NISTIR 4945

Electronics and Electrical Engineering Laboratory

Technical Publications Announcements

Covering Laboratory Programs,
January to March 1992,
with 1992/1993 EEEL Events Calendar

J. A. Gonzalez
Compiler

October 1992

32

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

NIST

NISTIR 4945

Electronics and Electrical Engineering Laboratory

Technical Publications Announcements

Covering Laboratory Programs,
January to March 1992,
with 1992/1993 EEEL Events Calendar

J. A. Gonzalez
Compiler

October 1992

32

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

U.S. DEPARTMENT OF COMMERCE
Barbara Hackman Franklin, Secretary

TECHNOLOGY ADMINISTRATION
Robert M. White, Under Secretary for Technology

NATIONAL INSTITUTE OF STANDARDS
AND TECHNOLOGY
John W. Lyons, Director

INTRODUCTION TO THE EEEL TECHNICAL PUBLICATION ANNOUNCEMENTS

This is the thirty-second 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 1992.

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 1992/1993 and a list of sponsors of the work.

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

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

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

Laboratory Sponsors: The Laboratory Programs are sponsored by the National Institute of Standards and Technology and a number of other organizations, in both the Federal and private sectors; these are identified on page 16.

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 13.

TABLE OF CONTENTS

FUNDAMENTAL ELECTRICAL MEASUREMENTS

Van Degrift, C.T., Yoshihiro, K., Cage, M.E., Yu, D., Segawa, K., Kinoshita, J., and Endo, T., **Anomalously Offset Quantized Hall Plateaus in High-Mobility Si-MOSFETs**, Surface Science, Vol. 263, (Elsevier Science Publishers B.V. and Yamada Science Foundation, North-Holland, 1992), pp. 116-119. [Proceedings of the Conference on Electronic Properties of Two-Dimensional Electron Systems, Nara, Japan, July 15-19, 1991.]

Measurements made using two independent, high-precision systems on different samples of high-mobility silicon-MOSFETs have revealed unexpected irregularities in their i=4 quantized Hall plateaus in spite of exceedingly low diagonal resistivities, 0.002 parts per million of the plateau value. Relatively flat, metastable plateaus were observed which were offset by up to 0.4 parts per million above the corresponding GaAs/AlGaAs value under the measurements at 14 to 14.5 T, 0.34 to 0.5 K, with about 10-μA sample current. Possible connection of these phenomena with the offset plateaus observed by Kawaji et al. is discussed. At present, no satisfactory explanation has been provided for these phenomena.
[Contact: Craig T. Van Degrift, (301) 975-4248]

SEMICONDUCTOR MICROELECTRONICS

Compound Materials

Bennett, H.S., Lowney, J.R., Tomizawa, M., and Ishibashi, T., **Experimentally Verified Majority and Minority Mobilities in Heavily Doped GaAs for Device Simulations**, IEICE Transactions Electron (Japan), Vol. E75-C, No. 2, pp. 161-171 (February 1992). [Special Issue on Selected Papers from '91 VPAD, Proceedings of the 1991 International Workshop on VLSI Process and Device Modeling (1991 VPAD), Oiso, Kanagawa, Japan, May 26-27, 1991.]

Low-field mobilities and velocity versus electric field relations are among the key input parameters for drift-diffusion simulations of field-effect and bipolar transistors. For example, most device simulations that treat scattering from ionized impurities contain mobilities or velocity versus field relations based on the Born approximation (BA). The BA is insensitive to the sign of the charged impurity and is especially poor for ionized impurity scattering because of the relatively strong scattering of long-wavelength carriers, which have low energies, and therefore violate the validity condition for the BA. Such carriers occur at high symmetry points in the Brillouin zone and are critical for device behavior.

There has been a tendency in the past to assume that majority and minority mobilities are equal. This assumption can lead to incorrect interpretations of device data, thereby misleading design strategies based on such simulations. We have calculated the majority electron and minority hole mobilities in GaAs at 300 K for donor densities between 5×10^{16} and 1×10^{19} cm^{-3} and the majority hole and minority electron mobilities for acceptor densities between 5×10^{16} and 1×10^{20} cm^{-3}. We have included all the important scattering mechanisms for GaAs: acoustic phonon, polar optic phonon, nonpolar optic phonon (holes only), piezoelectric, ionized impurity, carrier-carrier, and plasmon scattering.

The ionized impurity and carrier-carrier scattering processes have been calculated with a quantum mechanical phase-shift analysis to obtain more accurate matrix elements for these two scattering mechanisms. We compare the total scattering rate for majority electrons due to ionized impurities based on exact phase shifts and on the BA of Brooks-Herring. We also present additional data that show the differences between the exact phase-shift analyses and the BA for majority electron scattering rates as functions of carrier energy and scattering angle. These results show that the calculated low-field mobilities are in good agreement with experiment, but they predict that at high dopant densities, minority mobilities should increase with increasing dopant density for a short range of densities. This effect occurs because of the reduction of plasmon scattering and the removal of carriers from carrier-carrier scattering because of the Pauli exclusion principle. Some recent experiments support this finding. These results are important for device modeling because of the need to have reliable values for the minority mobilities and velocity-field relations.
[Contact: Herbert S. Bennett, (301) 975-2079]

DeSalvo, G.C., Tseng, W.F., and Comas, J., **Etch Rates and Selectivities of Citric Acid/Hydrogen Peroxide on GaAs, $Al_{0.3}Ga_{0.7}As$, $In_{0.2}Ga_{0.8}As$, $In_{0.53}Ga_{0.47}As$, $In_{0.52}Al_{0.48}As$, and InP**, Journal of

the Electrochemical Society, Vol. 139, No. 3, pp. 831-835 (March 1992).

Investigation of citric acid/hydrogen peroxide ($C_6H_8O_7/H_2O_2$) at volume ratios from 0.5 to 50 were found to provide good selective etching of various III-V semiconductor materials grown on GaAs and InP substrates. Choosing different volume ratios of citric acid/hydrogen peroxide provides both selective and uniform (non-selective) etching regions. Etchant selectivities of the GaAs-based materials were measured to be as high as 100 for $GaAs/Al_{0.3}Ga_{0.7}As$ and 120 for $In_{0.2}Ga_{0.8}As/Al_{0.3}Ga_{0.7}As$. In addition, the InP system had selectivities of approximately 60 and 80 for $In_{0.53}Ga_{0.47}As/In_{0.52}Al_{0.48}As$ and $In_{0.52}Al_{0.48}As/InP$, with the highest selectivity of 473 found for $In_{0.53}Ga_{0.47}As/InP$. The $C_6H_8O_7/H_2O_2$ can be used as a stop etch for InP-based devices, as InP is virtually unaffected by this etchant. Finally, citric acid/hydrogen peroxide can be used to preferentially etch these materials through a photoresist mask, since it does not erode photoresist at any volume ratio.
[Contact: Wen F. Tseng, (301) 975-5291]

Lowney, J.R., Seiler, D.G., Littler, C.L., and Yoon, I.T., **Intrinsic Carrier Concentration of Narrow-Gap Mercury Cadmium Telluride Based on the Nonlinear Temperature Dependence of the Band Gap**, Journal of Applied Physics, Vol. 71, No. 3, pp. 1253-1258 (1 February 1992).

