NISTIR 5607

Electronics and Electrical Engineering Laboratory

Technical Publication Announcements

J. M. Rohrbaugh
Compiler

March 1995

Covering Laboratory Programs,
July to September 1994
with 1995 EEEL Events Calendar

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

TECHNOLOGY ADMINISTRATION
Mary L. Good, Under Secretary for Technology

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
Arati Prabhakar, Director

ELECTRONICS AND ELECTRICAL ENGINEERING LABORATORY TECHNICAL PUBLICATION ANNOUNCEMENTS, MARCH 1995 ISSUE

INTRODUCTION

This is the forty-eighth issue of a quarterly publication providing information on the technical work of the National Institute of Standards and Technology Electronics and Electrical Engineering Laboratory (EEEL). This issue of the EEEL Technical Progress Bulletin covers the third quarter of calendar year 1994.

Organization of Bulletin: This issue contains abstracts for all relevant papers released for publication by NIST in the quarter and citations and abstracts for such papers published in the quarter. Entries are arranged by technical topic as identified in the Table of Contents and alphabetically by first author under each subheading within each topic. Unpublished papers appear under the subheading "Released for Publication." This does not imply acceptance by any outside organization. Papers published in the quarter appear under the subheading "Recently Published." 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 years 1994/1995 and a list of sponsors of the work.

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

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

Key contacts in the Laboratory are listed at the end of this publication; 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.

Certain commercial equipment, instruments, or materials are identified in this paper in order to specify adequately the experimental procedures. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

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NATIONAL SEMICONDUCTOR METROLOGY PROGRAM ESTABLISHED

The semiconductor industry has strongly urged the Administration and Congress to establish a major metrology program at NIST, and in March 1994, the resulting National Semiconductor Metrology Program was announced. Program funding is planned to ramp up over several years to a final level of $25 million per year. Industry's backing resulted from the record of useful solutions from NIST coupled with an increasing appreciation on the part of industry leaders of the key role of metrology in advanced competitive products. This program reinforces NIST's role as the nation's lead laboratory for metrology and exemplifies NIST's charter to serve industry. [Contact: Robert I. Scace, (301) 975-2485]

FUNDAMENTAL ELECTRICAL MEASUREMENTS

Shields, J.Q., Dziuba, R.F., Elmquist, R.E., and Lee, L.H., **NIST Comparison of Resistances Based on the Calculable Capacitor and the Quantum Hall Effect**, Conference Digest of the 1994 Conference on Precision Electromagnetic Measurements, Boulder, Colorado, June 27—July 1, 1994, pp. 391-392.

The latest NIST results comparing the quantized Hall resistance based on the value R_{K-90} = 25 812.807 Ω with the realization of the ohm in SI units obtained by direct calculable-capacitor measurements are reported.
[Contact: John Q. Shields, (301) 975-4233]

SEMICONDUCTOR MICROELECTRONICS

Silicon Materials

Lee, J.D., Park, J.C., Venables, D., Krause, S.J., and Roitman, P., **Defect Pair Formation by Implantation-Induced Stresses in High-Dose-Oxygen-Implanted-Silicon**, Proceedings of the Materials Research Society Conference, Boston, Massachusetts, Vol. 316, pp. 753-758 (1994).

Defect microstructure and the near-surface strain of high-dose oxygen-implanted silicon-on-insulator material were investigated as a function of dose, implant temperature, and annealing temperature by transmission electron microscopy and high-resolution X-ray diffraction. Dislocation half loops (DHLs) begin to form by stress-assisted climb at a critical stress level due to implantation-induced damage. DHLs evolve into through-thickness defect (TTD) pairs by expansion during annealing. Both DHL and TTD-pair density increase with higher implant dose and lower implant temperature. Possible methods for defect density and reduction are suggested based on the results of this study.
[Contact: Peter Roitman, (301) 975-2077]

Lee, J.D., Park, J.C., Venables, D., Krause, S.J., and Roitman, P., **Effect of Implantation Conditions on Defect Microstructure in Annealed SIMOX**, Proceedings of the Electrochemical Society, '94 International Symposium on SOI Technology and Devices, San Francisco, California, May 22-27, 1994, pp. 82-91.

Over the last ten years, there have been considerable efforts to develop new technologies for improved silicon-on-insulator (SOI) material. SIMOX (Separation by IMplanted OXygen) is a leading candidate for low-power, high-density, and high-speed device applications. The yield, reliability, and performance of devices rely on the quality of a top Si layer, but the density of through-thickness defects (TTDs) (which thread through the top Si layer) is still relatively high ($\sim 10^6$ cm^{-2}). A variety of mechanisms have been proposed for the formation of TTDs, but none have been verified experimentally. TTD density may be reduced with multiple low-dose implantation and annealing sequences. However, this procedure is time-consuming, expensive, susceptible to metal contamination, and introduces new defect types. Thus, an understanding of the origin of TTDs would lead to both scientific and economic benefits.
[Contact: Peter Roitman, (301) 975-2077]

Park, J.C., Lee, J.D., Venables, D., Krause, S., and Roitman, P., **Role of Oxygen Precipitation Processes in Defect Formation and Evolution in Oxygen Implanted Silicon-On-Insulator Material**, Proceedings of the Materials Research Society Conference, Vol. 279 (1993).

