NISTIR 4803

Electronics and Electrical Engineering Laboratory

Technical Publication Announcements

Covering Laboratory Programs,
July to September 1991,
with 1992 EEEL Events Calendar

J. A. Gonzalez
Compiler

March 1992

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

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INTRODUCTION TO THE EEEL TECHNICAL PUBLICATION ANNOUNCEMENTS

This is the thirtieth 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) (until February 1991, the Center for Electronics and Electrical Engineering). This issue of the EEEL Technical Publication Announcements covers the third quarter of calendar year 1991.

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 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 19.

Note on Publication Lists: Publication lists covering the work of each division are guides to earlier as well as recent work. These lists are revised and reissued on an approximately annual basis and are available from the originating division. The current set is identified in the Additional Information section, page 16.

TABLE OF CONTENTS

INTRODUCTION ..... inside title page

FUNDAMENTAL ELECTRICAL MEASUREMENTS 2

SEMICONDUCTOR MICROELECTRONICS 2
- Compound Materials 2
- Device Physics and Modeling 3
- Insulators and Interfaces 3
- Dimensional Metrology 4
- Integrated-Circuit Test Structures 4
- Plasma Processing 4
- Photodetectors 5
- Other Semiconductor Metrology Topics 6

SIGNAL ACQUISITION, PROCESSING, AND TRANSMISSION 6

- DC and Low-Frequency Metrology 6
- Waveform Metrology 7
- Cryoelectronic Metrology 7
- Antenna Metrology 7
- Microwave and Millimeter-Wave Metrology 8
- Electromagnetic Properties 9
- Laser Metrology 9
- Optical Fiber Metrology 10
- Optical Fiber Sensors 10
- Electro-Optic Metrology 11
- Other Signal Topics 11

ELECTRICAL SYSTEMS 12

- Power Systems Metrology 12
- Magnetic Materials and Measurements 13
- Superconductors 13
- Other Electrical Systems Topics 15

ELECTROMAGNETIC INTERFERENCE 15

- Conducted 15
- Radiated 16

ADDITIONAL INFORMATION 16
1992 EEEL CALENDAR 19
EEEL SPONSORS 19
KEY CONTACTS IN LABORATORY, LABORATORY ORGANIZATION ..... back cover

FUNDAMENTAL ELECTRICAL MEASUREMENTS

Olsen, P.T., Tew, W.L., Williams, E.R., Elmquist, R.E., and Sasaki, H., **Monitoring the Mass Standard via the Comparison of Mechanical to Electrical Power**, IEEE Transactions on Instrumentation and Measurement (Special Issue of selected papers, CPEM '90), Vol. 40, No. 2, pp. 115-120 (April 1991). [Also published in the Digest of the 1990 Conference on Precision Electromagnetic Measurements, Ottawa, Canada, June 11-14, 1990, pp. 180-181 (1990).]

This paper presents the current status of the NIST SI watt experiment. Included are goals for the near future as well as projections regarding the viability of monitoring and/or replacing the kilogram mass standard. Although several significant systematic errors have yet to be evaluated, the standard deviation of the mean of our present measurement distributions is 0.05 parts per million.
[Contact: P. Thomas Olsen, (301) 975-6553]

Tew, W.L., Olsen, P.T., and Williams, E.R., **The Use of Magnetic Forces in the Alignment of a Radial Field Superconducting Magnet**, Abstract, Proceedings of the 5th Joint Magnetism and Magnetic Materials - Intermag Conference, Pittsburgh, Pennsylvania, June 18-21, 1991, pp. 93-94 (June 1991).

A detailed description of the forces between a special radial field superconducting magnet and a suspended current-carrying coil is given. A primary vertical force is used directly in the determination of the SI watt. In addition, small nonvertical forces and torques are monitored to determine the magnetic alignment stability. Results are compared with calculations.
[Contact: Weston L. Tew, (301) 975-6552]

SEMICONDUCTOR MICROELECTRONICS

Compound Materials

Seiler, D.G., Lowney, J.R., Littler, C.L., Yoon, I.T., and Loloee, M.R., **Photoexcited Hot Electron Relaxation Processes in n-HgCdTe Through Impact Ionization Into Traps**, Journal of Vacuum Science Technology B, Vol. 9, No. 3, pp. 1847-1851 (May/Jun 1991). [Also published in American Vacuum Society Series 11, Physics and Chemistry of Mercury Cadmium Telluride and Novel IR Detector Materials, pp. 1847-1851 (American Institute of Physics, New York, 1991, D.G. Seiler, Ed.) (Proceedings of the 1990 U.S. Workshop on the Physics and Chemistry of Mercury Cadmium Telluride and Novel Infrared Detector Materials, San Francisco, California, October 2-4, 1990).]

In this paper we report on a new type of spectroscopy for impurity and/or defect levels in the energy gap of narrow-gap semiconductors using the near-band-gap photon energies from a laser. This spectroscopy is done under the conditions of intense laser photoexcitation and is associated with the Auger relaxation processes of hot electrons involving impact ionization of valence electrons into impurity or defect levels. Wavelength-independent structure in the photoconductive response versus magnetic field is observed at high intensities in samples of $Hg_{1-x}Cd_xTe$ with $x \approx 0.22$ and 0.24. This structure arises from hot electrons photoexcited high into the conduction band by sequential absorption of CO_2 laser radiation. The hot electrons lose their energy by impact-ionizing valence electrons into impurity/defect levels in the gap. For the sample with $x \approx 0.22$ and an energy gap of 95 meV, three levels are found at 15, 45, and 59 meV above the valence band. A level at 61 meV is found for the sample with $x \approx 0.24$ and a gap of 122 meV.
[Contact: David G. Seiler, (301) 975-2081]

Zawadzki, W., Song, X.N., Littler, C.L., and Seller, D.G, **High Excited States of Magnetodonors in InSb: An Experimental and Theoretical Study** [original title: High Excited States of Magneto-Donors in InSb: Experimental and Theoretical Study], Physical Review B, Vol. 42, No. 8, pp. 5260-5269 (15 September 1990).

New optical transitions between magnetodonor states in InSb assisted by optic-phonon emission have been observed and described theoretically. Photoconductive detection and magnetic-field modulation were used to obtain well-resolved magneto-optical data. Phonon-assisted excitations provide a unique opportunity to investigate high excited states of the magnetodonor system (up to principal quantum number n = 13), which simulates the hydrogen atom in gigantic magnetic fields. The magnetodonor states have been described variationally, taking into account the narrow energy gap and the spin-orbit interaction of the band structure of InSb. It has been shown how the phonon

emission breaks the selection rules for the magneto-optical excitations, allowing for transitions with large Δn. Good agreement between theory and experiment has been obtained. The results should also be of importance to atomic physics and astrophysics.
[Contact: David G. Seller, (301) 975-2081]

Device Physics and Modeling

Geist, J., Lowney, J.R., James, C.R., and Robinson, A.M., **Testing the Accuracy of Calculated Equilibrium Carrier Concentrations in the Presence of Surface Fields** (original title: Accuracy of Numerical Techniques in Calculating Equilibrium Carrier Concentrations in the Presence of Surface Fields], Journal of Applied Physics, Vol. 70, No. 1, pp. 236-242 (1 July 1991).

Simple analytic expressions for the one-dimensional, majority-carrier concentration in a uniformly doped, semi-infinite semiconductor with a charge-accumulated front surface are derived. These expressions are based on the assumption that the effective intrinsic carrier concentration depends only upon the concentration of the majority dopant. Within the framework of this assumption, the expressions derived here are rigorously accurate for intrinsic material, and are accurate to well within 100 parts per million for doping concentrations about 10^{12} cm^{-3}. The results of calculations of the majority-carrier concentration carried out using these expressions and using a widely available one-dimensional semiconductor device modeling program are compared to illustrate how these expressions are used for testing the accuracy of iterative solutions of the drift-diffusion equations in the presence of surface fields.
[Contact: Jon Geist, (301) 975-2066]

Hefner, A.R., Jr., and Diebolt, D.M., **An Experimentally Verified IGBT Model Implemented in the Saber Circuit Simulator**, PESC '91 Record, 22nd Annual IEEE Power Electronics Specialist Conference, Cambridge, Massachusetts, June 24-27, 1991, pp. 10-19 (1991).