The intrinsic carrier concentrations of narrow-gap $Hg_{1-x}Cd_xTe$ alloys have been calculated as a function of temperature between 0 and 300 K for x-values between 0.17 and 0.30. The new and more accurate relation for the temperature dependence of the energy gap, which is based on two-photon magnetoabsorption data, is used. This relation is further supported here by additional one-photon magnetoabsorption measurements for $x = 0.20$ and 0.23, which were made with a CO_2 laser. In this range of composition and temperature, the energy gap of mercury cadmium telluride is small, and very accurate values are needed for the gap to obtain reliable values for the intrinsic carrier density. Kane's $k \cdot p$ theory is used to account for the conduction-band nonparabolicity. Large percentage differences occur between our new calculations and previously calculated values for n_i at low temperatures. A nonlinear least-squares fit was made to the results of our calculations for ease of use. The implications of these results for $Hg_{1-x}Cd_xTe$ materials characterization and device operation are discussed.
[Contact: Jeremiah R. Lowney, (301) 975-2048]

McKeown, D.A., **X-Ray-Absorption Near-Edge Structure of Transition-Metal Zinc-Blende Semiconductors: Calculation Versus Experimental Data and the Pre-Edge Feature** [original title: XANES of Transition Metal Zinc-Blende Semiconductors], Physical Review B, Vol. 45, No. 6, pp. 2648-2653 (1 February 1992).

XANES data were collected for Zn in sphalerite, and Cu and Fe in chalcopyrite, where all three cations are in nearly identical coordination environments. The data have similar features, except near the edge, where the edge maximum decreases in amplitude, while a pre-edge feature appears and increases in amplitude from Zn to Cu to Fe. This pre-edge feature has been previously assigned to a 1s-to-3d atomic transition in the absorbing cation. XANES calculations, incorporating five shells of atoms around the absorbing cation, best match the data. The calculations show that the edge shape (sharpness of the edge maximum and the energy range of the edge jump) is due to the atomic states of the absorber, while the more rapidly varying features on the edge are due to interference effects from the arrangement of atoms surrounding the absorber. A feature near the beginning of the edge jump is observed for both Cu- and Fe-edge calculations and mimics the pre-edge feature found in the data. The results from the calculations suggest that the pre-edge feature is due to interference effects from the crystal structure and not due to atomic bound state transitions of the absorbing cation.
[Contact: David G. Seiler (301) 975-2074]

Analysis Techniques

Kopanski, J.J., Lowney, J.R., Miles, D.S., Novotny, D.B., and Carver, G.P., **High Spatial Resolution Mapping of Resistivity Variations in Semiconductors**, Solid-State Electronics, Vol. 35, No. 3, pp. 423-433 (1992).

A new approach to the mapping of resistivity variations in semiconductors uses probe sites provided by an array of lithographically defined contacts with a density of 60,000 sites per cm^2. One- or two-probe spreading resistance, or four-point-probe resistance measurements can be made. Solutions of the Laplace

equation and measurements on silicon that had been ion-implanted to form abrupt boundaries in resistivity are used to show that the spatial resolution of the technique is determined primarily by the spacing of the measurement sites, not by the spreading of the current from the contacts. The technique has been implemented with a resolution of lateral variations in resistivity of 45 μm in width and ±5% in magnitude from the background resistivity. As an example application, a study of the resistivity variations of a silicon boule with pronounced growth striations is presented.
[Contact: Joseph J. Kopanski, (301) 975-2089]

Device Physics and Modeling

Bennett, H.S., and Lowney, J.R., **Calculated Majority- and Minority-Carrier Mobilities in Heavily Doped Silicon and Comparisons With Experiment**, Journal of Applied Physics, Vol. 71, No. 5, pp. 2285-2296 (1 March 1992).

As silicon devices approach 0.1 μm in size, it will be essential to have accurate values for the majority and minority mobilities of electrons and holes. These mobilities have been calculated in silicon for donor and acceptor densities between 10^{17} cm^{-3} and 10^{20} cm^{-3}. All the important scattering mechanisms have been included. The ionized impurity scattering has been treated with a quantum-mechanical phase-shift analysis. The results are in good agreement with experiment, but predict that the change of minority electron mobility with increasing dopant density should decrease slightly at high dopant densities for a small range of densities. This effect occurs mainly because of the reduction of plasmon scattering. Some recent experiments support these findings. In addition, the ionized impurity scattering rates calculated from the quantum-mechanical phase shifts and those rates calculated from the Born approximation are shown to differ by more than factors of three. The Born approximation is not valid for low energy carriers near band extrema. Carrier scattering rates are key input quantities for Monte Carlo calculations of carrier-velocity versus electric-field relations and of simulations of device behavior. Our calculations do not treat the density-of-states modifications due to heavy doping, which should have only a small effect on the mobility at room temperature.
[Contact: Herbert S. Bennett, (301) 975-2079]

Bennett, H.S., Lowney, J.R., Tomizawa, M., and Ishibashi, T., **Experimentally Verified Majority and Minority Mobilities in Heavily Doped GaAs for Device Simulations**, IEICE Transactions Electron (Japan), Vol. E75-C, No. 2, pp. 161-171 (February 1992). [Special Issue on Selected Papers from '91 VPAD, Proceedings of the 1991 International Workshop on VLSI Process and Device Modeling (1991 VPAD), Oiso, Kanagawa, Japan, May 26-27, 1991.]

Low-field mobilities and velocity versus electric field relations are among the key input parameters for drift-diffusion simulations of field-effect and bipolar transistors. For example, most device simulations that treat scattering from ionized impurities contain mobilities or velocity versus field relations based on the Born approximation (BA). The BA is insensitive to the sign of the charged impurity and is especially poor for ionized impurity scattering because of the relatively strong scattering of long-wavelength carriers, which have low energies, and therefore violate the validity condition for the BA. Such carriers occur at high symmetry points in the Brillouin zone and are critical for device behavior.

There has been a tendency in the past to assume that majority and minority mobilities are equal. This assumption can lead to incorrect interpretations of device data, thereby misleading design strategies based on such simulations. We have calculated the majority electron and minority hole mobilities in GaAs at 300 K for donor densities between 5×10^{16} and 1×10^{19} cm^{-3} and the majority hole and minority electron mobilities for acceptor densities between 5×10^{16} and 1×10^{20} cm^{-3}. We have included all the important scattering mechanisms for GaAs: acoustic phonon, polar optic phonon, nonpolar optic phonon (holes only), piezoelectric, ionized impurity, carrier-carrier, and plasmon scattering.

The ionized impurity and carrier-carrier scattering processes have been calculated with a quantum mechanical phase-shift analysis to obtain more accurate matrix elements for these two scattering mechanisms. We compare the total scattering rate for majority electrons due to ionized impurities based on exact phase shifts and on the BA of Brooks-Herring. We also present additional data that show the differences between the exact phase-shift analyses and the BA for majority electron scattering rates as functions

of carrier energy and scattering angle. These results show that the calculated low-field mobilities are in good agreement with experiment, but they predict that at high dopant densities, minority mobilities should increase with increasing dopant density for a short range of densities. This effect occurs because of the reduction of plasmon scattering and the removal of carriers from carrier-carrier scattering because of the Pauli exclusion principle. Some recent experiments support this finding. These results are important for device modeling because of the need to have reliable values for the minority mobilities and velocity-field relations.
[Contact: Herbert S. Bennett, (301) 975-2079]

Insulators and Interfaces

[For Separation by Implanted Oxygen (SIMOX) and for Silicon-on-Insulator (SOI) see Silicon Materials]

Marchiando, J.F., and Geist, J., **Separation by Ion Implantation of Oxygen (SIMOX) Structures: Estimating Thicknesses** [original title: On Estimating Thicknesses in SIMOX Structures], Applied Optics, Vol. 31, No. 4, pp. 485-487 (1 February 1992).

