a linear background conductance, Coulomb blockage effects, and bound states at superconductor/normal metal interfaces. This chapter does not address many of the Josephson-like devices based on weak-links, point contacts, microbridges, or step-edge junctions.
[Contact: John Moreland, (303) 497-3641]

Peterson, R.L., **An Analysis of the Impact on U.S. Industry of the NIST/Boulder Superconductivity Programs: An Interim**

Study, NISTIR 5012 (November 1993).

This report is an interim study of the impact of the NIST/Boulder superconductivity programs on U.S. industry. Because the superconductor market is still small - the promising new technology of high-temperature superconductivity has not had time to significantly enter the marketplace - a detailed economic study of the NIST impact is not warranted. Nevertheless, it was felt useful to undertake a preliminary analysis of the impact of the NIST/Boulder programs. In this report, numerical estimates are made of the return on investment for areas which could be quantified. Anecdotal material and consideration of unquantified impacts are also included, and a survey of the U.S. superconductor industry is made. [Contact: Robert L. Peterson, (303) 497-3750]

Laser Metrology

Sanford, N.A., Malone, K.J., Aust, J.A., and Larson, D.R., **Rare-Earth-Doped Waveguide Devices**, Proceedings of the OSA Annual Meeting, Albuquerque, New Mexico, September 20-25, 1992, p. 57.

Rare-earth-doped integrated optic waveguide lasers have been demonstrated in glass, $LiNbO_3$ and other host materials. This technology offers a variety of new components that include diode-pumped amplifiers and lasers. The planar geometry is particularly attractive because selective doping permits the integration of passive and active devices on the same substrate and it is also compatible with pumping by laser diodes. Ion exchanged channel waveguides have been demonstrated to lase near 1060 nm and 1320 nm in Nd-doped silicate and Nd-doped phosphate glass, respectively. Nd-doped waveguide lasers have also been fabricated by chemical vapor deposition; Er-doped waveguide lasers have been similarly fabricated. Y-branch splitters with gain at 1060 nm have been reported in Nd-doped silicate glass waveguides. Ion implantation has been used to form waveguides in Nd-doped YAG and Nd-doped GGG. Nd and Er-doped $LiNbO_3$ waveguide lasers operating near 1060 nm and 1550 nm, respectively, have also been reported. Attempts have been made to demonstrate visible upconversion lasing in Er-doped $LiNbO_3$ and $LiTaO_3$ waveguides. We review the status of this technology and also highlight some of the more promising applications. [Contact: Norman A. Sanford, (303) 497-5239]

Integrated Optics — [formerly Electro-Optic Metrology]

Kumar, A., and Gallawa, R.L., **Bending-Induced Phase Shifts in Dual-Mode Planar Optical Waveguides**, Optics Letters, Vol. 18, No. 17, pp. 1415-1417 (September 1, 1993).

We examine the manner in which the effective index for each of the two modes of a bent dual-mode planar waveguide changes with curvature. We find that the bending-induced changes in the effective indices depend strongly on core-cladding index contrast and the value of *V*. For waveguides with large contrast, the changes in effective indices are such that the change in the phase difference between the modes is positive (or negative) at large (or small) values of *V*. The change becomes zero at a *V*-value that depends on the waveguide parameters and curvature. If the index contrast is small, the bending-induced phase difference may change sign with increase in curvature. This might help in ultimately explaining the bipolar phase shift seen in a recent experiment. The results of our study can be used to increase or decrease the bending sensitivity of dual-mode optical-waveguide sensors and devices.
[Contact: Robert L. Gallawa, (303) 497-3761]

Patrick, H., and Gilbert, S.L., **Growth of Bragg Gratings Produced by Continuous-Wave Ultraviolet Light in Optical Fiber**, Optics Letters, Vol. 18, No. 18, pp. 1484-1486 (September 15, 1983).

We have written Bragg gratings of as much as 94% reflectance in germanium-doped optical fiber by two-beam interference of 244-nm continuous-wave UV light. We measured grating reflectance as a function of exposure time for UV light intensities ranging from 1.5 to 47 W/cm^2. The observed dependence of index modulation on time and intensity does not agree with the predictions of a model based on depletion of a defect population by one-photon absorption.
[Contact: Heather Patrick, (303) 497-6353]

ELECTRICAL SYSTEMS

Power Systems Metrology

Anderson, W.E., **Research for Electric Energy Systems - An Annual Report**, NISTIR 5268 (December 1992).