The differences in defect type, density, and location between high-temperature implanted single and multiple implant/anneal SIMOX and the role of precipitation processes in defect development were studied by transmission electron microscopy. The dominant defects in single implanted and annealed material are pairs of narrow stacking faults (NSFs) at a density of $\sim 10^6$ cm^{-2}, while stacking fault pyramids (SFPs) at a similar density dominate multiple implant/anneal material. However, SFPs are confined to the buried oxide interface and thus the density of through-thickness defects is about two orders of magnitude lower in multiple implant ($<10^4$ cm^{-2}) than in single implant material ($\sim 10^6$ cm^{-2}). SFPs are formed from a collection of four NSFs pinned to residual oxide precipitates. This transformation is energetically possible only below a critical NSF length which is dictated by the relative location of the residual precipitates. In turn, the residual precipitate location is determined by the location of as-implanted defects on which SiO_2 preferentially nucleates and grows. Thus, the synergistic interaction between precipitation and defect formation and evolution processes plays a key role in determining the final defect microstructure of SIMOX.
[Contact: Peter Roitman, (301) 975-2077]

Rennex, B.G., ***Standard Reference Materials*: Certification of a Standard Reference Material for the Determination of Interstitial Oxygen Concentration in Semiconductor Silicon by Infrared Spectrophotometry**, NIST Special Publication 260-121 (August 1994).

A Standard Reference Material, SRM-2551, has been prepared, measured, and certified for the determination of interstitial oxygen number fraction (commonly referred to as the oxygen concentration) in semiconductor silicon. This SRM is intended for calibration of infrared spectrophotometers used to measure the 1107 cm^{-1} interstitial oxygen peak in silicon. Its purpose is to enable its users to improve their measurement agreement. The expanded SRM uncertainty is 0.17% for the low-oxygen specimens, 0.13% for the medium-oxygen specimens, and 0.12% for the high-oxygen specimens. The certifying instrument was a Fourier-transform infrared spectrophotometer which measured the oxygen peak height. Specimens from an earlier international Grand Round Robin (GRR) were used to convert these infrared values to oxygen number fraction (concentration) values. A major source of uncertainty had been measurement drift; this was largely compensated using a control specimen. The remaining sources of uncertainty were instrument reproducibility, nonuniformity in oxygen concentration and thickness over the specimen area, and variation in residual oxygen in the SRM float-zone specimens, each of which float-zone specimens served as the zero-oxygen reference for a measurement. These sources were combined in quadrature to arrive at the above-quoted 2σ estimate of expanded SRM uncertainty. This SRM uncertainty applies to a "derived" oxygen number fraction which is first measured by an infrared technique and which is then converted to an oxygen number fraction. The oxygen number fraction previously measured in the GRR has a much larger uncertainty than the expanded SRM uncertainty.
[Contact: Brian G. Rennex, (301) 975-2108]

Roitman, P., Mayo, S., Simons, D., Krause, S.J., Park, J.C., Lee, J.D., Venables, D., Lenahan, P., and Conley, J., **Effect of Nitrogen Ambients during High-Temperature SIMOX Annealing**, Proceedings of the Electrochemical Society '94 International Symposium on SOI Technology and Devices, San Francisco, California, May 22-27, 1994, pp. 92-97.

The high-temperature annealing sequence used to reduce implant damage in high-dose oxygen-implanted silicon-on-insulator material was modified to include the nitrogen-containing gases N_2, N_2O, and NH_3. Large nitrogen peaks were observed at the oxide interfaces in the annealed samples by secondary ion mass spectroscopy. The magnitude of the peaks varied only slightly with gas type, concentration, and time. The electron spin resonance signal, the oxide conductivity, and the silicon defect structure were relatively unaffected.
[Contact: Peter Roitman, (301) 975-2077]

<u>Insulators and Interfaces</u>

Dahmani, R., Salamanca-Riba, L., Nguyen, N.V., Chandler-Horowitz, D., and Jonker, B.T., **Determination of the Optical Constants of ZnSe Films by Spectroscopic Ellipsometry**, Journal of Applied Physics, Vol. 76, No. 1, pp. 514-517 (1 July 1994).

Spectroscopic ellipsometry was used to determine the real and imaginary parts of the dielectric function of ZnSe thin films grown on (00l) GaAs substrates by molecular-beam epitaxy, for energies between 1.5 and 5.0 eV. A sum of harmonic oscillators is used to fit the dielectric function in order to determine the values of the threshold energies at the critical points. The fundamental energy gap was determined to be at 2.68 eV. The $E_0 + \Delta_0$ and E_1 points were found to be equal to 3.126 and 4.75 eV, respectively. Below the fundamental absorption edge, a Sellmeir-type function was used to represent the refractive index. At the critical points, E_0 and $E_0 + \Delta_0$, the fitting was improved by using an explicit function combining the contributions of these two points to the dielectric function.
[Contact: Nhan V. Nguyen, (301) 975-2044]

Dimensional Metrology

Lowney, J.R., and Marx, E., ***Semiconductor Measurement Technology*****: User's Manual for the Program MONSEL-I: Monte Carlo Simulation of SEM Signals for Linewidth Metrology**, NIST Special Publication 400-95 (August 1994).