A physics-based Insulated Gate Bipolar Transistor (IGBT) model is implemented into the general purpose circuit simulator Saber. The IGBT model includes all of the physical effects that have been shown to be important for describing IGBTs, and the model is valid for general external circuit conditions. The Saber IGBT model is evaluated for the range of static and dynamic conditions in which the device is intended to be operated, and the simulations compare well with experimental results for all of the conditions studied.
[Contact: Allen R. Hefner, Jr., (301) 975-2071]

Insulators and Interfaces

Krause, S.J., Visitserngtrakul, S., Cordts, B.F., and Roitman, P., **Microstructural Evolution of Oxides During Processing of Oxygen Implanted SOI Material**, Extended Abstract, Proceedings of the 1990 IEEE SOS/SOI Technology Conference, Key West, Florida, October 2-4, 1990, pp. 47-48 (1990).

Silicon-on-insulator (SOI) material fabricated by oxygen implantation (SIMOX) is being used for radiation-hard, higher speed, and higher temperature integrated circuits. The microstructural evolution of oxides during implantation, thermal ramping, and annealing plays a crucial role in development of the structure of the top Si layer and of the buried oxide layer. To control the microstructure of the oxides and silicon, it is necessary to understand the effect of processing conditions on the mechanisms of oxide formation and evolution. These processing conditions include: implantation temperature, energy, and dose; thermal ramping rate; and annealing time, temperature, and atmosphere. Numerous questions still remain on the effects of processing conditions and include: formation and growth of the buried oxide; formation and evolution of oxygen bubbles in the top silicon layer; and precipitate evolution and elimination during ramping and annealing. The goal of this paper is to summarize recent work on the effects of processing conditions on oxide evolution and to present new results on effects of implantation conditions on buried oxide formation, effects of ramping conditions on oxygen bubble evolution and defect formation, and effects of annealing conditions on the structure of the buried oxide and its interfaces.
[Contact: Peter Roitman, (301) 975-2077]

Roitman, P., Simons, D.S., Visitserngtrakul, S., Jung, C.O., and Krause, S.J., **Effect of Annealing Ambient on the Precipitation Processes in Oxygen-Implanted Silicon-on-Insulator Material**, Extended Abstract, Proceedings of the XIIth International

Congress for Electron Microscopy, Seattle, Washington, August 12-17, 1990, Vol. 4, L.D. Peachey and D.B. Williams, Eds., pp. 644-645 (1990).

In the last decade, oxygen-implanted silicon-on-insulator material (SIMOX: separation by IMplantation of OXygen) has been extensively studied, due to its potential advantages of increased speed and radiation hardness in integrated circuits. SIMOX material requires two processing steps: first, implantation of a high dose of oxygen to form a buried oxide layer below a thin, top silicon layer, and second, a high-temperature anneal in an inert gas atmosphere to remove implantation damage and oxide precipitates. Most earlier studies investigated the effect of annealing temperature and time, but did not consider the effect of gas ambient. The effect of nitrogen and argon on the oxide-precipitate formation in bulk silicon has been established. Raider et al. found that in annealing of bulk silicon, nitrogen can diffuse to an oxide-silicon interface and chemically react with silicon. The nitrogen-containing layer acts as a barrier to further oxidation. Consequently, nitrogen influences the growth kinetics of the thermal oxide, while annealing in an argon ambient does not. This should apply to SIMOX as well. We have, therefore, investigated the effect of nitrogen and argon ambient on the oxide-precipitate removal during annealing of SIMOX material.
[Contact: Peter Roitman, (301) 975-2077]

Dimensional Metrology

Mattis, R.L, **The NIST Linewidth Measurement Program**, SRC Newsletter, Vol. 9, No. 9, pp. 4-5 (September 1991).

The NIST linewidth measurement program has produced several photomask linewidth standards. While continuing development of these standards, the Precision Engineering Division is working on optical overlay measurement, optical modeling, and length standards to be used with scanning electron microscopes.
[Contact: Richard L. Mattis, (301) 975-2235]

Integrated-Circuit Test Structures

Suehle, J.S., and Galloway, K.F., **The Effects of Localized Hot-Carrier-Induced Charge in VLSI Switching Circuits**, Microelectronics Journal, Vol. 21, No. 3, pp. 5-14, (1990). [Also to be published in the Proceedings of the 17th Yugoslav Conference on Microelectronics.]

This paper presents data collected from CMOS test circuits designed to characterize hot-carrier effects in digital switching circuits. Test circuits were configured as CMOS inverters, transmission gates, and NMOS transmission gates. The MOSFETs within the circuits could be probed so that the degradation of their dc characteristics could be directly measured These circuits were hot-carrier-stressed under pulsed switching conditions similar to their operation in VLSI circuits. The results indicate that device degradation is strongly dependent on the circuit configuration and switching conditions. Transmission gate circuits exhibit a more severe degradation in switching characteristics than inverter circuits due to the localization of the hot-carrier-induced charge. The localized nature of hot-carrier-induced charge must be considered at the circuit simulation level to accurately assess the effect on circuit performance.
[Contact: John S. Suehle, (301) 975-2247]

Plasma Processing

Olthoff, J.K., Van Brunt, R.J., Wan, H.X., and Moore, J.H., **Electron Attachment to SF_6 and SO_2**, Program of the Joint Symposium on Electron and Ion Swarms and Low Energy Electron Scattering, Queensland, Australia, July 18-20, 1991, pp. 25-27 (1991).

SF_6 is a favorable gas for use in the plasma etching of microelectronic devices. However, SF_6 plasmas are complex because of the large number of secondary products that are formed by reactions with oxygen and trace amounts of water. Under some etching conditions, the mole fraction of stable decomposition products in an SF_6/O_2 plasma can exceed 20% of the neutral species. A full understanding of the physical processes occurring in SF_6 discharges requires a detailed knowledge of the interaction of low-energy electrons with SF_6 and its electrical discharge by-products. We have measured absolute cross sections for electron scattering and for negative ion formation through electron attachment to SF_6 and to several by-products (SO_2, SOF_2, SO_2F_2, SOF_4, and SF_4) produced by electrical discharges in SF_6. Due to space limitations, only the results for SF_6 and SO_2 are presented in this abstract. Preliminary results of these

measurements were presented previously and are now superseded by the cross sections presented here.
[Contact: James K. Olthoff, (301) 975 2431]

Radovanov, S.B., Olthoff, J.K., and Van Brunt, R.J., **Off-Axis Measurements of Ion Kinetic Energies in RF Plasmas**, Proceedings of the XX International Conference on Phenomena in Ionized Gases, Barga, Italy, July 8-12, 1991, pp. 835-836 (Instituto di Fisica Atomica, Pisa, Italy, 1991).

Ion kinetic energy distributions are presented for argon plasmas in the GEC radiofrequency reference cell (developed by the Gaseous Electronics Conference - GEC) and are compared with other previous measurements.
[Contact: James K. Olthoff, (301) 975-2431]

Photodetectors

Geist, J., Chandler-Horowitz D., Robinson, A.M., and James, C.R., **Numerical Modeling of Silicon Photodiodes for High-Accuracy Applications. Part I: Simulation Programs**, Journal of Research of the National Institute of Standards and Technology, Vol. 96, No. 4, pp. 463-469 (July-August 1991).

The suitability of the semiconductor-device modeling program PC-1D for high-accuracy simulation of silicon photodiodes is discussed. A set of user interface programs optimized to support high-accuracy batch-mode operation of PC-1D for modeling the internal quantum efficiency of photodiodes is also described. The optimization includes correction for the dark current under reverse and forward bias conditions before calculating the quantum efficiency, and easy access to the highest numerical accuracy available from PC-1D, neither of which are conveniently available with PC-1D's standard user interface.
[Contact: Jon Geist, (301) 975-2066]

Geist, J., Kohler, R., Goebel, R., Robinson, A.M., and James, C.R., **Numerical Modeling of Silicon Photodiodes for High-Accuracy Applications. Part II: Interpreting Oxide-Bias Experiments**, Journal of Research of the National Institute of Standards and Technology, Vol. 96, No. 4, pp. 471-479 (July-August 1991).