This report documents the technical progress of two investigations. The first investigation is concerned with the measurement of magnetic fields in support of epidemiological and *in-vitro* studies of biological field effects. During 1992, the derivation of equations which predict differences between the average magnetic flux density using circular coil probes and the flux density at the center of the probe, assuming a dipole magnetic field, were completed. The information gained using these equations allows the determination of measurement uncertainty due to probe size when magnetic fields from many electrical appliances are characterized. Consultations with various state and federal organizations and the development of standards related to electric and magnetic field measurements continue. The second investigation is concerned with two different activities related to compressed-gas insulated high-voltage systems: 1) the measurement of dissociative electron attachment cross sections and negative ion production in S_2F_{10}, S_2OF_{10}, and $S_2O_2F_{10}$, and 2) Monte-Carlo simulations of ac-generated partial-discharge pulses that can occur in SF_6- insulated power systems and can be sources of gas decomposition.
[Contact: William E. Anderson, (301) 975-2432]

Van Brunt, R.J., von Glahn, P., and Las, T., **Partial Discharge-Induced Aging of Cast Epoxies and Related Nonstationary Behavior of the Discharge**, Proceedings of the 1993 Annual Report of the IEEE Conference on Electrical Insulation and Dielectric Phenomena, Pocono Manor, Pennsylvania, October 17-20, 1993, pp. 455-461.

Measurements were made of the time dependences of positive and negative integrated-charge distributions for ac-generated pulsating partial discharge (PD) in point-to-dielectric gaps where the dielectric material was cast epoxy either with or without an aluminum oxide filler. Other statistical characteristics of the PD were measured such as pulse-phase distributions. The dielectric surface resistivity was measured before and after exposure to PD. For epoxy with filler, the PD statistical characteristics changed significantly during times when there was a corresponding decrease in local surface resistivity. For example, the positive PD pulses were observed to cease after a time that is inversely proportional to the frequency of the applied voltage. Partial discharge from epoxy without filler exhibited a much more stationary behavior. The connection between changes in surface resistivity and changes in stochastic behavior are explained using a Monte Carlo simulation.
[Contact: Richard J. Van Brunt, (303) 975-2425]

Magnetic Materials and Measurements

Moreland, J., **Tunneling Stabilized Magnetic-Force Microscopy**, Proceedings of the 51st Annual Meeting of the Microscopy Society of America, Cincinatti, Ohio, August 2-6, 1993, pp. 1034-1035.

Magnetic force microscopy (MFM) can be done by making a simple change in conventional scanning tunneling microscopy (STM) where the usual rigid STM tip is replaced with a flexible magnetic tip. STM images acquired this way show both the topography and the magnetic forces acting on the flexible tip. The z-motion of the STM piezo tube scanner flexes the tip to balance the magnetic force so that the end of the tip remains a fixed tunneling distance from the sample surface. We present a review of some "tunneling-stabilized" MFM (TSMFM) images showing magnetic bit tracks on a hard disk, Bloch wall domains in garnet films, and flux patterns in high-T_c superconductor films. The image resolution of TSMFM is routinely 0.1 μm using Au-coated magnetic tips cut from Ni or Fe films. Recent results show that a TSMFM resolution of less than 40 nm is possible with micromachined cantilevers coated with a very thin Au-Fe bilayer.
[Contact: John Moreland, (303) 497-3641]

Moreland, J., Rice, P., and Wadas, A., **Magnetic Force Microscopy of Flux In Superconductors**, Proceedings of the 1993 International Workshop on Superconductivity, "Characterization of High Temperature Superconductors: Structures and Properties of Surfaces and Interfaces," Hokkaido, Japan, June 28—July 1, 1993, pp. 77-80.

We are developing a novel form of magnetic force microscopy (MFM) which is well suited for low-temperature imaging of magnetic flux lines penetrating superconductors. This method is based on standard scanning tunneling microscopy where the usual rigid tunneling tip is replaced with a flexible magnetic tip. We present a discussion of the interpretations of these images which includes theoretical aspects of MFM of flux lines in superconductors and experimental details regarding MFM which we believe are critical for flux imaging.
[Contact: John Moreland, (303) 497-3641]

Superconductors

Booi, P.A., Livingston, C.A., and Benz, S.P., **Intrinsic Stress in dc Sputtered Niobium**, IEEE Transactions on Applied Superconductivity, Vol. 3, No. 2, pp. 3029-3031 (June 1993).