This user's manual is a guide to the FORTRAN code MONSEL-I which is a Monte Carlo simulation of the transmitted and backscattered electron signals in a scanning electron microscope (SEM) associated with a line specimen with a trapezoidal cross section. The line is deposited on a multilayer substrate. The primary purpose of the code is to determine the actual linewidth from measured SEM signals. However, it can be used for many other purposes such as transmission electron microscopy. Future extensions to model secondary electron signals and multiple lines are planned.
[Contact: Jeremiah R. Lowney, (301) 975-2048]

Integrated-Circuit Test Structures

Cresswell, M.W., Allen, R.A., Linholm, L.W., Ellenwood, C.H., Penzes, W.B., and Teague, E.C., **New Test Structure for Nanometer-Level Overlay and Feature-Placement Metrology**, IEEE Transactions on Semiconductor Manufacturing, Vol. 7, No. 3, pp. 266-271 (August 1994).

A new electrical test structure for overlay measurement has been evaluated by replicating arrays of its complementary components from two different photomasks into a conducting film on a quartz substrate. The features resulting from images projected from the first mask were used as a reference grid which was calibrated by the NIST Line-Scale Interferometer. A first subset of the relative placements of the images projected from the second mask, which were derived from the electrical overlay measurements and the reference grid, agreed to within 13 nm with corresponding measurements made directly by the line-scale interferometer over distances up to 13.5 mm. A second comparison made at another substrate location indicated that gradients of projected feature linewidths across the exposure site may need to be measured, and corrected for, in the electrical extraction of overlay.
[Contact: Michael W. Cresswell, (301) 975-2072]

Khera, D., Cresswell, M.W., Linholm, L.W., Ramanathan, G., Buzzeo, J., and Nagarajan, A., **Increasing Profitability and Improving Semiconductor Manufacturing Throughput Using Expert Systems**, IEEE Transactions on Engineering Management, Vol. 41, No. 2, pp. 143-151 (May 1994).

This paper describes a new procedure for using a machine-learning classification technique coupled with an expert system to increase profitability and improve throughput in a semiconductor manufacturing environment. The authors show how to use this procedure to identify relationships between work-in-process data (information obtained during semiconductor fabrication) and potential integrated circuit yield. The relationships, in the form of IF-THEN rules, are extracted from databases of previously fabricated integrated circuits and final yield. It is further shown that these rules, when incorporated into expert systems, can advise the human operator as to which batches of circuits are likely to produce submarginal yield if processed to completion, thereby providing a basis for developing

or enhancing a quality control strategy. These rules also identify the parameters and values which have historically provided the highest and lowest final wafer yields. A cost analysis is given to illustrate the cost-effectiveness of this procedure. An introduction to semiconductor manufacturing and a glossary are provided.
[Contact: Dheeraj Khera, (301) 975-2240]

Photodetectors

Yang, S., Vayshenker, I., Li, X., and Scott, T.R., **Optical Detector Nonlinearity Measurement: A Comparison of Five Methods**, Conference Digest of the 1994 Conference on Precision Electromagnetic Measurements, Boulder, Colorado, June 27—July 1, 1994, pp. 455-456.

[See Laser Metrology.]

SIGNAL ACQUISITION, PROCESSING, AND TRANSMISSION

DC and Low-Frequency Metrology

Avramov, S., Oldham, N.M., Koffman, A.D., and Gammon, R.W., **Audio-Frequency Analysis of Inductive Voltage Dividers Based on Structural Models**, Digest of the 1994 Conference on Precision Electromagnetic Measurements, Boulder, Colorado, June 27—July 1, 1994, pp. 488-489.

A Binary Inductive Voltage Divider (BIVD) is compared with Decade Inductive Voltage Divider (DIVD) in an automatic IVD bridge. New detection and injection circuitry was designed and used to evaluate the IVDs, with either the input or output tied to ground potential. In the audio frequency range, the DIVD and BIVD error patterns are characterized for both in-phase and quadrature components. Differences between results obtained using a new error decomposition scheme based on structural modeling and measurements using conventional IVD standards are reported.
[Contact: Svetlana Avramov-Zamurovic, (301) 975-2414]

Elmquist, R.E. **Status of the Quantum Hall Resistance RISP**, Proceedings of the 1994 National Conference of Standards Laboratories Workshop and Symposium, Chicago, Illinois, August 1-5, 1994, pp. 475-478.