The propagation of errors in the model parameters is compared for cases which analyze a simple SIMOX structure using reflectometry and ellipsometry. Both methods give comparable values for the layer thicknesses. Both the radius of convergence and values of uncertainty tend to be larger with reflectometry than with ellipsometry.
[Contact: Jay F. Marchiando, (301) 975-2088]

Witczak, S.C., Suehle, J.S., and Gaitan, M., **An Experimental Comparison of Measurement Techniques to Extract Si-SiO_2 Interface Trap Density**, Solid-State Electronics, Vol. 35, No. 3, pp. 345-355 (1992).

For the first time, five methods of measuring Si-SiO_2 interface trap densities were compared on three otherwise identical MOSFETs which were radiation-stressed so as to induce different levels of interface trap densities. The results show that when sources of error and limitations are taken into account, these methods capable of estimating interface trap densities are in good quantitative agreement. Furthermore, the change in measured interface trap densities with radiation is independent of the method used. A comprehensive review of the methods is presented.
[Contact: Steven C. Witczak, (301) 975-2243]

Dimensional Metrology

Vezzetti, C.F., Varner, R.N., and Potzick, J.E., **Standard Reference Materials: Antireflecting-Chromium Linewidth Standard, SRM 475, for Calibration of Optical Microscope Linewidth Measuring Systems**, NIST Special Publication 260-117 (January 1992).

The precise and accurate measurement of feature dimensions on photomasks, such as those used in the production of integrated circuits, becomes increasingly difficult as the dimensions approach the wavelength of the light used to make the measurement. The undesirable effects of optical diffraction obscure the location of the feature edges. Raggedness and nonvertical walls along the edges add to the uncertainty of the measurement.

Standard Reference Material SRM 475 was developed for use in calibrating optical microscopes for measuring linewidths in the range of 0.9 to 10.8 μm on antireflecting-chromium photomasks. The SRM, the measurement system, and the procedures used to calibrate the SRM are described. The algorithm for determining the line edge location uses a threshold criterion derived from analysis of microscopy image profiles. The profiles are predicted by computer modeling based on the theory of partial coherence. The performance of the system is monitored by measuring line features on a control photomask before and after calibrating each SRM.

Precautions concerning care and handling and instruction for the use of SRM 475 to calibrate optical microscopes for photomask linewidth measurement are given.
[Contact: Beverly M. Wright, (301) 975-2166]

Integrated-Circuit Test Structures

Allen, R.A., and Cresswell, M.W., **Elimination of Effects Due to Patterning Imperfections in Electrical Test Structures for Submicrometer Feature Metrology**, Solid-State Electronics, Vol. 35, No. 3, pp. 435-442 (1992).

This paper describes the elimination of a substrate-dependent systematic error that was experienced in prior work on measuring the separation of parallel features with total errors less than 10 nm with an electrical test structure. The test structure was an enhancement of a sliding wire voltage dividing potentiometer which scaled the overall test structure geometry to obtain greater sensitivity. It also incorporated features to eliminate adverse effects of voltage tap- and bridge-linewidth scaling. The measurement algorithm that was developed provided the relative separations of sets of features to the 10-nm level. However, absolute measurements were offset by a quantity characteristic of the substrate from which they were extracted. The evidence suggested that these systematic errors were not caused by the primary pattern generation tool. Through observations, measurements, and simulations, this paper attributes the substrate-characteristic systematic error to an orientation dependence of the quality of the replication of certain features of the test structure. An alternative design and measurement algorithm is shown to be able to greatly reduce the errors.
[Contact: Richard A. Allen, (301) 975-5026]

Allen, R.A., Cresswell, M.W., Ellenwood, C.H., and Linholm, L.W., **Voltage-Dividing Potentiometer Enhancements for High-Precision Feature Placement Metrology**, Proceedings of the IEEE 1992 International Conference on Microelectronic Test Structures, San Diego, California, March 16-19, 1992, Vol. 5, pp. 175-179 (1992).

A new, robust, high-sensitivity, electrical test structure based on the voltage-dividing potentiometer principle, and designed for the measurement of the separations of pairs conducting features, has recently been reported. In earlier work, the uncorrected measurements had a systematic error in the hundreds of nanometers. However, after compensating for this error, the residual errors were typically as low as 15 nm. In later work, through further measurements and extensive modeling, the origin of the systematic error was attributed to substrate-dependent asymmetries of certain imperfections in the replication of the test structure. In this paper, modified test structures are described that confirm the model and show how all design-rule and substrate-dependent systematic errors can be eliminated.
[Contact: Richard A. Allen, (301) 975-2075]

Microfabrication Technology

Larson, D.R., and Veasey, D.L., **Localized Plasma Etching for Device Optimization**, Journal of Vacuum Science Technology B, Vol. 10, No. 1, pp. 27-29 (Jan/Feb 1992).

We have developed an unconventional approach to down-stream plasma etching: only a small area of the substrate is exposed to the low-pressure, reactive gaseous environment. The remainder of the substrate is outside the miniature plasma chamber, providing physical access for probing apparatus. Etch rates of 6 μm/h were obtained. The process can be especially useful when in-situ monitoring of the effects of etching is required. Using this process, we improved the responsivity of a semiconductor optical detector deposited on top of an optical waveguide. This was accomplished by monitoring the transmitted intensity of light in an integrated optical waveguide while etching a thin semiconductor film covering a small region of the waveguide.
[Contact: Donald R. Larson, (303) 497-3440]

Miller, Jr., W.R., Boettinger, W.J., Tseng, W.F., Pellegrino, J.G., and Comas, J., **Controlled Interface Roughness in GaAs/AlAs Superlattices**, Proceedings of the Materials Research Society Symposium, Anaheim, California, April 29-May 2, 1991, Vol. 230, pp. 213-281 (1992).

We report the results of our study of controlled interface roughness in low-order GaAs/AlAs superlattices. Samples were prepared using either the interrupted growth or the migration-enhanced epitaxy (MEE) technique. The samples were prepared with m atomic planes of GaAs and m atomic planes of AlAs (m × m) per modulation wavelength and repeated p times. For this study, m = 1 or 3. The samples were studied using X-ray diffraction. The interrupted growth samples both showed a split in one diffraction line, indicating layers were not of integral order, while the MEE samples showed no splitting, indicating integral order layers.
[Contact: William R. Miller, Jr. (301) 975-2086]

Myers, D.R., Vawter, G.A., Jones, E.D., Zipperian, T.E., Drummond, T.J., Fritz, I.J., Dawson, L.R., Brennan, T.M., Hammons, B.E., Datye, A.K., Simons, D.S., and Comas, J., **Rapid-Thermal Annealing for Quantum-Well Heterostruc-**

ture Device Fabrication, IEEE Transactions on Electron Devices, Vol. 39, No. 1, pp. 41-49 (January 1992).

We examine ion implantation and rapid-thermal processing for the fabrication of quantum-well, compound semiconductor heterostructure devices in strained and in lattice-matched material systems. We demonstrate improvements to the performance of two classes of devices that would be particularly sensitive to process-induced defects: p-channel strained-quantum-well field-effect transistors and single-quantum-well diode lasers. We correlated the device results with secondary-ion mass spectroscopy, Hall-effect, transmission-electron microscopy, and photoluminescence.
[Contact: James Comas, (301) 975-2061]

Pellegrino, J.G., Qadri, S., Tseng, W.F., Miller, W.R., and Comas, J., **Periodicities in the X-Ray Diffraction of Low Order AlAs/GaAs Superlattices,** Proceedings of the Material Research Society Symposium, Anaheim, California, April 29-May 2, 1991, Vol. 230, pp. 219-224 (1992).