[See Cryoelectronic Metrology.]

Chen, D.-X., Goldfarb, R.B., Cross, R.W., and Sanchez, A., **Surface Barrier and Lower Critical Field in $YBa_2Cu_3O_{7-\delta}$ Superconductors**, Physical Review B, Vol. 48, No. 9, pp. 6426-6430 (September 1993).

The fields for first vortex entry and last vortex exit, H_1 and H_2, and the lower critical field H_{c1} for a grain-aligned, sintered $YBa_2Cu_3O_{7-\delta}$ superconductor have been determined from saturated magnetic-hysteresis loops using an extended critical-state model. For fields oriented along the grain *c* axis, H_1 increases with decreasing temperature, showing an upturn below 50 K, whereas H_2 remains small and positive, in general agreement with the theory of Bean-Livingston surface barriers. H_{c1} has a Bardeen-Cooper-Schrieffer temperature dependence above 50 K, but it rises at low temperatures. For fields oriented in the ab plane, H_{c1} has a similar temperature dependence, but surface barriers are not evident in the magnetization.
[Contact: Ronald B. Goldfarb, (303) 497-3650]

Coffey, M.W., **Transverse Thermomagnetic Effects In the Mixed State and Lower Critical Field of High-T_c Superconductors**, Physical Review B, Vol. 48, No. 13, pp. 9767-9771, (October 1993).

Transverse thermomagnetic effects (Ettingshausen, Nernst effects) are discussed for a variety of phenomenological models of high-T_c and other layered superconductors. The use of the temperature-dependent vortex-line energy in determining the transport entropy is stressed, leading to predictions and possibilities for additional experiments. The dynamics of both Abrikosov and Josephson vortices is considered.
[Contact: Mark W. Coffey, (303) 497-3703]

Ekin, J.W., **Preparation of Low Resistivity Contacts for High-T_c Superconductors**, in Processing and Properties of High-T_c Superconductors, Vol. 1, Chapter 9 (World Scientific Publishing Company, Singapore, 1993), pp. 371-407.

[See Cryoelectronic Metrology.]

Goodrich, L.F., Srivastava, A.N., Yuyama, M., and Wada, H., **n-Value and Second Derivative of the Superconductor Voltage-Current Characteristic**, IEEE Transactions on Applied Superconductivity, Vol. 3, No. 1, pp. 1265-1268 (March 1993).

We studied the n-value ($V \propto I^n$) and second derivative (d^2V/dI^2) of the voltage-current curve of high- and low-temperature superconductors and superconductor simulators. We used these parameters for diagnosing problems with sample heating and data acquisition, and as indicators of the superconducting-to-normal state transition. The superconductor simulator may be useful in testing the measurement system integrity and reducing measurement variability since its characteristics are highly repeatable.
[Contact: Loren F. Goodrich, (303) 497-3143]

Ishida, T., Goldfarb, R.B., Okayasu, S., Kazumata, Y., Franz, J., Arndt, T., and Schauer, W., **Harmonic and Static Susceptibilities of $YBa_2Cu_3O_7$**, Materials Science Forum, Vol. 137-139, pp. 103-131 (1993).

Intergranular properties of the sintered superconductor $YBa_2Cu_3O_7$ have been studied in terms of