The NCSL Working Group that is developing a Recommended Intrinsic/Derived Standards Practice (RISP) for a quantum Hall resistance (QHR) standard has surveyed a group of standards laboratories to learn where a need for the standard exists. Smaller national laboratories are actively seeking to develop QHR facilities to support industrial needs. U.S. major industrial standards laboratories are suitable sites for the QHR standard, but few are eager to pursue development due to the perceived difficulty and expense of operating a QHR facility. The development of the RISP will reduce the ambiguity in the planning process. Initial questions about the method of measuring the resistance standard and scaling to the decade levels are addressed.
[Contact: Randolph E. Elmquist, (301) 975-6591]

Huang, D.X., Lipe, T.E., Kinard, J.R., and Childers, C.B., **AC-DC Difference Characteristics of High-Voltage Thermal Voltage Converters**, Conference Digest of the 1994 Conference on Precision Electromagnetic Measurements, Boulder, Colorado, June 27—July 1, 1994, pp. 409-410.

This paper describes a study of thermal voltage converters at voltages above 500 V and at frequencies up to 100 kHz. The effects of aging and dielectric loss on the resistor, as well as changes in the timing sequence of ac-dc difference tests, relay dead-times, warmup times, and voltage level dependence, are described.
[Contact: Thomas E. Lipe, (301) 975-4251]

Kinard, J.R., Huang, D.X., and Novotny, D.B., **Integrated Thin-Film Micropotentiometers**, Conference Digest of the 1994 Conference on Precision Electromagnetic Measurements, Boulder, Colorado, June 27—July 1, 1994, pp. 380-381.

Using thin-film technology and micromachining of silicon, new integrated micropotentiometers have been fabricated for the accurate determination of ac voltage from 1 to 200 mV up to 100 kHz and with the potential for higher frequencies.
[Contact: Joseph R. Kinard, (301) 975-4250]

Oldham, N.M., and Booker, S.R., **Programmable Impedance Transfer Standard to Support LCR Meters**, Proceedings of the 1994 IEEE Instrumentation Measurement Technology Conference, Hamamatsu, Japan, May 10-12, 1994, pp. 929-930.

A programmable transfer standard for calibrating impedance (LCR) meters is described. The standard makes use of low loss chip components and an electronic impedance generator (to synthesize arbitrary complex impedances) that operate up to 1 MHz. Intercomparison data between several LCR meters, including estimated uncertainties, will be provided in the final paper.
[Contact: Nile M. Oldham, (301) 975-2408]

Oldham, N.M., Hetrick, P.S., and Parker, M.E., **Programmable Digitally Synthesized Source for Low-Frequency Calibrations**, Conference Digest of the 1994 Conference on Precision Electromagnetic Measurements, Boulder, Colorado, June 27—July 1, 1994, pp. 419-420.

A digitally synthesized source (DSS) designed to calibrate low-frequency (0.1- to 1-kHz) digital voltmeters and thermal converters is described. The DSS output voltage, frequency, and waveform are programmable over the general purpose interface bus. The rms value of the output voltage is calculated, with an uncertainty of less than 5 ppm, by measuring the dc voltage of each of the steps used to create the waveform.
[Contact: Nile M. Oldham, (301) 975-2408]

Jarrett, D.G., and Moore, T.P., **Improvements to Automated System for Measuring Standard Resistors at NIST**, Proceedings of the 1994 National Conference of Standards Laboratories, Chicago, Illinois, August 1-5, 1994 (unpaged).

Improvements to an automated measurement system at NIST for calibrating four-terminal standard resistors in the range 1 kΩ to 1 MΩ have been made as a result of data analysis. Changes in hardware have included upgrading of instruments and remounting the instrumentation to protect relays from contamination due to mineral oil wicking through the cables connecting instrumentation and standard resistors. A study of data taken over several years has indicated differences in the measured values of 1-MΩ standard resistors depending upon the relative positions the resistors occupied in the bridge circuit. Leakages to ground and the immersion of the ring stands in mineral oil introduce resistances that shunt the bridge. A correlation has been made between this positional effect and the resistance shunting of the bridge in each test resistor position. A guarded scanner could contribute towards minimizing this positional effect.
[Contact: Dean G. Jarrett, (301) 975-4240]

Waveform Metrology

Deyst, J.P., and Souders, T.M., **Phase Plane Compensation of the NIST Sampling Comparator System**, Proceedings of the 1994 IEEE Instrumentation and Measurement Technology Conference, Hamamatsu, Japan, May 10-12, 1994, pp. 914-916.

This paper describes a compensation method to improve the static and dynamic linearity of an equivalent-time digitizer. "Phase plane" compensation is based on a multidimensional lookup table that represents a digitizer's nonlinearity as a function of appropriate signal parameters and digitizer state history. The lookup table is indexed by signal parameters of which the nonlinearity is a function, such as the signal's instantaneous value and estimated slope. In operation, the table is used to compensate for the nonlinearity of the digitizer by subtracting the appropriate table value from each new sample taken of the input signal. A separate lookup table may be added to compensate digitizer timebase nonlinearity. A lookup table that compensates well is useful not only for on-line compensation, but may also be applicable as a general description of digitizer nonlinearity, or a tool for inferring the sources of nonlinearity. The digitizer being compensated is a sampling comparator system. It produces noticeable distortion in signals such as high-frequency sine waves. The performance of the compensated sampling comparator system is presented, for a range of input test signals having a variety of trajectories in the phase plane.
[Contact: John P. Deyst, (301) 975-2437]

Deyst, J.P., Souders, T.M., and Solomon, O.M., **Bounds on Least-Squares Four-Parameter**

Sine-Fit Errors Due to Harmonic Distortion and Noise, Proceedings of the l994 IEEE Instrumentation and Measurement Technology Conference, Hamamatsu, Japan, May 10-12, 1994, pp. 700-703.