In this work we examine the physical properties for the superlattice system $(GaAs)n_1(AlAs)n_2/GaAs(100)$ for low values of n_1 and n_2, i.e., $n_1 = n_2 = 3, 6, 12$. Normal, interrupted growth, and migration enhanced epitaxy growth techniques were used to grow the superlattice structures in a molecular beam epitaxy system. X-ray diffraction spectra were obtained, and the major and satellite peak positions were analyzed to obtain the superlattice periodicity. An analysis of the major diffraction peaks and their associated satellites produced superlattice periodicity in good agreement with theory. Diffraction peaks were also observed in regions adjacent to the primary diffraction peaks which did not occur in the expected satellite positions. An analysis of these peaks relative to the primary peak indicate periodicities corresponding to layer thickness greater than the intended period. One possible cause for these periodicities is growth conditions that exist during the growth of the superlattice which result in the deposition of fractional monolayers. In this study we present results which suggest that an arsenic-deficient growth condition may be a contributing factor in the deposition of fractional monolayers.
[Contact: Joseph G. Pellegrino, (301) 975-2123]

Photodetectors

Geist, J., Chandler-Horowitz, D., Robinson, A.M., James, C.R., Kohler, R., and Goebel, R., **Numerical Modeling of Silicon Photodiodes for High-Accuracy Applications with PC-1D,** NISTIR 4592 (January 1992).

The purpose of this National Institute of Standards and Technology Interagency/Internal Report (NISTIR) is to provide the source code for two Turbo Pascal 5.5 programs and an MSDOS batch program, along with a paper that describes the programs and provides examples of their use. These three programs serve as a batch mode interface to support high-accuracy photodiode modeling with Version 2 of the semiconductor device modeling program PC-1D. These programs are useful because the interactive user interface of PC-1D is optimized for solar cell modeling, and it is somewhat difficult to access the highest accuracy available from PC-1D through this interface. Part I describes PC-1D from the point of view of high-accuracy photodiode modeling and describes the programs that support its use in this application. Parts II and III present examples of the use of the programs described in Part I to model two different types of experiments performed on silicon photodiodes in various high-accuracy applications.
[Contact: Jon Geist, (301) 975-2066]

Livigni, D., and Li, X., **Spatial Uniformity Measurement of Optical Detector Response,** Proceedings of the Measurement Science Conference, Anaheim, California, January 30-31, 1992, unpaged (1992).

The response of optical detectors to light can vary when the light illuminates different areas of the detector. A perfectly uniform detector would have no change in response when the illuminated area is varied, but the response of real detectors can vary significantly. A scanning system for measuring the response uniformity and methods of quantifying the degree of uniformity are described here. Surface plots and topographical maps of the measured response are presented along with a statistical treatment. Sampling theorem restrictions affecting the accuracy of the results are described. Scans of actual detectors are included to show the wide range of uniformity possible.
[Contact: David Livigni, (303) 497-5898]

Radiation Effects

Witczak, S.C., Suehle, J.S., and Gaitan, M., **An Experimental Comparison of Measurement Techniques to Extract Si-SiO_2 Interface Trap Density**, Solid-State Electronics, Vol. 35, No. 3, pp. 345-355 (1992).

For the first time, five methods of measuring Si-SiO_2 interface trap densities were compared on three otherwise identical MOSFETs which were radiation-stressed so as to induce different levels of interface trap densities. The results show that when sources of error and limitations are taken into account, these methods capable of estimating interface trap densities are in good quantitative agreement. Furthermore, the change in measured interface trap densities with radiation is independent of the method used. A comprehensive review of the methods is presented.
[Contact: Steven C. Witczak, (301) 975-2243]

Reliability

Schafft, H.A., Suehle, J.S., and Lechner, J.A., **Measurement for Controlling Electromigration in Metallization Interconnects: Today and Tomorrow**, Proceedings of the Sixth International Conference on Interconnection Technology in Electronics, Fellbach, Federal Republic of Germany, February 18-20, 1992, pp. 116-120 (1992).

There is a new and important use for accelerated stress tests such as are used to characterize electromigration in metallizations. It is to employ these measurement tools to identify and optimize the input parameters that affect the reliability of the product and thereby promote the implementation of a new approach to reliability for the semiconductor industry -- the building-in reliability approach.

The classical stress test and, to a smaller extent, the SWEAT test are discussed to promote their most effective use in implementing the building-in reliability approach. In particular, the measurement procedure and analysis, extrapolations to use conditions, measurement and interpretation pitfalls, and ways to reduce test time by censoring are discussed.
[Contact: Harry A. Schafft, (301) 975-2234]

SIGNAL ACQUISITION, PROCESSING, AND TRANSMISSION

DC and Low-Frequency Metrology

Huang, D.X., and Kinard, J.R., **AC-DC Differences of High Voltage Thermal Converters**, Proceedings of the Measurement Science Conference, Anaheim, California, January 30-31, 1992, Session 5-B (1992).

For some high-voltage thermal converters (HVTCs), their ac-dc differences vary with age, test timing sequence, and voltage level, especially for 1000-V ranges at frequencies above the audio range. A major contributor to these variations is dielectric loss which varies with temperature, voltage, and frequency. The results of intercomparisons of HVTCs and certain methods to reduce ac-dc differences and their voltage coefficients are presented.
[Contact: Joseph R. Kinard, (301) 975-4250]

Microwave and Millimeter-Wave Metrology

Free, G. M., and Jones, R.N., **Calibration Service for Low-Loss, Three-Terminal Capacitance Standards at 100 kHz and 1 MHz**, NIST Technical Note 1348 (February 1992).

This document describes the three-terminal, capacitance calibration service at 100 kHz and 1.0 MHz at the National Institute of Standards and Technology, Boulder Laboratories. The document discusses the purpose of the service, contact points for initiating the service, what capacitors are appropriate for calibration, the measurement methods used, the instrumentation used for the measurements, and an analysis of the errors in the measurement. It also lists the calibration uncertainties for the stated frequencies and capacitance magnitudes. Finally, the document discusses the quality assurance program used at NIST to ensure the integrity of the calibration.
[Contact: George M. Free, (303) 497-3609]

Furlow, R., Shimoda, R.Y., Williams, D.F., Marks, R.B., and Gupta, K.C., **Benchmark for the Verification of Microwave CAD Software**, 38th ARFTG Conference Digest, San Diego, California, December 5-6, 1991, pp. 97-106 (1992).

A set of microstrip structures which constitute a comprehensive benchmark for the validation of microwave Computer Aided Design (CAD) software has been developed in a collaborative effort led by

Boeing Defense and Space. The benchmark is designed so as to exhibit a wide range of physical mechanisms which may or may not be incorporated into commercial microwave CAD software. The structures are characterized experimentally with respect to a well understood calibration in which the reference impedance is set real.
[Contact: Dylan F. Williams, (303) 497-3138]

Marks, R.B., and Williams, D.F., **Reciprocity Relations for On-Wafer Power Measurement** [original title: Reciprocity Relations in Waveguide Junctions], 38th ARFTG Conference Digest, San Diego, California, December 5-6, 1991, pp. 82-89 (1992).

The implications of expressions relating the forward and reverse transmission coefficients of a waveguide junction derived from the Lorentz reciprocity condition are explored. The two terms in the relation, the phase of the reference impedance in the guide and a new reciprocity factor, lead to an asymmetric scattering parameter matrix when one of the transmission lines connected to the junction is lossy.
[Contact: Roger B. Marks, (303) 497-3037]

Williams, D.F., Marks, R.B., and Davidson, A., **Comparison of On-Wafer Calibrations,** 38th ARFTG Conference Digest, San Diego, California, December 5-6, 1991, pp. 68-81 (1992).