The semiconductor device modeling program PC-1D and the programs that support its use in high-accuracy modeling of photodiodes, all of which were described in Part I of this paper, are used to simulate oxide-bias self-calibration experiments on three different types of silicon photodiodes. It is shown that these simulations can be used to determine photodiode characteristics, including the internal quantum efficiency for the different types of photodiodes. In the latter case, the simulations provide more accurate values than can be determined by using the conventional data reduction procedure, and an uncertainty estimated can be derived. Finally, it is shown that 0.9997 ± 0.0003 is a nominal value for the internal quantum efficiency of one type of photodiode over the 440- to 460-nm spectral region.
[Contact: Jon Geist, (301) 975-2066]

Geist, J., Robinson, A.M., and James, C.R., **Numerical Modeling of Silicon Photodiodes for High-Accuracy Applications. Part III: Interpolating and Extrapolating Internal Quantum-Efficiency Calibrations**, Journal of Research of the National Institute of Standards and Technology, Vol. 96, No. 4, pp. 481-492 (July-August 1991).

The semiconductor device modeling program PC-1D and the programs that support its use in high-accuracy modeling of photodiodes, all of which were described in Part I, are used to simulate the interpolation of high-accuracy internal quantum-efficiency calibrations near 450 nm and 850 nm to the spectral region between these wavelengths. Convenient interpolation formulae that depend only upon wavelength are derived, as are uncertainty spectra for a number of sources of error. The formulae are normalized to experimental internal quantum-efficiency calibrations in the 440- to 470-nm spectral region and at 860 nm, and used to interpolate the calibrations to intermediate wavelengths. The results of the interpolations are compared with experimental calibration data that are available at a few wavelengths between 440 and 860 nm. The disagreement between the interpolated and measured internal quantum-efficiency data is never worse than 0.0003.
[Contact: Jon Geist, (301) 975-2066]

Seiler, D.G., Harman, G.G., Lowney, J.R., Mayo, S., and Liggett, W.S., Jr., **HgCdTe Detector Reliability Study for the GOES Program**, NISTIR 4687 (September 1991).

This report summarizes the results of a special assessment carried out by the National Institute of Standards and Technology (NIST) at the request of the National Oceanic and Atmospheric Administration of the reliability of certain infrared detectors for the Geostationary Operational Environmental Satellite (GOES) system. The data made available by ITT on detector resistances and signals support the conclusion that degradation of some detector responses has occurred, even when the estimated measurement uncertainty is included. Statistical analysis of the 11-μm detectors confirmed that detector 11-105 decreased in signal with time. The existing data available to NIST are not sufficient to identify uniquely the cause of degradation or unstable behavior present in a number of detectors. NIST's physical examination of several detectors by optical and SEM microscopy methods and an examination and analysis of a detector measurement database has yielded several plausible possible mechanisms for the observed degradation. These possible mechanisms are related to the detector fabrication or processing steps and include: incomplete or poor passivation procedures, excess mercury diffusion resulting from the ion-beam milling fabrication step, poor indium electrical contacts produced by the indium-plated fabrication step, and delamination of the ZnS anti-reflection optical coating. Other observed problems were poor wire bonding, use of tin-lead solder to couple the fine gold wire (bonded to the detector) to the package terminal, and use of silicone RTV to stake the bond wires to the edge of the ZnS substrate.
[Contact: David G. Seiler, (301) 975-2081]

Other Semiconductor Metrology Topics

Cummings, C.K., **Office of Microelectronics Programs Opens at NIST**, SRC Newsletter, Vol. 9, No. 9, pp. 3-4 (September 1991).

The Office of Microelectronic Programs has been established, with Robert I. Scace as Director, in the NIST Electronics and Electrical Engineering Laboratory. The responsibility of the Office is to coordinate important semiconductor measurement problems in industry with technical and scientific skills available in NIST. The purpose and function of the Office are briefly discussed, and examples of programs being carried out under the Office are identified.
[Contact: Carol K. Cummings, (301) 975-3075]

Scace, R.I., **Metrology for the Semiconductor Industry**, NISTIR 4653 (September 1991).

This report reviews the metrological needs of the semiconductor industry and its infrastructure, the materials and equipment industries that supply it, for the remainder of the present decade to the extent that they now can be foreseen. The text will also appear as one chapter of a larger assessment of needs for the electronics industry to be published later in 1991.

Only a needs assessment is included here. The manner in which the needs can be met is not discussed, largely because the task is of such a magnitude that no single organization can possibly do the necessary research and development on the time scale that the industry requires. Clearly, there is ample opportunity for contributions from universities, industrial laboratories, and government organizations such as NIST.

One principal purpose for preparing this report is to guide the planning of NIST's activities. Identification of the needs is only the first step in planning. Priorities must also be set. These depend on feedback from the industries that need the measurements described here, on knowledge of the work of others who may be working on related topics, and on the resources available to NIST. So much must be done that the luxury of duplicated efforts cannot be afforded.

This report draws on numerous recent publications of workshops and technology forecasts that are footnoted in the text. Early drafts were reviewed by others in the industry whose comments and advice are gratefully acknowledged.
[Contact: Robert I. Scace, (301) 975-2220]

SIGNAL ACQUISITION, PROCESSING, AND TRANSMISSION

DC and Low-Frequency Metrology

Burroughs, C.J., and Hamilton, C.A., **Voltage Calibration Systems Using Josephson Junction Arrays**, IEEE Transactions on Instrumentation and Measurement, Vol. 39, No. 6, pp. 972-975 (December 1990).

The recent development of large arrays of Josephson junctions is allowing an ever-increasing number of

laboratories to maintain intrinsic Josephson voltage standards at an accuracy level near 0.05 parts per million. This paper reviews the fundamentals of Josephson voltage standards and shows how computer control makes these standards simple to use in a variety of applications.
[Contact: Charles J. Burroughs, (303) 497-3901]

Waveform Metrology

Oldham, N.M., and Hetrick, P.S., **High-Frequency, High-Speed Phase-Angle Measurements and Standards**, Proceedings of the 1991 National Conference of Standards Laboratories Workshop and Symposium, Albuquerque, New Mexico, August 18-22, 1991, pp. 251-256 (August 1991).

Counter-timers capable of measuring the delay between two signals at frequencies up to 20 MHz have been evaluated as phase angle meters with applications in heterodyne interferometry. A scheme for calibrating these instruments, both statically and dynamically (with the phase angle changing as fast 10°/μs), is described.
[Contact: Nile M. Oldham, (301) 975-2408]

Cryoelectronic Metrology

Benz, S.P., and Burroughs, C.J., **Coherent Emission From Two-Dimensional Josephson Junction Arrays**, Applied Physics Letter, Vol. 58, No. 19, pp. 2162-2164 (13 May 1991).

Coherent emission has been generated by two-dimensional arrays of superconductor-insulator-superconductor Josephson junctions and detected in a junction coupled to the array through a dc-blocking capacitor. The detector junction exhibits Shapiro steps at frequencies corresponding to the voltage across single array junctions and ranging from 60 to 210 GHz. The maximum power coupled to the detector junction occurs at 150 GHz and is estimated to be 0.4 μW, based on simulations of the detector circuit. Possible mechanisms for coherent emission from two-dimensional arrays are discussed.
[Contact: Sam P. Benz, (303) 497-3988]

Burroughs, C.J., and Hamilton, C.A., **Voltage Calibration Systems Using Josephson Junction Arrays**, IEEE Transactions on Instrumentation and Measurement, Vol. 39, No. 6, pp. 972-975 (December 1990).

The recent development of large arrays of Josephson junctions is allowing an ever-increasing number of laboratories to maintain intrinsic Josephson voltage standards at an accuracy level near 0.05 parts per million. This paper reviews the fundamentals of Josephson voltage standards and shows how computer control makes these standards simple to use in a variety of applications.
[Contact: Charles J. Burroughs, (303) 497-3901]

Grossman, E.N., McDonald, D.G., and Sauvageau, J.E., **Two-Dimensional Analysis of Microbolometer Arrays**, Journal of Applied Physics, Vol. 68, No. 11, pp. 5409-5414 (1 December 1990).