Least-squares sine-fit algorithms are used extensively in signal processing applications. The parameter estimates produced by such algorithms are subject to both random and systematic errors when the record of input samples consists of a fundamental sine wave corrupted by harmonic distortion or noise. The errors occur because, in general, such sine-fits will incorporate a portion of the harmonic distortion or noise into their estimate of the fundamental. Bounds are developed for these errors for least-squares four-parameter (amplitude, frequency, phase, and offset) sine-fit algorithms. The errors are functions of the number of periods in the record, the number of samples in the record, the harmonic order, and fundamental and harmonic amplitudes and phases. The bounds do not apply to cases in which harmonic components become aliased.
[Contact: John P. Deyst, (301) 975-2437]

Cryoelectronic Metrology

Berkowitz, S.J., Skocpol, W.J., Mankiewich, P.M., Ono, R.H., Missert, N., Rosenthal, P.A., and Vale, L.R., **Thermal Noise in High-Temperature Superconducting-Normal-Superconducting Step-Edge Josephson Junctions**, Journal of Applied Physics, Vol. 76, No. 2, pp. 1337-1339 (July 1994).

We have fabricated $YBa_2Cu_3O_{7-\delta}$-normal metal-$YBa_2Cu_3O_{7-\delta}$ step-edge Josephson junctions that fit the resistively shunted junction model with Johnson-Nyquist thermal noise. The *I-V* curves are well fit over a large temperature range for junctions of varying critical current values. There is good agreement between the fitted thermal noise temperature and the measured ambient temperature. This is strong evidence that these junctions are not dominated by superconducting shorts longer than the superconducting coherence length.
[Contact: Ronald H. Ono, (303) 497-3762]

Booi, P.A.A., and Benz, S.P., **Characterization of the Emission from 2D Array Josephson Oscillators**, Proceedings of the Fifth International Symposium on Space Terahertz Technology, Ann Arbor, Michigan, May 10-12, 1994, pp. 234-243.

We present experimental results on the emission from phase-locked two-dimensional arrays of Josephson junctions. We have coupled the emission from 10 x 10 arrays to a room-temperature mixer through a fin-line antenna and a WR-12 waveguide. A single voltage-tunable peak was detected up to 230 GHz. A stripline resonance in the antenna reduced the array's dynamic resistance and thereby the emission linewidth to as low as 10 kHz. We extract an effective noise temperature of 14 K from the linewidth data. When the array's emission was coupled to an on-chip detector junction through a dc blocking capacitor, we detected voltage-tunable emission from 75 GHz up to 300 GHz, and in some circuits emission above 400 GHz. The coherent power spectrum depends primarily on internal resonances.
[Contact: Samuel P. Benz, (303) 497-5258]

Goodrich, L.F., Srivastava, A.N., Stauffer, T.C., Roshko, A., and Vale, L.R., **High Current Pressure Contacts to Ag Pads on Thin Film Superconductors**, IEEE Transactions on Applied Superconductivity, Vol. 4, No. 2, pp. 61-64 (June 1994).

[See Superconductors.]

Reintsema, C.D., Ono, R.H., Harvey, T.E., Missert, N., and Vale, L.R., **Phase Locking in Two-Junction Systems of High-Temperature Superconductor-NormalMetal-Superconductor Junctions**, Applied Physics Letters, Vol. 64, No. 5, pp. 637-639 (31 January 1994).

Mutual phase locking between two high-temperature step-edge superconducting-normal metal-superconducting junctions has been investigated using a two-junction circuit with a nonsuperconducting feedback path. The strength of the phase-locked state has been characterized as a function of locking frequency and temperature. Results are presented for a planar circuit as well as for a multilayer circuit incorporating a superconducting ground plane. The observed behavior was significantly enhanced for the circuit over a ground plane. Characterization of the

phase-locked state at 4 K yielded locking strengths as large as $| I_L | / \bar{I}_c$ = 9%, and maximum locking frequencies to 1.06 THz. The magnitude of the locking strength decreased rapidly with increasing temperature with complete loss of coherence occurring at temperatures greater than 35 K.
[Contact: Ronald H. Ono, (303) 497-3762]

Rice, J.P., Grossman, E.N., Borcherdt, L.J. and Rudman, D.A., **High-T_c Superconducting Antenna-Coupled Microbolometer on Silicon**, Proceedings of SPIE (The International Society for Optical Engineering, P.O. Box 10, Bellingham, Washington 98227-0010), High-Temperature Superconducting Detectors: Bolometric and Nonbolometric, Vol. 2159, pp. 98-109 (1994).