A powerful new technique enables the verification of the measurement accuracy of scattering parameter calibrations. This technique determines the relative reference impedance, reference plane offset, and the worst-case measurement deviations of any calibration in comparison to a benchmark calibration. The technique is applied to several popular on-wafer scattering parameter calibrations, and the deviations between those calibrations and the thru-reflect line calibration are quantified.
[Contact: Dylan F. Williams, (303) 497-3138]

Electromagnetic Properties

Domich, P.D., Baker-Jarvis, J., and Geyer, R.G., **Optimization Techniques for Permittivity and Permeability Determination,** Journal of Research of the National Institute of Standards and Technology, Vol. 96, No. 5, pp. 565-575 (September-October 1991).

This paper discusses optimization techniques for the determination of complex permittivity and permeability in transmission lines. The traditional theoretical model using scattering parameters is extended into a mathematical regression model that can be solved with widely accepted numerical techniques. This new model produces accurate primary mode results for the samples tested including nonmagnetic and magnetic materials with high dielectric constants. An extension of the model includes responses due to higher order modes. The general model determines parameters to specify the spectral functional form of complex permittivity and permeability and is capable of small corrections to independent variable data including angular frequency, sample length, sample position, and cutoff wavelength. The method provides reliable determination for both low and high permittivity materials.
[Contact: James Baker-Jarvis, (303) 497-5852]

Optical Fiber Metrology

Esman, R.D., and Iwashita, K., **High-Frequency Optical FM Noise Reduction Employing a Fiber-Insertable Feedforward Technique,** Technical Digest, Optical Fiber Communication Conference, San Jose, California, February 2-7, 1992, pp. 72-73 (1992).

We have proposed and demonstrated a new insertable fiber-optic device that reduces optical FM noise and linewidth. Experimental results reveal FM modulation reduction to 1 GHz, which we believe is the widest reported bandwidth for FM suppression. This technique should be especially useful in conjunction with feedback, where FM noise at low frequencies is reduced by feedback and at high frequencies (including feedback-induced FM noise enhancement) by feedforward.
[Contact: Ronald D. Esman, (303) 497-3346]

Franzen, D.L., **Overview of Photonic Primary Standards Development,** Proceedings of the DoD Fiber Optics '92 Conference, McLean, Virginia, March 24-27, 1992, pp. 357-358 (1992).

The National Institute of Standards and Technology is working on primary standards to support lightwave communications. Primary standards are being developed to support the following measurements: absolute optical power, optical fiber geometry, and wavelength. Present capabilities and eventual goals of the various

standards programs are discussed.
[Contact: Douglas L. Franzen, (303) 497-3346]

Ghatak, A.K., Gallawa, R.L., and Goyal, I.C., **Accurate Solutions to Schrodinger's Equation Using Modified Airy Functions**, IEEE Journal of Quantum Electronics, Vol. 28, No. 2, pp. 400-403 (February 1992).

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

Obarski, G., Drapela, T., and Young, M., **Scanning Confocal Microscopy for Measuring Diameter and Linewidth: Numerical Modelling** [original title: Scanning Confocal Microscopy for Finding Diameters of Circular Objects: Numerical Modelling], Proceedings of SPIE (The International Society for Optical Engineering, P.O. Box 10, Bellingham, Washington 98227-0010), Time-Resolved Laser Spectroscopy in Biochemistry III, Vol. 1640, pp. 761-772 (1992).

We calculated the image of a circular edge as determined by a scanning confocal microscope. In scalar theory, the quarter-intensity point of the edge response locates the geometrical-optics image of a straight edge. For a circular object, however, the quarter-intensity point is displaced from the geometrical-optics image of the edge according to the diameter of the object. For example, for an object that has a diameter of 21 resolution limits, the displacement error is ≈0.01 resolution limits. We give the error that results from locating the quarter-intensity point for diameters as small as 1 resolution limit. The error will be even greater if the object is scanned off-axis. For example, the error for an object whose diameter is 21 resolution limits and which is scanned 3 resolution limits off-axis is ≈0.45 resolution limits. Finally, we calculated displacement errors for vertical lines of width as small as 1 resolution limit.
[Contact: Gregory Obarski, (303) 497-5747]

Tewari, R., Pal, B.P., and Das, U.K., **Dispersion-Shifted Dual-Shape Core Fibers: Optimization Based on Spot Size Definitions** [original title: Optimization of Dispersion-Shifted Dual-Shape Core Fibers: Design Features Based on Spot-Size Definitions], Journal of Lightwave Technology, Vol. 10, No. 1, pp. 1-5 (January 1992).

Design features for very low bend and splice losses in dispersion-shifted dual-shape core (DSC) single-mode fibers are obtained in terms of characteristic mode spot sizes $\overline{W}$ responsible for splice loss, and W_∞ responsible for bend loss. Dual-shape core fiber designs are given with $W_\infty/\overline{W}$ (which should be close to 1 for optimum splice and bending performance) lying between 1.16 and 1.33 while maintaining the mode spot size ($\overline{W}$) between 4 and 5 μm at the operating wavelength of 1550 nm. These spot sizes were obtained by adjusting the fiber parameters so that both the zero dispersion wavelength (↓↓o) and the cutoff wavelength (↓↓c) are fixed at 1550 nm. With this design goal we show that bending loss would be lower in a step-index than in a graded-index DSC fiber. Further, we show that conventional single clad step-index or triangular-index dispersion-shifted fibers have higher bending loss than well-designed DSC fibers.
[Contact: Bishnu P. Pal, (303) 497-6363]

Optical Fiber Sensors

Deeter, M.N., **Domain Effects in Faraday Effect Sensors Based on Iron Garnets**, Proceedings of the 8th Optical Fiber Sensors Conference, Monterey, California, January 29-31, 1992, Post Deadline Paper PD2 (1992).

Domain effects in Faraday effect fiber-optic magnetic field sensors which employ thick films and bulk crystals of iron garnets produce fundamentally different responses. Iron garnet films with uniaxial magnetic anisotropy exhibit domain-induced diffraction which produces a nonlinear signal even in films for which the net magnetization is exactly linear with the applied field. Fortunately, differential detection eliminates this nonlinearity. Moreover, differential detection applied to these films produces a signal which is linear regardless of the value of the saturation Faraday rotation. This behavior is quite unlike that of other Faraday effect sensors, which exhibit sinusoidal output signals. Domain effects in bulk crystals, which exhibit three-dimensional domain structure, are less evident than in films.
[Contact: Merritt N. Deeter, (303) 497-5400]

Wolfe, R., Gyorgy, E.M., Lieberman, R.A., Fratello, V.J., Licht, S.J., Deeter, M.N., and Day, G.W., **High Frequency Magnetic Field Sensors Based on the Faraday Effect in Garnet Thick Films**, Proceedings of the Eighth Optical Fiber Sensors Conference, Monterey, California, January 29-31, 1992, pp. 390-393 (1992).

Thick films of modified yttrium iron garnet with uniaxial magnetic anisotropy can be used in fiber optic magnetic-field sensors. Theory and experiments show good sensitivity and upper frequency limits between 10^6 and 10^9 Hz.
[Contact: Merritt N. Deeter, (303) 497-5400]

Electro-Optic Metrology

Esman, R.D., and Iwashita, K., **High-Frequency Optical FM Noise Reduction Employing a Fiber-Insertable Feedforward Technique**, Technical Digest, Optical Fiber Communication Conference, San Jose, California, February 2-7, 1992, pp. 72-73 (1992).