A two-dimensional, time-dependent analysis is made of array-compatible bolometers directly deposited onto a single substrate. It applies both to antenna-coupled and surface-absorbing configurations. Unlike previous spherically symmetric treatments, it allows analysis of thermal crosstalk between closely neighboring detectors and of the effects of finite substrate thickness. It is shown that in a closely packed array of surface-absorbing detectors, thermal crosstalk generally degrades the array's resolution more severely than optical (diffractive) crosstalk. Diffraction-limited resolution with surface-absorbing detectors is only possible by sacrificing either thermal resistance, and therefore sensitivity, or filling factor. With a minimum substrate thickness of L_{min}, a closely packed, diffraction-limited array is limited to a thermal resistance of $Z, \leq 0.08(\kappa L_{min})^{-1}$, where κ is the thermal conductivity of the substrate. An array of antenna-coupled bolometers is not subject to this limitation since the thermally and optically sensitive areas need not be equal.
[Contact: E. N. Grossman, (303) 497-5102]

Antenna Metrology

Muth, L.A., **Analytic Correction for Probe-Position Errors in Spherical Near-Field Measurements** [original title: An Analytic Technique to Correct Probe-Position Errors in Spherical Near-Field Measurements], Proceedings of the Seventh International Conference on Antennas and Propagation, York, United Kingdom, April 15-18, 1991, pp. 762-765

(1991).

A recently developed analytic technique that can correct for probe position errors in planar near-field measurements to arbitrary accuracy is shown to be also applicable to spherical near-field data after appropriate modifications. The method has been used successfully to remove probe position errors in the planar near field, leading to more accurate far-field patterns, even if the maximum error in the probe's position is as large as 0.2λ. Only the error-contaminated near-field measurements and an accurate probe position error function are needed to be able to implement the correction technique. It is assumed that the probe position error function is a characteristic of the near-field range, and that it has been obtained using state-of-the-art laser positioning and precision optical systems. The method also requires the ability to obtain derivatives of the error-contaminated near field defined on an error-free regular grind with respect to the coordinates. In planar geometry the derivatives are obtained using FFTs, and in spherical geometry one needs to compute derivatives of Hankel functions for radial errors and derivatives of the spherical electric and magnetic vector basis functions for errors in the θ and ϕ coordinates. Efficient computer codes have been developed to accomplish this.
[Contact: Lorant A. Muth, (303) 497-3603]

Muth, L.A., **General Analytic Correction for Probe-Position Errors in Spherical Near-Field Measurements,** Journal of Research of the National Institute of Standards and Technology, Vol. 96, No. 4, pp. 391-410 (July-August 1991).

A general theoretical procedure is presented to remove known probe-position errors in spherical near-field data to obtain highly accurate far fields. We represent the measured data as a Taylor series in terms of the displacement error and the ideal spectrum of the antenna. This representation is then assumed to be an actual near field on a regularly spaced error-free spherical grid. The ideal spectrum is given by an infinite series of an error operator acting on data containing errors of measurement. This error operator is the Taylor series without the zeroth-order term. The nth-order approximation to the ideal near field of the antenna can be explicitly constructed by inspection of the error operator. Computer simulations using periodic error functions show that we are dealing with a convergent series, and the error-correction technique is highly successful. This is demonstrated for a triply periodic function for errors in each of the spherical coordinates. Appropriate graphical representations of the error-contaminated, error-corrected, and error-free near fields are presented to enhance understanding of the results. Corresponding error-contaminated and error-free far fields are also obtained.
[Contact: Lorant A. Muth, (303) 497-3603]

Muth, L.A., and Lewis, R.L., **Personal Computer Codes for Analysis of Planar Near Fields,** NISTIR 3970 (June 1991).

We have developed FORTRAN codes for analysis of planar near-field data. We describe some of the inner workings of the codes, the data management schemes, and the structure of the input/output sections to enable scientists and programmers to use these codes effectively as a research tool in antenna metrology. The open structure of the codes allows a user to incorporate into the package new applications for future use with relative ease. The subroutines currently in existence are briefly described, and a table showing the interdependence among these subroutines is constructed. Some basic research problems, such as transformation of a near field to the far field and correction of probe position errors, are carried out from start to finish to illustrate use and effectiveness of these codes. Sample outputs are shown. The advantage of a high degree of modularization is demonstrated by the use of DOS batch flies to execute FORTRAN modules in a desired sequence.
[Contact: Lorant A. Muth, (303) 497-3603]

Microwave and Millimeter-Wave Metrology

Daywitt, W.C., **Exact Principal Mode Field for a Lossy Coaxial Line,** IEEE Transactions on Microwave Theory and Techniques, Vol. 39, No. 8, pp. 1313-1322 (August 1991).

Exact field equations for a lossy coaxial transmission line with an infinite outer conductor are presented. The corresponding determinantal equation is solved to obtain an exact propagation constant from which errors in the microwave approximation and an alternative full frequency range approximation are calculated. The calculations show that the microwave approximation, although containing a large relative

error at the lower frequencies, is still useful in practical applications.
[Contact: William D. Daywitt, (303) 497-3720]

Marks, R.B., **A Multiline Method of Network Analyzer Calibration,** IEEE Transactions on Microwave Theory and Techniques, Vol. 39, No. 7, pp. 1205-1215 (July 1991).

This paper presents a new method for the calibration of network analyzers. The essential feature is to use the multiple, redundant transmission line standards. The additional information provided by the redundant standards is used to minimize the effects of random errors, such as those due to imperfect connector repeatability. The resulting method exhibits improvements in both accuracy and bandwidth over conventional methods. The basis of the statistical treatment is a linearized error analysis of the through-reflect-line calibration method. This analysis, presented here, is useful in the assessment of calibration accuracy. It also yields new results relevant to the choice of standards.
[Contact: Roger B. Marks, (303) 497-3037]

Williams, D.F., and Marks, R.B., **Transmission Line Capacitance Measurement** [original title: Approximate Determination of the Capacitance of Coplanar Lines], IEEE Microwave and Guided Wave Letters, Vol. 1, No. 9, pp. 243-245 (September 1991).

The capacitance and conductance per unit length of a transmission line are useful in the determination of its characteristic impedance, particularly with lossy transmission lines such as coplanar waveguide. The capacitance of coplanar lines is measured with two independent techniques. The results of both measurements agree closely with calculations. A technique for directly comparing the capacitance of two similar transmission lines is also demonstrated.
[Contact: Dylan F. Williams, (303) 497-3138]

Electromagnetic Properties

Tofani, S., Ondrejka, A.R., and Kanda, M., **A Time-Domain Method for Characterizing the Reflection Coefficient of Absorbing Materials from 30 to 1000 MHz** [original title: Time-Domain Method for Absorbing Material Reflectivity Characterization in the 30-1000 MHz Frequency Range], IEEE Transactions on Electromagnetic Compatibility, Vol. 33, No. 3, pp. 234-240 (August 1991).

A wideband time-domain reflectometer is used to evaluate the reflection characteristics of rf/microwave absorbers. The reflectometer uses an array of two identical broadband antennas, both transmitting and receiving. The method uses the two antennas in a difference mode to remove the undesired signals and to enhance the small reflections being measured. Using this technique, we can separate front surface reflections from those which are generated at greater angles. The spectrum bandwidth of our pulses is 30 MHz to 1000 MHz, and reflection characteristics are measured over this entire range. The method has been used to characterize the reflectivity of three different types of absorber placed in an anechoic chamber. The results are reported together with the measurement accuracy. A discussion regarding main sources of errors is also presented.
[Contact: Arthur R. Ondrejka, (303) 497-3309]

Laser Metrology

Scott, T.R., **Megawatt Laser Calorimeter Design,** Conference Record, IEEE Instrumentation and Measurement Technology Conference, Atlanta, Georgia, May 14-16, 1991, pp. 227-231 (1991).

The accurate determination of laser energy becomes extremely difficult when seeking to measure the output of laser sources having average powers in the megawatt range. This paper describes the conceptual design of a calorimeter which could safely capture the output of megawatt-class, continuous-wave laser sources operating in the near-infrared wavelength region. A primary consideration in this design was the possibility that at some point in the future it would have to be scaled to even larger dimensions. Accordingly, the design uses non-exotic optical techniques and a simple geometry to handle the high power densities expected from the laser sources. An array of curved, reflective rods is used to spread the laser radiation before it is absorbed by a black-walled cavity. The calorimeter is designed to capture the entire laser beam with subsequent conversion of the electromagnetic energy to thermal energy. The temperature of the calorimeter is monitored and used to determine the incident laser radiation.
[Contact: Thomas R. Scott, (303) 497-3651]

Optical Fiber Metrology

Franzen, D.L., **Precision Measurements on Optical Fibers**, Optics & Photonics News, pp. 30-31 (May 1991).

The precision and accuracy of single-mode optical fiber measurements are discussed. Included in the discussion are measurements for: attenuation, mode-field diameter, cut-off wavelength, and geometrical parameters.
[Contact: Douglas L. Franzen, (303) 497-3346]

Young, M., **Fiber Cladding Diameter by Contact Micrometry**, Conference Digest, Optical Fibre Measurement Conference, York, United Kingdom, September 17-18, 1991, pp. 123-126 (1991).