A process is described for fabricating antenna-coupled resistive-edge microbolometers based on the high-T_c superconductor $YBa_2Cu_3O_7$ (YBCO) on silicon. The YBCO and a buffer layer of yttria-stabilized zirconia (YSZ) were grown epitaxially on silicon to minimize excess electrical noise. A silicon-micromachined YBCO/YSZ air-bridge was incorporated to minimize the thermal conductance and the heat capacity. The thermal conductance of the air-bridge was measured to be 3 x 10^{-6} W/K at a temperature of 100 K. At an operating temperature of 89 K, the detector is estimated to have a response time of 2 μs, a responsivity in the 1000 V/W range, and a noise-equivalent power in the 10^{-12} $W/(Hz)^{1/2}$ range at 1000 Hz.
[Contact: Joseph P. Rice, (303) 497-7366]

<u>Antenna Metrology</u>

Francis, M.H., Newell, A.C., Grimm, K.R., Hoffman, J., and Schrank, H.E., **Planar Near-Field Measurements of Low-Sidelobe Antennas**, Proceedings of the 15th Annual Meeting and Symposium, Antenna Measurement Techniques Association, Dallas, Texas, October 4-8, 1993, pp. 184-190.

The planar near-field measurement technique is a proven technology for measuring ordinary antennas operating in the microwave region. The development of very low-sidelobe antennas raised the question whether this technique could be used to accurately measure these antennas. We show that data taken with an open-ended waveguide probe and processed with the planar near-field methodology, including probe correction, can be used to accurately measure the sidelobes of very low-sidelobe antennas to levels of -55 to -60 dB relative to the main beam peak. We discuss the major sources of error and show that the probe-antenna interaction is one of the limiting factors in making accurate measurements. The test antenna for this study was a slotted-waveguide array whose low sidelobes were known. The near-field measurements were conducted on the NIST planar near-field facility.
[Contact: Michael H. Francis, (303) 497-5873]

Guerrieri, J.R., Kremer, D.P., and Rusyn, T., **A New Extrapolation/Spherical/Cylindrical Measurement Facility at the National Institute of Standards and Technology**, Proceedings of the 15th Annual Meeting and Symposium, Antenna Measurement Techniques Association, Dallas, Texas, October 4-8, 1993, pp. 343-352.

A new multi-purpose antenna measurement facility was put into operation at the National Institute of Standards and Technology in 1993. This facility is currently used to perform gain, pattern, and polarization measurements on probes and standard gain horns. The facility can also provide spherical and cylindrical near-field measurements. The frequency range is typically from 1 to 75 GHz. This paper discusses the capabilities of this new facility in detail.

The facility has 10-m-long horizontal rails for gain measurements using the NIST-developed extrapolation technique. This length was chosen so that gain calibrations at 1 GHz could be performed on antennas with apertures as large as 1 m. This facility also has a precision phi-over-theta rotator setup used to perform spherical near-field, probe pattern and polarization measurements. This setup uses a pair of 4-m-long horizontal rails for positioning antennas over the center of rotation of the theta rotator. This allows antennas up to 2 m in length to be accommodated for probe pattern measurements. A set of 6-m-long vertical rails that are part of the source tower gives the facility the added capability of performing cylindrical near-field measurements. Spherical and cylindrical near-field measurements can be performed on antennas up to 3.5 m in diameter.

[Contact: Jeffrey R. Guerrieri, (303) 497-3863]

Kremer, D.P., Newell, A.C., Repjar, A.G., Rose, C., Trabelsi, A., and Pinkaski, M., **Planar Near-Field Alignment**, Proceedings of the 15th Annual Meeting and Symposium, Antenna Measurement Techniques Association, Dallas, Texas, October 4-8, 1993, pp. 198-204.

This paper discusses one method of characterizing the scan plane for planar near-field measurements. The method uses a theodolite auto-collimator, a laser interferometer, an electronic level, and an optical square. The data obtained using these techniques are first used to make alignment corrections to the scan plane; then new data are used to determine the best fit for the realigned scan plane. The normal to this plane is referenced using a permanently placed mirror. In addition, the final data obtained can be used in probe position-correction techniques, developed for planar near-field measurements.
[Contact: Douglas P. Kremer, (303) 497-3732]

Microwave and Millimeter-Wave Metrology

Engen, G.F., Judish, R.M., and Juroshek, J.R., **The Multi-State Two-Port: An Alternative Transfer Standard**, Proceedings of the 43rd Automatic RF Techniques Group, San Diego, California, May 27, 1994, pp. 11-18.

In a companion paper, the proposed use of a "stable solid state programmable impedance generator" as a calibration transfer and verification standard, for vector network analyzers, has been suggested. An obvious requirement is that the multistate device provide a high degree of stability and repeatability. This paper describes a series of preliminary tests, using the NIST six-port systems to evaluate the parameters of interest. The application of this device in connector evaluation is also reported.
[Contact: Robert M. Judish, (303) 497-3380]

Jargon, J.A., **A Revised Uncertainty Analysis for the NIST 30-MHz Attenuation Calibration System**, Proceedings of the 1994 Measurement Science Conference Symposium and Workshop, Pasadena, California, January 27-28, 1994, 6 pages.