We have proposed and demonstrated a new insertable fiber-optic device that reduces optical FM noise and linewidth. Experimental results reveal FM modulation reduction to 1 GHz, which we believe is the widest reported bandwidth for FM suppression. This technique should be especially useful in conjunction with feedback, where FM noise at low frequencies is reduced by feedback and at high frequencies (including feedback-induced FM noise enhancement) by feedforward.
[Contact: Ronald D. Esman, (303) 497-3346]

Franzen, D.L., **Overview of Photonic Primary Standards Development**, Proceedings of the DoD Fiber Optics '92 Conference, McLean, Virginia, March 24-27, 1992, pp. 357-358 (1992).

The National Institute of Standards and Technology is working on primary standards to support lightwave communications. Primary standards are being developed to support the following measurements: absolute optical power, optical fiber geometry, and wavelength. Present capabilities and eventual goals of the various standards programs are discussed.
[Contact: Douglas L. Franzen, (303) 497-3346]

Larson, D.R., and Veasey, D.L., **Localized Plasma Etching for Device Optimization**, Journal of Vacuum Science Technology B, Vol. 10, No. 1, pp. 27-29 (Jan/Feb 1992).

We have developed an unconventional approach to down-stream plasma etching: only a small area of the substrate is exposed to the low-pressure, reactive gaseous environment. The remainder of the substrate is outside the miniature plasma chamber, providing physical access for probing apparatus. Etch rates of 6 μm/h were obtained. The process can be especially useful when in-situ monitoring of the effects of etching is required. Using this process, we improved the responsivity of a semiconductor optical detector deposited on top of an optical waveguide. This was accomplished by monitoring the transmitted intensity of light in an integrated optical waveguide while etching a thin semiconductor film covering a small region of the waveguide.
[Contact: Donald R. Larson, (303) 497-3440]

Complex System Testing

Stenbakken, G.N., and Starzyk, J.A., **Diakoptic and Large Change Sensitivity Analysis**, IEE Proceedings-G (Institution of Electrical Engineers, London), Vol. 139, No. 1, pp. 114-118 (February 1992).

This paper presents an approach for the analysis of large circuits based on the use of the large change sensitivity technique applied to decomposed networks. As a result of this approach, a simple, compact notation for the solution vector is derived. The method is applicable to nonlinear analog networks with hierarchical decomposition simulated by inserted ideal switches. A simple illustrative example is given.
[Contact: Gerard N. Stenbakken, (301) 975-2440]

Other Signal Topics

Wittmann, R.C., **Probe-Corrected Spherical Near-Field Scanning Theory in Acoustics**, IEEE Transactions on Instrumentation and Measurement, Vol. 41, No. 1, pp. 17-21 (February 1992).

Spherical near-field scanning is well known in electromagnetics. The acoustical analog is outlined here. Data are taken, with an arbitrary probe, on a spherical surface surrounding an unknown transducer. The algorithm uses these data to characterize the fields of the transducer everywhere outside the measurement

sphere. The results can be corrected for probe effects if the probe's receiving pattern is known.
[Contact: Ronald C. Wittmann, (303) 497-3326]

ELECTRICAL SYSTEMS

Power Systems Metrology

Martzloff, F.D., **Performance Criteria for Power-System Compatibility,** Proceedings of the Seventh Annual Applied Power Electronics Conference and Exposition, Boston, Massachusetts, February 23-27, 1992, pp. 287-292 (1992).

Power electronics create an opportunity for better utilization of electric energy but can become a source of problem if the electromagnetic characteristics (immunity and emissions limits) of the equipment are not compatible with the characteristics (avoidable and unavoidable disturbances) of the power supply. Equipment performance criteria can help the end-user obtain better compatibility, reliability, and cost effectiveness of the equipment-power supply combination.
[Contact: Francois D. Martzloff, (301) 975-2409]

Van Brunt, R.J., Stricklett, K.L., Steiner, J.P., and Kulkarni, S.V., **Recent Advances in Partial Discharge Measurement Capabilities at NIST,** IEEE Transactions on Electrical Insulation, Vol. 27, No. 1, pp. 114-129 (February 1992).

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

Magnetic Materials and Measurements

Deeter, M.N., **Domain Effects in Faraday Effect Sensors Based on Iron Garnets,** Proceedings of the 8th Optical Fiber Sensors Conference, Monterey, California, January 29-31, 1992, Post Deadline Paper PD2 (1992).

Domain effects in Faraday effect fiber-optic magnetic field sensors which employ thick films and bulk crystals of iron garnets produce fundamentally different responses. Iron garnet films with uniaxial magnetic anisotropy exhibit domain-induced diffraction which produces a nonlinear signal even in films for which the net magnetization is exactly linear with the applied field. Fortunately, differential detection eliminates this nonlinearity. Moreover, differential detection applied to these films produces a signal which is linear regardless of the value of the saturation Faraday rotation. This behavior is quite unlike that of other Faraday effect sensors, which exhibit sinusoidal output signals. Domain effects in bulk crystals, which exhibit three-dimensional domain structure, are less evident than in films.
[Contact: Merritt N. Deeter, (303) 497-5400]

Superconductors

Goodrich, L.F., and Srivastava, A.N., **Critical-Current Simulation and Data Acquisition** [original title: Superconductor Critical Current Simulation And Data Acquisition], Superconductor Industry, Spring 1992, pp. 28-36 (1992).

The superconductor simulator is an electronic circuit that emulates the extremely nonlinear voltage-current characteristic (the basis of a critical-current measurement) of a superconductor along with its other major electrical properties. We designed three different types of simulators: the passive, temperature-con-

trolled passive, and active simulators. These simulators are high-precision instruments, and are thus useful for establishing the integrity of part of a superconductor measurement system. They could significantly benefit superconductor measurement applications that require high-precision quality assurance.

We have also designed software to control our computer-driven data acquisition and analysis system. It uses various algorithms to efficiently characterize the conductor's electrical properties, and generates summaries of the acquisition and analysis phase of the measurement along with plots of relevant data. The software and the superconductor simulator serve as diagnostic tools for determining sources of systematic and random errors in our measurement systems.
[Contact: Loren F. Goodrich, (303) 497-3143]

Goodrich, L.F., and Srivastava, A.N., **Trends in Superconductor Critical-Current Measurement Technology in the USA**, Proceedings of the International Symposium on Pre-standards Research for Advanced Materials (ISPRAM), Tokyo, Japan, December 16-18, 1991, pp. 297-300 (December 1991).

This paper indicates trends in superconductor measurement technology in the USA, and discusses available methods to reduce measurement uncertainty and imprecision. The results of interlaboratory comparisons of critical-current measurements have indicated that a detailed sample test procedure is essential to reduce interlaboratory measurement variation. High-temperature superconductors are particularly susceptible to degradation with time, mounting, and use. These factors contribute to the overall uncertainty in the measurement, and play a similar role in the measurement uncertainty as do random processes. A standard reference material such as SRM-1457 or a superconductor simulator can greatly aid in identifying sources of measurement variation. Although high-temperature superconductor and low-temperature superconductor technologies are in different states of maturity, their respective uncertainties in critical current may be reduced using a detailed sample test procedure.
[Contact: Loren F. Goodrich, (303) 497-3143]

Rice, P., and Moreland, J., **Tunneling Stabilized Magnetic Force Microscopy of $YBa_2Cu_3O_{7-\delta}$ Films on MgO at 76 K**, IEEE Transactions on Magnetics, Vol. 27, No. 6, pp. 5181-5183 (November 1991).