This paper reports very precise measurements of the cladding diameter of optical fibers by contact micrometry. A committee of the Telecommunications Industry Association was reluctant to accept an artifact standard other than an optical fiber because the measured result is a function of illumination, and because reflection from a metal film displays phase shifts that are not present in reflection from a glass edge. Indeed, the concern about phase shifts is not misplaced; we have measured widths of chrome-on-glass lines with a scanning confocal microscope and found the measured results to change by nearly 0.1 μm with polarization. At any rate, even if a chrome-on-glass standard is finally adopted, it is necessary to measure a fiber very accurately to verify the relevance of the chrome standard.
[Contact: Matt Young, (303) 497-3223]

Optical Fiber Sensors

Deeter, M.N., Rose, A.H., and Day, G.W., **Faraday-Effect Magnetic Field Sensors Based on Substituted Iron Garnets**, Proceedings of SPIE (The International Society for Optical Engineering, P.O. Box 10, Bellingham, Washington 98227-0010), Fiber Optic and Laser Sensors VIII, San Jose, California, September 16-21, 1990, pp. 243-245 (1990).

The performance of fiber-optic magnetic field sensors based on the Faraday effect mainly depends on the magneto-optic properties of the sensor element. Certain ferrimagnetic materials known as substituted iron garnets display characteristics which make them suitable for applications of magnetometry requiring high sensitivity, high spatial resolution, or high speed. The potential of these materials for magnetic field sensing is illustrated by comparing results of measurements made on two different iron garnet compositions.
[Contact: Merritt Deeter, (303) 497-5400]

Tang, D., Rose, A.H., Day, G.W., and Etzel, S.M., **Annealing of Linear Birefringence in Single-Mode Fiber Coils: Application to Optical Fiber Current Sensors**, Journal of Lightwave Technology, Vol. 9, No. 8, pp. 1031-1037 (August 1991).

Annealing procedures that greatly reduce linear birefringence in single-mode fiber coils are described in detail. These procedures have been successfully applied to coils ranging from 5 mm to 10 cm in diameter and up to 200 or more turns. They involve temperature cycles that last 3 to 4 days and reach maximum temperatures of about 850 °C. The primary application of these coils is optical fiber current sensors, where they yield small sensors that are more stable than those achieved by other techniques. A current sensor with a temperature stability of $+8.4 \times 10^{-5}$/K over the range from -75 to +145 °C has been demonstrated. This is approximately 20% greater than the temperature dependence of the Verdet constant. Packaging degrades the stability, but a packaged sensor coil with a temperature stability of about $+1.6 \times 10^{-4}$/K over the range from -20 to +120 °C has also been demonstrated.
[Contact: Allen H. Rose, (303) 497-5599]

Williams, P.A., Day, G.W., and Rose, A.H., **Compensation for the Temperature Dependence of Faraday Effect in Diamagnetic Materials: Application to Optical Fiber Sensors**, Electronics Letters, Vol. 27, No. 13, pp. 1131-1132 (20 June 1991).

The temperature dependence of the Faraday effect in a diamagnetic material can be compensated by varying the polarization state of the light entering the material as a function of temperature. We demonstrate that this can be done automatically by exploiting the temperature dependence of a linear retarder (waveplate).
[Contact: Paul Williams, (303) 497-3287]

Electro-Optic Metrology

Deeter, M.N., Rose, A.H., and Day, G.W., **Fast, Sensitive Magnetic-Field Sensors Based on the Faraday Effect in YIG** [original title: High-Speed, High-Sensitivity Magnetic Field Sensors Based on the Faraday Effect in YIG], Journal of Lightwave Technology, Vol. 8, No. 12, pp. 1838-1842 (December 1990).

Magnetic field sensors based on the Faraday effect in ferrimagnetic iron garnets are characterized in terms of their sensitivity, speed, and directionality. Sensitivity measurements at 80 Hz on small (e.g., 5-mm-diameter by 3-mm-long) samples of yttrium iron garnet (YIG) yield noise equivalent magnetic fields of 10 nT/Hz. Frequency response measurements exhibit virtually flat response to approximately 700 MHz.
[Contact: Merritt N. Deeter, (303) 497-5400]

Tu, Y., Goyal, I.C., Gallawa, R.L., and Ghatak, A.K., **Optical Waveguide Modes: An Approximate Solution Using Galerkin's Method with Hermite-Gauss Basis Functions** [original title: Solving the Scalar Wave Equation: Expansion in Terms of Hermite Gauss Functions], IEEE Journal of Quantum Electronics, Vol. 27, No. 3, pp. 518-522 (March 1991).

In Galerkin's method, an orthogonal set of functions is used to convert a differential equation into a set of simultaneous linear equations. We choose the Hermite-Gauss functions as the set of orthogonal basis functions to solve the eigenvalue problem based on the two-dimensional scalar-wave equation subject to the radiation boundary conditions at infinity. The method gives an accurate prediction of modal propagation constant and of the field distribution. The method is tested by using the step-index optical fiber, which has a known exact solution, and the truncated parabolic profile fiber, for which trends are well known. We also test the method using square and elliptic core fibers. The method is found to agree with known results.
[Contact: Robert L. Gallawa, (303) 497-3761]

Other Signal Topics

Capobianco, T.E., and Ciciora, S.J., **Characterizing Differential Air-Core Eddy Current Probes**, Review of Progress in Quantitative Nondestructive Evaluation, Vol. 10A, D. O. Thompson and D. E. Chimenti, Eds. (Plenum Press, New York, 1991), pp. 897-903. [Proceedings of the Review of Progress in Quantitative Nondestructive Evaluation Conference, La Jolla, California, September 15-20, 1990.]

We report the results of measurements establishing the flaw response of a differential, air-core, eddy current probe. The parameters chosen for the probe's construction were picked from a set of 32 combinations of five factors which were varied at two levels. These five factors include: (1) the number of layers of the inner coils, (2) the number of layers of the outer coil, (3) the number of turns on the inner coils, (4) the number of turns on the outer coil, and (5) the inside diameter of the inner coils. We report the results of calibrating this probe constructed in our laboratory, and we also discuss some of the idiosyncracies we encountered in the calibration process. The calibration reported here was carried out on seven notches made by electrical discharge machining in blocks of 7075-T6 aluminum alloy. The probe output is correlated to changes in flaw area.
[Contact: Thomas E. Capobianco, (303) 497-3141]

Field, B.F., and Fenimore, C., **Video Processing With the Princeton Engine at NIST**, NIST Technical Note 1288 (August 1991).

This document describes the NIST program in digital processing, including a newly created Image Processing Laboratory at NIST that is available to governmental, industrial, and academic researchers working on digital image processing. The centerpiece of the laboratory is a video supercomputer, the Princeton Engine, designed and constructed by the David Sarnoff Research Center. The engine provides real-time video and image-processing capability, accepting a variety of video formats over multiple wideband input channels and outputting real-time video for immediate viewing. Because the Engine is programmable, it is possible to use it to evaluate prototypes of image-processing components rapidly and efficiently.

The hardware capabilities of the Princeton Engine are described, as well as the available supporting video equipment in the Laboratory. Two programming examples are included to demonstrate the unusual programming environment and "language" used to program the Engine. Appendices list the available

predefined library modules and the processor assembly language instructions.
[Contact: Bruce F. Field, (301) 975-4230]

Goyal, I.C., Gallawa, R.L., and Ghatak, A.K., **An Approximate Solution to the Wave Equation — Revisited** [original title: An Approximate Solution to Second Order Linear Homogeneous Differential Equations], Journal of Electromagnetic Waves and Applications, Vol. 5, No. 6, pp. 623-636 (1991).

We revisit here an old but neglected approximate analytic solution to the electromagnetic wave equation. Our method of derivation is reminiscent of the WKB methodology (WKB refers to the initials of three independent workers -- Wentzel, Kramers, Brillouin -- who first used the approximation procedure to solve the Schroedinger wave equation in one dimension), but the solution, although approximate, is much more accurate than the traditional WKB solution and can be used with almost as much ease. The method is extremely powerful but, to our knowledge, has never been used by the optics community, where its use in analyzing optical fibers and integrated optical waveguides would be beneficial.
[Contact: Robert L. Gallawa, (303) 497-3761]

ELECTRICAL SYSTEMS

Power Systems Metrology

Martzloff, F.D., **On the Propagation of Old and New Surges**, Proceedings of the Open Forum on Surge Protection Application, Gaithersburg, Maryland, June 18-19, 1991, pp. 19-25 (1991).