Although the 30-MHz Attenuation Calibration System has been in operation for many years at the National Institute of Standards and Technology, several modifications have been made to the system since the last published uncertainty analysis. The linear displacement of the standard attenuator's receiving coil is now measured with a laser interferometer instead of a steel ruled scale and optical projector, and a new comparison receiver has been installed in the system. The expanded uncertainty is on the order of ±0.003 dB per 10-dB step. Type A uncertainties depend upon the repeatability and resettability of the system and the device under test. Type B uncertainties are due to the standard waveguide below-cutoff attenuator, and the resolution of the comparison receiver, the change in level of the precision phase shift standard, the level set attenuator, rf leakage, and mismatch uncertainty. The individual uncertainty components are stated and combined to fully comply with the new NIST policy on statements of uncertainty.
[Contact: Jeffrey A. Jargon, (303) 497-3596]

Jargon, J.A., Ginley, R.A., and Sutton, D.D., **The NIST 30 MHz Linear Measurement System**, Journal of Research of the National Institute of Standards and Technology, Vol. 99, No. 1, pp. 19-30 (January-February 1994).

An automated linear measurement system (LMS) has been developed to determine the nonlinearity of a tuned 30-MHz power detector over a 6,021-dB range. This detector uses a single thermistor bead design with thermal isolation to obtain nearly linear tracking over a 4:1 change in input power. The nonlinear correction for this change, determined by the LMS, is on the order of 1.00030 (+ 130 μB) for the detector presently in use. Initial experiments indicate an expanded uncertainty of ±0.138% (±598 μB), which is based upon Type A and Type B components.
[Contact: Jeffrey A. Jargon, (303) 497-3596]

Juroshek, J.R., and Free, G.M., **Measurements of the Characteristic Impedance of Coaxial Air Line Standards**, IEEE Transactions on Microwave Theory and Techniques, Vol. 42, No. 2, pp. 186-191 (February 1994).

A method for electrically measuring the character-

istic impedance of coaxial air line standards is described. This method, called the gamma method, determines the characteristic impedance of a coaxial air line from measurements of its propagation constant and capacitance per unit length. The propagation constant is measured on a network analyzer, and the capacitance per unit length is measured on a capacitance bridge at 1 kHz. The measurements of characteristic impedance with the gamma method are independent of any dimensional measurements. Measurements of the characteristic impedance using the gamma method are compared to theoretical predictions from dimensional measurements. Test results are shown for 14-mm, 7-mm, and 3.5-mm coaxial air lines.
[Contact: John R. Juroshek, (303) 497-5362]

Williams, D.F., and Marks, R.B., **On-Wafer Impedance Measurement on Lossy Substrates**, Microwave and Guided Wave Letters, Vol. 4, No. 6, pp. 175-176 (June 1994).

This paper introduces a new method for measuring impedance parameters in transmission lines fabricated on lossy or dispersive dielectrics. The method, which uses an independent calibration to provide an impedance reference, compares well with conventional techniques when applied to lossless substrates. The effectiveness of the technique is illustrated for resistors fabricated on lossy silicon substrates.
[Contact: Dylan F. Williams, (303) 497-3138]

Williams, D.F., and Marks, R.B., **Reciprocity Relations in Waveguide Junctions**, IEEE Transactions on Microwave Theory and Techniques, Vol. 41, No. 6/7, pp. 1105-1110 (June/July 1993).

The Lorentz reciprocity condition is applied to junctions composed of reciprocal media which connect uniform but otherwise arbitrary waveguides. An expression relating the forward and reverse transmission coefficients is derived and factored into two terms: the first involving the phase of the reference impedance in the guide, and the second a new reciprocity factor. The usual condition equating the forward and reverse transmission coefficients is shown not to hold in the general case. Experimental evidence supporting the theoretical results is presented.
[Contact: Dylan F. Williams, (303) 497-3138]

Electromagnetic Properties

Baker-Jarvis, J.R., **Dielectric and Magnetic Relaxation by a Maximum-Entropy Method**, Smart Materials and Structures, Vol. 2, pp. 113-23 (1993). [Also published in Proceedings of the 1992 AMTA Workshop on Electromagnetic Characterization of Materials for Antenna/RCS Applications, Chicago, Illinois, July 25, 1992, pp. 1-23.]

Linear- and nonlinear-response theories are developed using a maximum-entropy approach. The approach is compared with classical linear-response theory. Expressions for linear and nonlinear responses to simultaneously applied electric., magnetic, stress and temperature fields are derived. The statistical-mechanical theories of dynamic and thermally driven systems are used to obtain generalized equations of evolution for the driven quantities. In a linear approximation, the Kubo expression is obtained. These equations are valid far from equilibrium. The time evolution of the electric polarization vector can be separated into a relaxation term and an external source term. Expressions for time-dependent entropy are developed and analyzed. In the very special case of the *relaxation approximation*, commonly used in the Boltzmann equation, the equation reduces to Debye's equation. Linear constitutive relations are given for electro-acoustic interactions at low driving fields.
[Contact: James R. Baker-Jarvis, (303) 497-5621]