Tunneling stabilized magnetic force microscopy (TSMFM) is an elementary variation of scanning tunneling microscopy (STM). As in STM, a sharp conductive tip is scanned across a conductive sample with an electrical potential applied. As the tip is scanned, changes in tunneling current are plotted on a computer screen as a topographical image. The difference between STM and TSMFM is that the TSMFM tip is made from a flexible magnetic film which deflects in response to sample surface magnetic forces. Pinning of the Abrikosov flux lattice in high temperature superconductors determines the critical current. We have applied TSMFM to these high-temperature superconductors. We present images of sputter- deposited $YBa_2Cu_3O_{7-\delta}$ films below the critical temperature.
[Contact: Paul Rice, (303) 497-3841]

ELECTROMAGNETIC INTERFERENCE

Radiated

Kanda, M., and Hill, D.A., **A Three-Loop Method for Determining the Radiation Characteristics of an Electrically Small Source**, IEEE Transactions on Electromagnetic Compatibility, Vol. 34, No. 1, pp. 1-3 (February 1992).

This short paper describes a method for determining the radiation characteristics of an electrically small source. The source is located at the center of three orthogonal loop antennas, each terminated with identical loads at diametrically opposite points. The electrically small source is represented by equivalent electric and magnetic dipole moments, and these dipole moments can be determined from the appropriate combinations of the loop responses.
[Contact: Motohisa Kanda, (303) 497-5320]

ADDITIONAL INFORMATION

Lists of Publications

DeWeese, M.E., **Metrology for Electromagnetic Technology: A Bibliography of NIST Publications**, NISTIR 3972 (August 1991).

This bibliography lists the publications of the person-

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

Lyons, R.M., and Gibson, K.A., **A Bibliography of the NIST Electromagnetic Fields Division Publications,** NISTIR 3973 (August 1991).

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 1991. Selected earlier publications from the Division's predecessor organizations are included.
[Contact: Kathryn A. Gibson, (303) 497-3132]

Palla, J.C., and Meiselman, B., **Electrical and Electronic Metrology: A Bibliography of NIST Electricity Division's Publications, NIST List of Publications 94** (January 1992).

This bibliography covers publications of the Electricity Division, Center for Electronics and Electrical Engineering, NIST, and of its predecessor sections for the period January 1968 to December 1991. A brief description of the Division's technical program is given in the introduction.
[Contact: Jenny C. Palla, (301) 975-2220]

Walters, E.J., **Semiconductor Measurement Technology, 1990-1991, NIST List of Publications 103** (April 1992) 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 1991. 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]

Continuing Production-Expanded Capability Standard Reference Materials

The Semiconductor Electronics Division announces the continuing production of three thicknesses and the addition of two new thicknesses for the Standard Reference Material (SRM) for **ellipsometrically derived thickness and refractive index of a silicon dioxide film on silicon.** For sale to the public through the NIST Standard Reference Material Program [(301) 975-6776], the following three individual oxide thicknesses continue to be available: 50 nm (SRM 2531), 100 nm (SRM 2532), and 200 nm (SRM 2533). Recently, two new thicknesses, 25 nm (SRM 2534) and a limited number of 14-nm prototypes (SRM 2535), were added to the availability list.

SRMs 2531, 2532, and 2533, originally released as SRM 2530-1, 2530-2, and 2530-3, were developed in response to the industry's need to evaluate the accuracy of ellipsometers and other thin-film thickness-monitoring instruments. The scope of these SRMs has now expanded with the recent issuance of the 25-nm and 14-nm oxide thicknesses so they have application as thickness standards for use in research as well as in semiconductor fabrication production lines.

Each SRM unit, consisting of a 76-mm (3-in) diameter silicon wafer on which a uniform silicon dioxide layer has been grown, is individually measured and certified over a 5-mm diameter area in the center of the wafer for the ellipsometric parameters delta, Δ, and psi, ψ, at the vacuum wavelength $\lambda = 633.0$ nm using the High-Accuracy Ellipsometer built at NIST. Each SRM is also certified for the derived values for the thicknesses and indices of refraction of both layers of a two-layer optical model of an oxide film on a single-crystal silicon substrate.
[Contact: Barbara J. Belzer, (301) 975-2248]

Recently Issued Standard Reference Materials

The Microelectronics Dimensional Metrology Group of the Precision Engineering Division announces the release of two Standard Reference Materials (SRMs) for calibrating optical microscopes used to measure linewidths on photomasks. Each SRM consists of a 63.5 × 63.5 × 1.5 mm (2.5 × 2.5 × 0.060 in) photomask patterned with chromium lines of widths in the range of 0.9 to 10.8 μm. SRM 475, patterned with antireflecting chromium on a quartz substrate, is being

reissued after being out of production for almost four years. SRM 476, a new SRM, is patterned with bright chromium on a borosilicate substrate.

In addition to isolated opaque lines on a clear background and isolated clear lines on an opaque background, these SRMs contain opaque line pairs for calibrating the length scale of optical microscopes, adjacent clear and opaque lines of approximately equal widths for setting the line-to-space ratio (contrast) on video image-scanning instruments, and features with 10 approximately equally spaced opaque lines for checking the linearity of measurement systems (e.g., the magnification as a function of position over the field of view).

The certified linewidth and spacing values were determined from measurements made with the NIST automated linewidth measurement system. The uncertainty of the linewidth measurements is 0.081 μm or less for SRM 475 and 0.064 μm or less for SRM 476. The dominant contribution to this uncertainty is the nonvertical geometry of the line edges, and finding a source of photomasks with better edge geometry would lead to considerable improvement in the calibration uncertainty.
[Contact: James Potzick, (301) 975-3481 or Robert Larrabee, (301) 975-2298]

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

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

Transfer of Pulse Waveform Measurements Services to NIST, Gaithersburg, MD

The responsibility for the Special Test Services Provided by NIST for pulse waveform measurements has now been officially transferred to the Electricity Division, Electronic Instrumentation and Metrology Group (811.02) in Gaithersburg, MD. These services include:

Test Number	Description of Services
65100S	Impulse Generator Spectrum Amplitude (50 Ohm)
65200S	Fast Repetitive Broadband Pulse Parameters (50 Ohm)
65300S	Network Impulse Response (S_{21}) of Coaxial Networks
65400S	Pulse Time Delay through Coaxial Transmission Lines

Service for test number 65400S is already available; it is anticipated that the equipment and software necessary for bringing the other waveform measurement services on line will also become available by June 30, 1992. Please direct specific technical questions concerning these services to Mr. William L. Gans, (301) 975-2502.