complex harmonic magnetic susceptibility $\chi_n = \chi'_n - i\chi''_n$ (n integer) as well as dc susceptibility χ_{dc}. As functions of temperature T, χ'_1 and χ''_1 depend on both the ac magnetic field amplitude H_{ac} and the magnitude of a superimposed dc field H_{dc}. Only odd-harmonic susceptibilities are observed below the critical temperature, T_c, for zero H_{dc} while both odd and even harmonics are observed for nonzero H_{dc}. With T constant, odd-harmonic susceptibilities are even functions of H_{dc}, whereas even-harmonic susceptibilities are odd functions of H_{dc}. Experimental intergranular characteristics of χ'_1 and χ''_1 are in good agreement with theoretical predictions from a simplified Kim model of magnetization. In contrast, even-harmonic susceptibilities measured for a $GdBa_2Cu_3O_7$ thin film and an $YBa_2Cu_3O_7$ single crystal are not prominent due to missing weak links, whereas odd-harmonic susceptibilities are remarkable. A survey of several models for the harmonic response of superconductors is presented. The dc susceptibility curve for the zero-field-cooled $YBa_2Cu_3O_7$ sample, $\chi_{ZFC}(T)$, has a two-step structure arising from intra- and inter-granular components, similar to χ'_1. The dc susceptibility measured upon warming, $\chi_{FCW}(T)$, shows a negative peak near T_c for the sample cooled rapidly in small dc fields. The dc susceptibility measured upon cooling, $\chi_{FCC}(T)$, does not show a peak. A negative peak is not seen in measurements on a powdered sample. The negative peak can be explained by intergranular flux depinning upon warming.
[Contact: Ronald B. Goldfarb, (303) 497-3650]

Moreland, J., **Tunneling Spectroscopy of Thallium-Based High Temperature Superconductors**, Chapter in Thallium-Based High-Temperature Superconductors, A.M. Hermann and J.V. Yakhmi, Eds. (Marcel Dekker, Inc., New York, NY, 1994), pp. 569-577.

[See Cryoelectronic Metrology.]

Peterson, R.L., **An Analysis of the Impact on U.S. Industry of the NIST/Boulder Superconductivity Programs: An Interim Study**, NISTIR 5012 (November 1993).

[See Cryoelectronic Metrology.]

Shi, D., Wang, Z., Sengupta, S., Smith, M., Goodrich, L.F., Dou, S.X., Liu, H.K., and Guo, Y.C., **Critical Current Density Irreversibility Line and Flux Creep Activation Energy In Silver-Sheathed $Bi_2Sr_2Ca_3Cu_3O_x$ Superconducting Tapes**, IEEE Transactions on Applied Superconductivity, Vol. 3, No. 1, pp. 1194-1196 (March 1993).

Transport data, magnetic hysteresis, and flux creep activation energy experimental results are presented for silver-sheathed high-T_c $Bi_2Sr_2Ca_2Cu_3O_x$ superconducting tapes. The 110-K superconducting phase was formed by lead doping in a Bi-Sr-Ca-Cu-O system. The transport critical current density was measured at 4.0 K to be 0.7 × 10^5 A/cm^2 (the corresponding critical current is 74 A) at zero field and 1.6 × 10^4 A/cm^2 at 12 T for $H \parallel ab$. Excellent grain alignment in the a-b plane was achieved by a short-melting method, which considerably improved the critical current density and irreversibility line. Flux creep activation energy as a function of current is obtained based on the magnetic relaxation measurements.
[Contact: Loren F. Goodrich, (303) 497-3143]

ELECTROMAGNETIC INTERFERENCE

Conducted EMI

Lai, J.-S., and Martzloff, F.D., **Coordinating Cascaded Surge Protection Devices: High-Low Versus Low-High**, IEEE Transactions on Industry Applications, Vol. 29, No. 4, pp. 680-687 (July/August 1993). [Also published in the Conference Record of the IEEE/IAS Annual Meeting, Dearborn, Michigan, October 1-4, 1991, Vol. II, pp. 1812-1819.]

Cascading surge-protection devices located at the service entrance of a building and near the sensitive equipment are intended to ensure that each device shares the surge stress in an optimum manner to achieve reliable protection of equipment against surges impinging from the utility supply. However, depending on the relative clamping voltages of the two devices, their separation distance, and the waveform of the impinging surges, the coordination may or may not be effective. The paper provides computations with experimental verification of the energy deposited in the devices for a matrix of combinations of these three parameters. Results

show coordination to be effective for some combinations and ineffective for some others which is a finding that should reconcile contradictory conclusions reported by different authors making different assumptions. From these results, improved coordination can be developed by application standards writers and system designers.
[Contact: François D. Martzloff, (301) 975-2409]

ADDITIONAL INFORMATION

Lists of Publications

Smith, A.J., **Metrology for Electromagnetic Technology: A Bibliography of NIST Publications**, NISTIR 5008 (September 1993).

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.
[Contact: Annie Smith, (303) 497-3678]

Lyons, R.M., and Gibson, K.A., **A Bibliography of the NIST Electromagnetic Fields Division Publications**, NISTIR 5009 (September 1993).