The objective of the paper is to review the propagation characteristics of the old and new generation of surge waveforms encountered in low-voltage ac power systems. To complement information developed on this subject over the last ten years, measurement results are reported for the new 10/1000 μs waveform, and the effect (or, rather, the lack of effect) of wire size is documented by a simple experimental demonstration.
[Contact: Francois D. Martzloff, (301) 975-2409]

Martzloff, F.D., **Proceedings, Open Forum on Surge Protection Application**, Gaithersburg, Maryland, June 18-19, 1991, NISTIR 4657 (August 1991).

An Open Forum on Surge Protection Application was convened by the National Institute of Standards and Technology to provide a conduit for a wide range of positions, opinions, and needs to be fed into the voluntary standards-writing process. Twenty papers are included in the Proceedings, grouped in major categories of surge environment, device performance, application standards, installation practices, and coordination of cascaded devices. Appendices include a listing of the interests of the participants, their initial expectations, and an action wish list developed at the conclusion of the Forum.
[Contact: Francois D. Martzloff, (301) 975-2409]

Stricklett, K.L., Fenimore, C., Kelley, E.F., Yamashita, H., Pace, M.O., Blalock, T.V., Wintenberg, A.L., and Alexeff, I., **Observation of Partial Discharge in Hexane Under High Magnification**, IEEE Transactions on Electrical Insulation, Vol. 26, No. 4, pp. 692-698 (August 1991).

Partial discharges are observed in hexanes by shadow photography under the application of dc voltages. A nonuniform field geometry is employed, and the growth of cavities associated with partial discharges at a point cathode is photographed at 200X magnification. The use of an image-preserving optical delay allows a record of the conditions which exist in the liquid prior to the initiation of the partial discharge to be obtained; a simultaneous record of the partial discharge current is obtained. Analysis of these data indicates that electrostatic forces are adequate to drive streamer growth.
[Contact: Kenneth L. Stricklett, (301) 975-3955]

Van Brunt, R.J., Misakian, M., Kulkarni, S.V., and Lakdawala, V.K., **Influence of a Dielectric Barrier on the Stochastic Behavior of Trichel-Pulse Corona**, IEEE Transactions on Electrical Insulation, Vol. 26, No. 3, pp. 405-415 (June 1991).

The stochastic behavior of a negative, point-to-plane (Trichel-pulse) corona discharge in air has been investigated for the case where the plane electrode is partially covered with a solid PTFE (polytetrafluoroethylene) dielectric of varying size and position relative to the point electrode. This behavior is revealed from measurements of conditional and unconditional corona pulse-amplitude and pulse-time-separation distributions. The results indicate that the presence of a dielectric surface on the anode does not

affect the occurrence of Trichel pulses provided the point-to-plane gap spacing is greater than a critical value d_c which depends on the size of the dielectric and the applied voltage. As the gap spacing approaches d_c, the effect of dielectric surface charging by the corona introduces measurable "memory effects" indicated by correlations between pulse amplitude and time separation from the previous pulse. For spacings less than d_c, detectable corona-pulse activity is quenched by the presence of a quasi-permanent surface charge on the dielectric.
[Contact: Richard J. Van Brunt, (301) 975-2425]

Magnetic Materials and Measurements

Deeter, M.N., Rose, A.H., and Day, G.W., **Faraday-Effect Magnetic Field Sensors Based on Substituted Iron Garnets**, Proceedings of SPIE (The International Society for Optical Engineering, P.O. Box 10, Bellingham, Washington 98227-0010), Fiber Optic and Laser Sensors VIII, San Jose, California, September 16-21, 1990, pp. 243-245 (1990).

The performance of fiber-optic magnetic field sensors based on the Faraday effect mainly depends on the magneto-optic properties of the sensor element. Certain ferrimagnetic materials known as substituted iron garnets display characteristics which make them suitable for applications of magnetometry requiring high sensitivity, high-spatial resolution, or high speed. The potential of these materials for magnetic field sensing is illustrated by comparing results of measurements made on two different iron garnet compositions.
[Contact: Merritt N. Deeter, (303) 497-5400]

Moreland, J., and Rice, P., **Tunneling Stabilized, Magnetic Force Microscopy With a Gold-Coated, Nickel-Film Tip** [original title: Tunneling Stabilized, Magnetic Force Microscopy with a Au Coated, Ni-Film Tip], Journal of Applied Physics, Vol. 70, No. 1, pp. 520-522 (1 July 1991).

Tunneling stabilized magnetic force microscopy (TSMFM) is done with a scanning tunneling microscope (STM) having a flexible magnetic tip. TSMFM can be used to generate maps of magnetic records with submicrometer resolution. We find that Au-coated, Ni-film tips made from a free-standing 0.5-μm-thick Ni film can be used as a noninvasive probe for imaging magnetic bit patterns on the surfaces of a computer hard disk and floppy disks and computer tape. This variant of STM shows promise as a viable tool for diagnostic use in the magnetic recording industry.
[Contact: John Moreland, (303) 497-3641]

Rice, P., and Moreland, J., **Tunneling-Stabilized Magnetic Force Microscopy of Bit Tracks on a Hard Disk** [original title: Tunneling Stabilized Magnetic Force Microscopy], IEEE Transactions on Magnetics, Vol. 27, No. 3, pp. 3452-3454 (May 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. The application of TSMFM to image the Abrikosov flux lattice is presented. We present results of attempts to image sputter-deposited YBCO films above and below the critical temperature.
[Contact: Paul Rice, (303) 497-3541]

Superconductors

Ekin, J.W., and Bray, S.L., **Effect of Transverse Stress on the Critical Current of Bronze-Process and Internal-Tin Nb_3Sn**, Journal of Applied Physics, Vol. 69, No. 8, pp. 4436-4438 (15 April 1991).

The effect of transverse stress on the measured critical current of two substantially different Nb_3Sn superconductors, a bronze-process conductor and an internal-tin conductor, has been measured. Photomicrographs of the two conductors reveal a basic difference in their microstructure. The bronze-process conductor exhibits columnar grains that are radially

oriented within the Nb_3Sn filaments, while the grains of the internal-tin conductor are more equiaxed and randomly oriented. The radial orientation of the bronze-process grains defines an anisotropy between the axial and transverse directions that might account for the greater sensitivity of the critical current to transverse stress reported previously. The effect of transverse stress on the internal-tin conductor, however, is comparable to that of the bronze-process conductor. Thus, these data indicate that the transverse stress effect is not highly dependent on either grain morphology or fabrication process. From an engineering standpoint, the similarity of the transverse stress effect for these two types of Nb_3Sn superconductors represents an important simplification for setting first-order quantitative limits on the mechanical design of large superconducting magnets.
[Contact: John W. Ekin, (303) 497-5448]

Ekin, J.W., Salama, K., and Selvamanickam, V., **High-Transport Current Density Up to 30 T in Bulk $YBa_2Cu_3O_7$ and the Critical Angle Effect**, Applied Physics Letter, Vol. 59, No. 3, pp. 360-362 (15 July 1991).

Measurements of the dc transport critical current of oriented-grained $YBa_2Cu_3O_7$ have been made using high-quality Ag contacts and a high-current sample mount. The critical-current density J_c at 77 K for mutually perpendicular current and magnetic field B in the a,b plane is 8 kA/cm^2 at 8 T, decreasing gradually to 3.7 kA/cm^2 at 20 T, and remaining over 1 kA/cm^2 out to 30 T. High magnetic field measurements of J_c as a function of the angle θ of B with respect to the c axis are also reported. In contrast to earlier results at lower fields ($\leq$3 T), the measurements reported here in high fields reveal a J_c vs θ curve with a head-and-shoulders shape, consisting of a sharp peak ("head") <5° wide for B parallel to the CuO_2 planes, and a wide (30° at 9 T, for example) shoulder region on either side of B$\perp$c axis, where the transport J_c remains high and constant. Beyond the shoulder region, however, the transport J_c decreases sharply, giving rise to the concept of a critical field angle for application design, defined by the minima in $d^2J_c/d\theta^2$ at the edge of the shoulders.
[Contact: John W. Ekin, (303) 497-5448]

Goodrich, L.F., **High-T_c Superconductor Voltage-Current Simulator and the Pulse Method of Measuring Critical Current**, Cryogenics, Vol. 31, pp. 720-727 (August 1991).