1992/1993 EEEL CALENDAR

November 9-10, 1992 (Austin, Texas)

Workshop on Process Control Measurements for Advanced IC Manufacturing. In conjunction with SEMICON Southwest, the workshop, cosponsored by ASTM, JEIDA, JESSI, NIST, SEMATECH, SEMI, and SRC, will begin with overviews of the status of process control measurements in silicon device fabrication. Working sessions will consider the critical process control measurement issues in the following areas: film deposition, contamination, implant, etching, oxidation/diffusion, lithography, and materials. Standards development meetings will be held concurrently by ASTM Committee F-1 on Electronics and a selected number of SEMI Standards committees.
[Contact Robert I. Scace, (301) 975-4400]

November 30 and December 1-2, 1992 (Kyoto, Japan)

1st VLSI Packaging Workshop of Japan. The IEEE CHMT Society, the Japan Chapter thereof, and NIST are jointly sponsoring this workshop, which will extend this successful series of meetings to Japan. Topics to be discussed include: packaging for hand-held applications, packaging production processes, package design for high-speed applications, multichip modules, modeling/CAE, reliability physics and chemistry, materials, and thermal management.
[Contact: George G. Harman, (301) 975-2097

February 2-4, 1993 (Austin, Texas)

9th 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: analytical and computational modeling; measurement techniques including temperature, fluid flow, and thermal-mechanical properties; and thermal reliability screening and testing.
[Contact: David Blackburn, (301) 975-2053]

EEEL SPONSORS

National Institute of Standards and Technology
U.S. Air Force
Hanscom Field; McClelland Air Force Base; Newark Air Force Station; Rome Air Development Center; Space & Missile Organization; Wright-Patterson Air Force Base; CRDEC; SAF/FMBMB, Pentagon
U.S. Army
Fort Belvoir; Fort Huachuca; Harry Diamond Laboratory; Strategic Defense Command; AVRADCOM (Aviation)
Department of Commerce
NOAA; Census
Department of Defense
Advanced Research Projects Agency; Defense Nuclear Agency; Combined Army/Navy/Air Force (CCG); National Security Agency
Department of Energy
Energy Systems Research; Fusion Energy; Basic Energy Sciences; Oak Ridge National Laboratory
Department of Justice
Law Enforcement Assistance Administration; FBI
U.S. Navy
Naval Sea Systems Command; Weapons Support Center/Crane; Office of Naval Research; Naval Air Systems Command; Naval Air Engineering Center; Naval Surface Warfare Center; Naval Research Laboratory; Naval Ocean Systems Center
National Aeronautics and Space Administration
NASA Headquarters; Goddard Space Flight Center; Lewis Research Center
Nuclear Regulatory Commission
Department of Transportation
National Highway Traffic Safety Administration
MIMIC Consortium
Various Federal Government Agencies

NIST-114A
(REV. 3-90)

U.S. DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

BIBLIOGRAPHIC DATA SHEET

1. PUBLICATION OR REPORT NUMBER
NISTIR 4945

2. PERFORMING ORGANIZATION REPORT NUMBER

3. PUBLICATION DATE
October 1992

4. TITLE AND SUBTITLE

Electronics and Electrical Engineering Laboratory Technical Publication Announcements Covering Laboratory Programs, January to March 1992, with 1992/1993 EEEL Events Calendar

5. AUTHOR(S)

J. A. Gonzalez, compiler

6. PERFORMING ORGANIZATION (IF JOINT OR OTHER THAN NIST, SEE INSTRUCTIONS)

U.S. DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
GAITHERSBURG, MD 20899

7. CONTRACT/GRANT NUMBER

8. TYPE OF REPORT AND PERIOD COVERED
January-March 1992

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (STREET, CITY, STATE, ZIP)

U.S. Department of Commerce
National Institute of Standards and Technology
Electronics and Electrical Engineering Laboratory

10. SUPPLEMENTARY NOTES

11. ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

This is the thirty-second issue of a quarterly publication providing information on the technical work of the National Institute of Standards and Technology, Electronics and Electrical Engineering Laboratory. This issue of the EEEL Technical Publication Announcements covers the first quarter of calendar year 1992. Abstracts are provided by technical area for papers published this quarter.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

antennas; electrical engineering; electrical power; electromagnetic interference; electronics; instrumentation; laser; magnetics; microwave; optical fibers; semiconductors; superconductors

13. AVAILABILITY

[X] UNLIMITED

[ ] FOR OFFICIAL DISTRIBUTION. DO NOT RELEASE TO NATIONAL TECHNICAL INFORMATION SERVICE (NTIS).

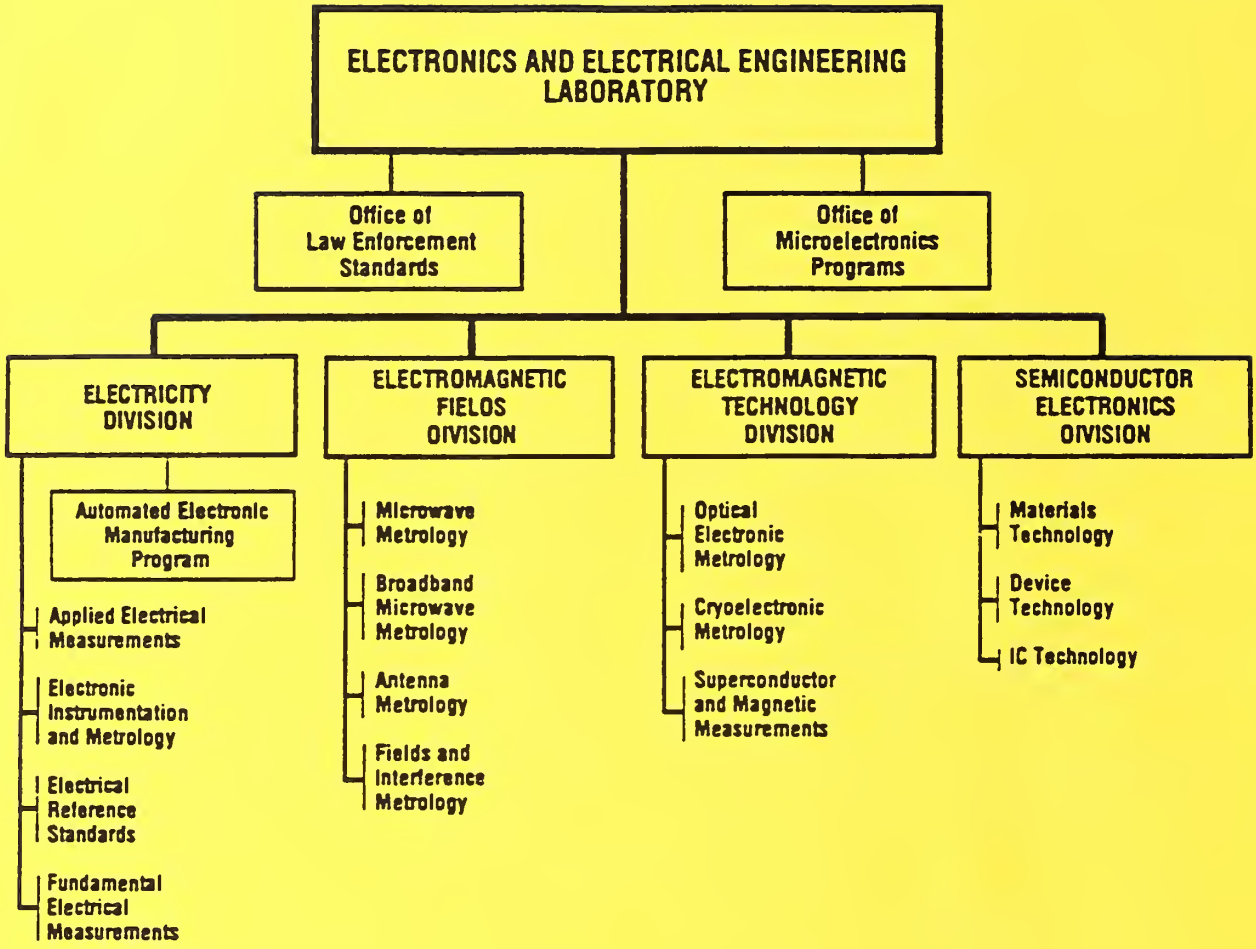
[ ] ORDER FROM SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, DC 20402.

[X] ORDER FROM NATIONAL TECHNICAL INFORMATION SERVICE (NTIS), SPRINGFIELD, VA 22161.

14. NUMBER OF PRINTED PAGES
24

15. PRICE
A01

ELECTRONIC FORM



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