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 July 1993. 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 1994).

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 1993. A brief description of the Division's technical program is given in the introduction.
[Contact: Katherine H. Magruder, (301) 975-2401]

Walters, E.J., **Semiconductor Measurement Technology, 1990-1993, NIST List of Publications 103** (January 1994).

The bibliography provides information on technology transfer in the field of microelectronics at NIST for the calendar years 1990 through 1993. 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.

Guide -- 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.

Introductory Information -- 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.

Fields of Technology -- 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.

1994/1995 Calendar of Events

April 28, 1994 (Hudson, Massachusetts)

Ion Implant Users Group Meeting. This NIST-sponsored meeting will be held at the facilities of Digital Equipment in Hudson, Massachusetts. Among the topics to be discussed is Large Area Implantation.
[Contact: John Albers, (301) 975-2075]

June 8-10, 1994 (near Windsor, U.K.)

IEEE/CHMT Workshop on MCM and VLSI Packaging Techniques and Manufacturing Technologies. Sponsored by IEEE/CHMT Society and NIST, this Workshop will be held in cooperation with the European Communities DGXIII-A. The main topics of the Workshop will be the design and implementation of first-level electronic packaging and the technologies, materials, and equipment for the manufacture of multichip modules (MCM) and single-chip packages.
[Contact: George G. Harman, (301) 975-2097]

June 14-17, 1994 (Boulder, Colorado)

Computer Modeling of Optical Waveguides and Components: A Hands-On Workshop. The purpose of this Workshop, sponsored by NIST, is to disseminate computer modeling tools for fiber and integrated optics waveguides and to discuss and demonstrate methods of understanding engineering parameters of optical waveguides.
[Contact: Robert L. Gallawa, (303) 497-3761]

June 27-July 1, 1994 (Boulder, Colorado)

Conference on Precision Electromagnetic Measurements. In sponsorship with the IEEE Instrumentation and Measurement Society and Union Radio Scientifique Internationale, NIST will be holding the biennial meeting of CPEM in Boulder, Colorado. Topics to be discussed include: advanced instrumentation including new sensors and measurement methods; automated measurement methods; dielectric and antenna measurements; direct current and low-frequency measurements; fundamental constants and special standards; laser, optical fiber, and optical electronic measurements; RF, microwave, and millimeter-wave measurements; superconducting and other low-temperature measurements; and time and frequency measurements. CPEM '94 is extended to five days to provide for added special sessions on the fundamental con-

stants.
[Contact: Gwen E. Bennett, (303) 497-3295]

September 13-15, 1994 (Boulder, Colorado)

Symposium on Optical Fiber Measurements. Sponsored by the IEEE Lasers & Electro-Optics Society, the Optical Society of America, and NIST, the Symposium will provide a forum for reporting the results of recent measurement research in the area of lightwave communications, including optical fibers.
[Contact: Douglas L. Franzen, (303) 497-3346]

January 30–February 2, 1995 (Gaithersburg, Maryland) — *(PLEASE NOTE NEW DATE.)*

International Workshop on Semiconductor Materials Characterization: Present Status and Future Needs. Papers will be presented in all relevant fields of interest to materials characterization in semiconductor device manufacturing, growth, processing, diagnostics, in-situ, real-time control and monitoring, etc. All relevant semiconductor materials will be addressed: Group IV elements, Group III-V compounds, Group II-VI compounds, IV-VI compounds, and others. The Workshop is sponsored by the Advanced Research Projects Agency (ARPA), SEMATECH, and NIST. Other cosponsors are expected.
[Contact: David G. Seiler, (301) 975-2074]

February 7-9, 1995 (San Jose, California)

IEEE Semiconductor Thermal Measurement and Management (SEMI-THERM) Symposium. Cosponsored by IEEE, CPMT, and NIST, SEMI-THERM is an international forum dedicated to new developments in the thermal characterization of electronic components and systems. Topics to be discussed at this 11th Annual Symposium include thermal characterization; analytical and computational thermal modeling; measurement techniques including temperature, fluid flow, and thermal-mechanical properties; and thermal reliability screening and testing.
[Contact: David L. Blackburn, (301) 975-2053]

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  National Highway Traffic Safety Administration; Federal Aviation Administration
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Various Federal Government Agencies

NIST Silicon Resistivity SRMs

In response to needs of the semiconductor industry, NIST's Semiconductor Electronics Division provides silicon bulk resistivity Standard Reference Materials (SRMs) through the NIST Standard Reference Materials Program. A new class of resistivity SRMs is being introduced to respond better to users' requirements.