A passive voltage-current (V-I) simulator has been developed and tested using pulse-current and conventional direct-current methods. The simulator was designed to generate the extremely nonlinear V-I characteristic of a superconductor. It is intended to be used to test various components of the measurement system such as instrumentation, measurement method, and data analysis software to determine the transport critical current or critical current density of a superconductor. Since this simulator does not emulate all of the subtle effects of a superconductor, it provides a necessary but not sufficient test of the measurement system. A comparison of preliminary results of the pulse-current and direct-current methods on the passive simulator is presented. Also, comparisons of methods using bulk and thin-film YBCO samples are given.
[Contact: Loren F. Goodrich, (303) 497-3143]

Moreland, J., Li, Y.K., Goodrich, L.F., Roshko, A., and Ono, R.H., **Novel Procedure for Mapping the J_c-H_{c2}-T_c Surface and Its Application to High Temperature Superconductors**, Science and Technology of Thin Film Superconductors 2, pp. 429-438 (Plenum Press, New York, 1990). [Proceedings of the Conference on Science and Technology of Thin Film Superconductors, Denver, Colorado, April 30-May 4, 1990).]

We have used an ac lock-in method for measuring the dynamic resistance versus current (dV/dI-I) curves to determine J_c(T,H). The sample current consisted of a small constant oscillating current added to a variable dc current. The dc current was either slowly ramped for dV/dI-I measurements or controlled, keeping the dV/dI level constant while ramping temperature or field. In this way, it was possible to measure J_c(T) at constant H. The temperature is controlled between 4 and 300 K using a bathysphere cryostat. The bathysphere cryostat was inserted into a high field magnet for measurements at fields up to 7 T. We have measured several high-temperature superconductors including YBCO thin films. In addition, we have measured the dV/dI-I curve of a simulator with a V-I curve having the form V = 10 μV x (I/1.4 A)^{13}. Upon numerical integration, our data for the superconductors and the simulator are consistent with those

obtained using a dc method using an analog nanovoltmeter to measure the V-I curves directly.
[Contact: John Moreland, (303) 497-3641]

Takagi, T., Chiang, Y.-M., and Roshko, A., **Origin of Grain Boundary Weak Links in $BaPb_{1-x}Bi_xO_3$ Superconductor** [original title: Origin of Grain Boundary Weak Links in $BaPb_{0.75}Bi_{0.25}O_3$ Superconductors], Journal of Applied Physics, Vol. 68, No. 11, pp. 5750-5758 (1 December 1990).

Although $BaPb_{0.75}Bi_{0.25}O_3$ (BPB) has a comparatively large superconducting coherence length of ~7 nm and no reported anisotropy in its superconducting parameters, polycrystalline BPB exhibits the same rapid decrease in transport critical-current density (J_{ct}) with low applied field (< ~5 Oe) that is characteristic of grain boundary weak-links in cuprate superconductors (e.g., $La_{2-x}Sr_xCuO_4$, $YBa_2Cu_3O_{7-x}$). We have studied the effects of processing thermal history on the formation and morphology of grain boundary phases, and on the chemistry of BPB boundaries with and without second phase, in order to understand the origin of these weak links. Scanning transmission electron microscopy and Auger electron spectroscopy results show the presence of a Pb-Bi-Ba-O phase that is wetting and liquid above ~570 °C, but which retracts to three-grain junctions upon slow cooling or annealing at lower temperatures. The composition of the grain boundaries as well as J_{ct} vs. temperature measurements suggest that the boundaries act as SIS tunnel junctions.
[Contact: Alexana Roshko, (303) 497-5420]

Other Electrical Systems Topics

Martzloff, F.D., and Perry, A.G., **Annotated Bibliography - Diagnostic Methods and Measurement Approaches to Detect Incipient Defects Due to Aging of Cables**, NIST 4485 (July 1991).

Open literature papers and some limited distribution documents were reviewed in a search to identify promising approaches to the in-situ detection of incipient defects in nuclear power plant cables. The search was extended to the topics of detection of any defect, to radiation effects, and to basic considerations on partial discharges. This report presents a review of 150 papers that appeared significant from their title, but many of which were found not applicable upon close review. A compilation of 850 references cited in the reviewed papers is included in this paper.
[Contact: Francois D. Martzloff, (301) 975-2409]

ELECTROMAGNETIC INTERFERENCE

Conducted EMI

Martzloff, F.D., **Diverting Surges to Ground: Expectations Versus Reality**, Proceedings of the Open Forum on Surge Protection Application, Gaithersburg, Maryland, June 18-19, 1991, pp. 125-132 (1991).

A misconception is sometimes encountered that surges can be eliminated by sending them on a one-way trip to "ground" in a manner similar to leftovers that disappear in the kitchen sink disposal, never to be seen again. Unfortunately, electricity travels on closed loops, and no amount of "grounding" - be it dedicated, isolated, separated, or otherwise - can dispose of unwanted electrons. Sending them down the drain of a grounding conductor makes them reappear in a microsecond about 200 m away on some other conductor. The cycle for the waste through the environment takes longer, giving the illusion of disposal (at least as seen from the point of view of the kitchen sink - from the global point of view, one should take a different view, but that is another story). This paper presents a brief review of some of the fallacies, with illustrative measurement results, and proposes two approaches for remedy, rather than counterproductive grounding practices based on misconceptions.
[Contact: Francois D. Martzloff, (301) 975-2409]

Martzloff, F.D., **Testing Varistors Against the VDE 0160 Standard**, Proceedings of the Open Forum on Surge Protection Application, Gaithersburg, Maryland, June 18-19, 1991, pp. 81-88 (1991).

High-energy surge tests have been performed on metal-oxide varistors of a type in common use, according to a proposed IEC standard derived from German Standard VDE 0160. Depending on the position of the varistor within its tolerance band, failure or degradation can occur, validating the concern that this test requirement may be too severe

for a universal application.
[Contact: Francois D. Martzloff, (301) 975-2409]

Radiated EMI

Crawford, M.L., and Ladbury, J.M., **Mode-Stirred Chamber for Measuring Shielding Effectiveness of Cables and Connectors: Assessing MIL-STD-1344A Method 3008**, Connection Technology, pp. 45-51 (June 1989).

The mode-stirred method for measuring the shielding effectiveness (SE) of cables and connectors as specified in MIL-STD-1344A Method 3008 is examined. Problems encountered in applying the method are identified, and recommendations to improve the measurement results are provided. These include chamber design, type and placement of transmitting and reference receiving antenna, determination and correction for voltage standing-wave ratio of the reference antenna and equipment under test (EUT), and the measurement approach to use at specified test frequencies. Design and measurement setups for a small mode-stirred chamber suitable for performing SE measurements in the frequency range 1 to 18 GHz with dynamic ranges up to 130 dB are given along with SE measurement results of some sample EUTs.
[Contact: Myron L. Crawford, (303) 497-5497]

Hill, D.A., **Diffraction by a Half-Plane in a Lossy Medium**, Journal of Applied Physics, Vol. 69, No. 12, pp. 8405-8407 (15 June 1991).

The classical problem of plane-wave diffraction by half plane is extended to allow for loss in the surrounding medium. The loss causes the arguments of the integral functions to become complex. Numerical results show that the relative importance of the edge-diffracted field decreases as the loss is increased. This effect is important in interpreting the effects of off-path scatterers in remote sensing of lossy media. The results for both electric and magnetic polarizations are in qualitative agreement with previous results based on the Kirchhoff approximation.
[Contact: David A. Hill, (303) 497-3472]

Randa, J., Kanda, M., and Orr, R.D., **Resistively-Tapered-Dipole Electric-Field Probes up to 40 GHz**, Proceedings of the IEEE 1991 International Symposium on Electromagnetic Compatibility, Cherry Hill, New Jersey, August 12-16, 1991, pp. 265-266 (1991).