The first NIST (then NBS) resistivity SRMs were fabricated from crystal 50 mm (2 in) in diameter. These wafers represented various combinations of crystal growth process, crystallographic orientation, and doping, each combination chosen to give the best expected wafer uniformity for a given resistivity level. Each wafer in every set was individually measured and certified. Some of these sets are still available until the supply is exhausted (see table).

The Division is now certifying single-wafer resistivity standards at approximately the same resistivity values as were available in the earlier sets. These new SRMs are fabricated from crystal 100 mm in diameter, intended to provide improved compatibility with newer end-use instrumentation. In response to user comments, the new SRMs will be more uniform in both thickness and resistivity, will have reduced uncertainty of certified value due to use of an improved certification procedure using a four-point probe, and will be measured and certified at additional measurement sites for better characterization of wafer uniformity at its core. The additional measurements needed to qualify the improved SRMs will make them more expensive on a per-wafer basis than the earlier sets.

NIST SILICON BULK RESISTIVITY STANDARD REFERENCE MATERIALS

DATE PREPARED: 8 OCTOBER 1993

NOMINAL RESISTIVITY (ohm · cm)	OLD SRMs	AVAILABILITY	NEW SRMs	ANTICIPATED AVAILABILITY
0.01	1523 (one of set of two wafers)	limited supply	2541	to be announced
0.1	1521 (one of set of two wafers)	limited supply	2542	to be announced
1	1523 (one of set of two wafers)	limited supply	2543	to be announced
10	1521 (one of set of two wafers)	limited supply	2544	early in calendar year 1994
25	1522	set of three wafers no longer available	2545	to be announced
75	1522		2546 (100)	to be announced
180	1522		2547 (200)	early in calendar year 1994

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.

INTERNATIONAL WORKSHOP ON

Semiconductor Characterization: Present Status and Future Needs

January 30 - February 2, 1995
Gaithersburg, Maryland, U.S.A.

Sponsors

The Advanced Research Projects Agency, National Institute of Standards and Technology, and SEMATECH. Other expected co-sponsors: Air Force Office of Scientific Research, Department of Energy, Office of Naval Research, and the National Science Foundation.

Purpose and Goals of the Workshop

Semiconductors form the backbone of all modern-day microelectronic and optoelectronic devices. Semiconductor characterization has proven to be fundamental for the advancement of semiconductor technology. A comprehensive "world-class" workshop dedicated to giving critical reviews of the most important semiconductor characterization techniques that are useful to the semiconductor industry is envisioned. Because of the increasing importance of in-line and in-situ characterization methods, a strong emphasis will be placed on ascertaining their present status and future needs.

The purpose of this workshop is to bring together scientists and engineers interested in all aspects of characterization (research, development, manufacturing, diagnostics...): chemical and physical, electrical, optical, in-situ, and real-time control and monitoring.

The workshop goals are: (1) to provide a forum in which measurements of current and future interest to the semiconductor industry can be reviewed, discussed, critiqued, and summarized; (2) to demonstrate and review important applications for diagnostics, manufacturing, and in-situ monitoring and control in real-time environments; and (3) to act as an important stimulus for new progress in the field by providing new perspectives.

Scope of the Workshop

Papers are solicited in all relevant fields of interest to characterization in semiconductor device manufacturing, growth, processing, diagnostics, in-situ, real-time control and monitoring, etc. All relevant semiconductor materials will be addressed: Group IV elements (Si, etc.), Group III-V compounds (GaAs, InP, etc.), Group II-VI compounds (ZnSe, HgCdTe, etc.), IV-VI compounds (PbTe, etc.), and others. Heavy emphasis will be placed on invited papers that provide up-to-date critical reviews that discuss and evaluate the science and technology of the major techniques or areas. Recent developments of novel measurement methods will also be considered.