We have developed an electric-field probe for use as a transfer standard at frequencies up to 40 GHz. The lower frequency cutoff is below 1 MHz. The design is based on the resistively-tapered-dipole (RTD) probes developed for frequencies up to 18 GHz. Those probes used 8-mm tapered dipoles. In this work, we have used 6-, 4- and 2-mm dipoles to extend the frequency range. Because the new probes are isotropic, have relatively flat frequency response, and have a response which drops off outside their operating frequency range, they could also be used as hazard meters.
[Contact: James P. Randa, (303) 497-3150]

Randa, J.P., Kanda, M., and Orr, R.D., **Thermo-Optic Designs for Electromagnetic-Field Probes for Microwaves and Millimeter Waves**, IEEE Transactions on Electromagnetic Compatibility, Vol. 33, No. 3, pp. 205-214 (August 1991).

We report the development of an electromagnetic-field probe for microwave and millimeter-wave frequencies. The probe uses an optically sensed thermometer to measure the heating of a resistive element in an electromagnetic field. The response is calculated for several different configurations of the resistive element, and two optimal designs are chosen. Measurements on experimental probes of these designs are presented. One of the designs displays a flat frequency response above 30 GHz and a sensitivity of 38 V/m. We identify improvements in the design which should significantly increase the sensitivity and improve the low-frequency response.
[Contact: James P. Randa, (303) 497-3150]

ADDITIONAL INFORMATION

Lists of Publications

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

This bibliography lists the publications of the personnel of the Electromagnetic Technology Division of NIST in the period from January 1970 through publication of this report. A few earlier references that are directly related to the present work of the Division are included.
[Contact: 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, Electronics and Electrical Engineering Laboratory, 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, NIST List of Publications 72** [a bibliography of NIST publications concerning semiconductor measurement technology for the years 1962-1989] (March 1990), and **LP72 Supplement, Publications for the Year 1990** (April 1991).

The bibliography contains reports of work performed at the National Institute of Standards and Technology in the field of Semiconductor Measurement Technology in the period from 1962 through December 1990. An index by topic area and a list of authors are provided. The supplement provides information on technology transfer at NIST for calendar year 1990, not only from those groups specializing in semiconductor electronics, but also including NIST-wide research now coordinated by the NIST Office of Microelectronics Programs.
[Contact: E. Jane Walters, (301) 975-2050]

New NIST Research Material

NIST has announced the availability of **Research Material 8458,** a well-characterized artificial flaw used as an **artifact standard in eddy current nondestructive evaluation (NDE).** The new Research Material (RM) is the outcome of work carried out by the Electromagnetic Technology Division to address the need for calibration standards for eddy-current NDE, for example, as used to detect fatigue cracks in aircraft structures. The RM flaw is produced in an annealed aluminum alloy block by first indenting the block and then compressively deforming the resulting notch until it is tightly closed. The next operation is to restore a flat finish to the block face, after which the block is heat treated to the original temper. The controlled flaw has been named the "CDF notch," after its inventors (listed on patent application) Thomas E. Capobianco (Electromagnetic Technology Division), William P. Dube (Division 832), and Ken Fizer (Naval Aviation Depot, NAS Norfolk, Virginia).

In the past, the challenge has been to manufacture artificial flaws that closely simulate the mechanical properties of fatigue cracks. Currently used artifacts include electrical-discharge-machined and saw-cut notches, both of which are relatively poor representations of fatigue cracks as their widths are too great. The Division-developed method provides notches that can be made controllably in a variety of geometries, have known dimensions, with widths that are narrow enough to provide an acceptable representation of fatigue cracks.

An NIST Research Material is not certified by NIST, but meets the International Standards Organization definition of "a material or substance one or more properties of which are sufficiently well established to be used in the calibration of an apparatus, the assessment of a measurement method, or for assigning values to materials." The documentation issued with RM 8458 is a "Report of Investigation." Contact: technical information — Fred Fickett, (303) 497-3785; order information — Standard Reference Materials Program, (301) 975-6776.

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 Office [(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 E. Potzick, (301) 975-3481 or Robert D. 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 EEEL CALENDAR

April 23-24, 1992 (Boston, Massachusetts)

Ion Implant Users Group Meeting. Sponsored by NIST, the next regular meeting will be expanded to two days. Topics to be discussed on the first day are: parallelism and high angle implant; artificial intelligence and implantation; and discussion of uptime calculation. Visits to Eaton, Varian, and Genus facilities are scheduled for the second day of the meeting. Preregistration is required.
[Contact: John Albers, (301) 975-2075]

June 24-26, 1992 (Stockholm, Sweden)

11th Workshop on VLSI Packaging Techniques and Manufacturing Technologies. The IEEE CHMT Society and NIST are co-sponsoring this 11th Workshop. Featured will be the design and implementation of electronic packaging and the technologies and equipment for high-frequency and high-density applications using single-chip packages and multichip modules.
[Contact George G. Harman, (301) 975-2097]

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]

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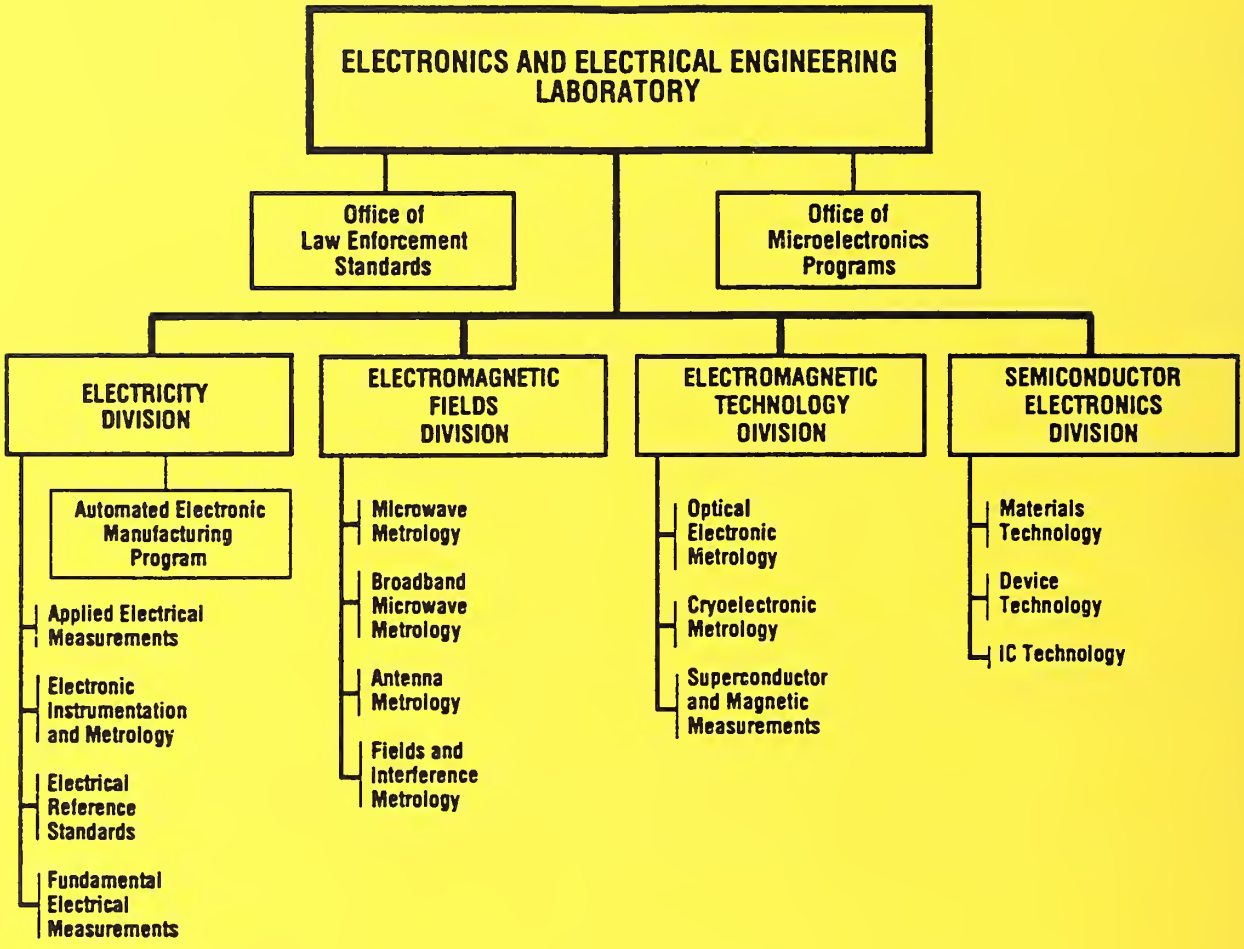

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