For technical information, contact: Dr. David G. Seiler, NIST, A305 Technology Bldg., Gaithersburg, MD 20899-0001, USA, Telephone: 301/975-2081, Fax: 301/948-4081, email: seiler@apollo.sed.eeel.nist.gov

The National Institute of Standards and Technology

- NIST Standard Reference Materials (SRMs) are used by thousands of companies to calibrate their equipment
- NIST photomask SRMs help reduce linewidth measurement errors by a factor of 10 and save manufacturers over $30 million annually
- NIST research in electromigration is saving manufacturers over $26 million and has contributed to a new thrust in building-in reliability
- NIST research improved production yield of high reliability devices by factors of 2 to 35
- NIST developed a tester that characterizes the breakdown of semiconductor power devices without destroying them
- NIST is developing test structures and test methods for nanometer overlay metrology
- NIST is developing new optical measurement tools for advanced semiconductor manufacturing

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Hall 4, Booth 5722
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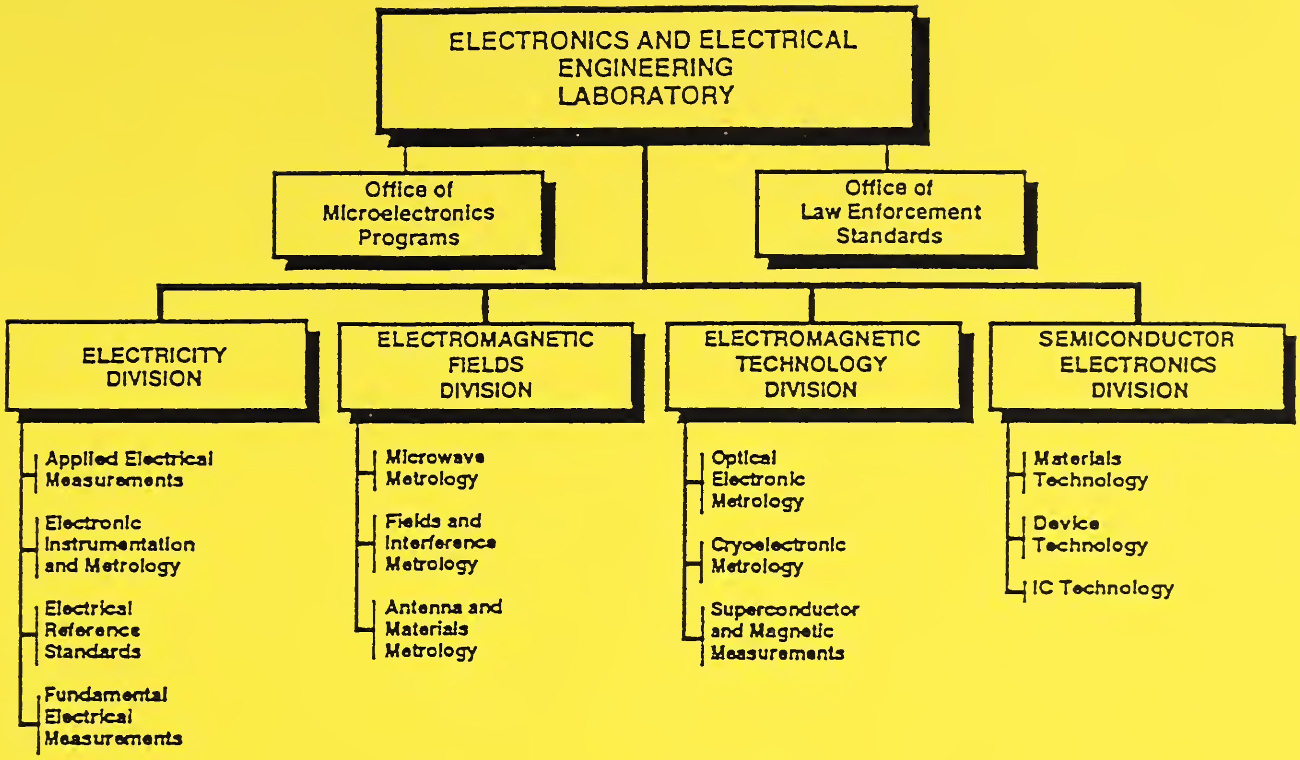

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Office of Law Enforcement Standards	Director, Mr. Lawrence K. Eliason (301) 975-2757
Electricity Division (811)	Chief, Dr. Oskars Petersons (301) 975-2400
Semiconductor Electronics Division (812)	Chief, Mr. Frank F. Oettinger (301)975-2054
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