Laser Metrology

Jones, R.D., and Scott, T.R., **Widths and Propagation of a Truncated Gaussian Beam, Proceedings of the 2nd Workshop on Laser Beam Characterization, Berlin, Germany, May 30, 1994—June 1, 1994, pp. 161-172.**

We calculated irradiance profiles resulting from the truncation of a gaussian beam by hard-edged slits transmitting 95% or 99% of the incident power. Three definitions - second moment, slit, and knife edge - were used to obtain widths of the near- and far-field profiles. From these widths, we calculated the propagation factors of the beam, with and

without a lens. Second moment widths are indeterminate, due to their dependence on the extent of integration. Scanning slit and knife-edge widths are measurable, but do not, in general, fit the hyperbolic propagation equation. Least-squares fits of these measurements can result in propagation ofactors better than the ideal limit. Beam divergence values calculated from single beam width measurements, or from least-squares fits of many data, differ by several percent.
[Contact: Richard D. Jones, (303) 497-3439]

Vayshenker, I., Li, X., and Scott, T.R., **Optical Power Meter Calibration Using Tunale Laser Diodes**, Proceedings of the 1994 National Conference of Standards Laboratories Workshop and Symposium, Chicago, Illinois, August 1-5, 1994, pp. 363-371.

We describe a measurement system developed by NIST to Calibrate optical power meters using either collimated beam or connectorized-fiber configurations. This calibration system uses tunable laser diodes which operates in the three fiber optics wavelength windows of 850, 1310, and 1550 nm. This paper describes standards, techniques, and systems involved in these calibrations.
[Contact: Thomas R. Scott, (303) 497-3651]

Yang, S., Vayshenker, I., Li, X., and Scott, T.R., **Optical Detector nonlinearity Measurement: A Comparison of Five Methods**, Conference Digest of the 1994 Conference on Precision Electromagnetic Measurements, Boulder, Colorado, June 27—July 1, 1994, pp. 455-456.

We derived a set of unified equations for five methods to evaluate nonlinearity of power meters and detectors. We performed computer simulations of these methods. The simulations assist in design of a measurement system to meet a target accuracy. Measurements verified the simulations.
[Contact: Igor Vayshenker, (303) 497-3394]

Integrated Optics

Goyal, I.C., Gallawa, R.L., and Chatak, A.K., **Improved Variational Analysis of Inhomogeneous Optical Waveguides Using Airy Functions**, Journal of Lightwave Technology, Vol. 11, No. 10, pp. 1575-1578 (October 1993).

Variational trial fields that are based on modified Airy functions are proposed to obtain the propagation characteristics of inhomogeneous planar optical waveguides. We compare with other recently proposed trial fields to demonstrate the improved accuracy obtained through the use of these Airy function trial fields. The probable reason that the proposed fields are better suited than others is that, unlike the others, they depend on the profile shape. The argument of the Airy function trial field is also sensitive to the rate of change of the profile. The fields are thus better matched to the exact field, improving the variational results.
[Contact: Robert L. Gallawa, (303) 497-3761]

Kumar, A., and Gallawa, R.L., **Bending-Induced Loss in Dual-Mode Rectangular Waveguides**, Optics Letters, Vol. 19, No. 10, pp. 707-709 (May 15, 1994).

We examine how the bending-induced mode losses in a dual-mode rectangular-core waveguide vary with bend orientation. Bending about the minor axis [case (i)] and bending about the major axis [case (ii)] are considered. The second (LP_{11}) mode is more lossy in case (i) than in case (ii), while the reverse is true for the first (LP_{01}) mode. Further, in case (i) the LP_{11}-mode loss is larger than the LP_{01}-mode loss, but in case (ii), the LP_{01}-mode loss is, surprisingly, larger than the LP_{11}-mode loss. LP_{11}-mode loss is consistent with the recent experimental results. This study should be useful in designing efficient elliptical-core fiber components such as LP_{11}-mode strippers based on differential mode loss of the first two modes.
[Contact: Arun Kumar, (303) 497-7367]

Schaafsma, D.T., Hickernell, R.K., and Christensen, D.H., **Measurement and Simulation of Photoluminescence Spectra from Vertical-Cavity Quantum-Well Laser Structures**, Proceedings of SPIE (The International Society for Optical Engineering, P.O. Box 10, Bellingham, Washington 98227-0010), Optical Engineering/Laser Application and Science Engineering, Vol. 2139, pp. 93-102 (1994).

We compare photoluminescence data collected in either a surface-normal configuration (NPL) or with the pump and collection paths perpendicular to a cross-section of the epitaxial layers (XPL) for

various vertical-cavity surface-emitting lasers and distributed quantum well structures. We report the spatial resolution of the XPL technique, particularly as it applies to distinguishing features in complex spectra into the unperturbed XPL spectra, taking into account a number of experimental and material parameters which may influence the lineshape. These factors include the pump field distribution and its influence on the weighting of the emitters, the collection optics, and the changes in the dispersive complex dielectric constant of the quantum wells. This information is of importance not only to optimizing device manufacture, but to basic physical and materials research as well. Whereas the XPL technique is a relatively simple but destructive characterization tool, a complete understanding of NPL emission could be made to yield the same information via rapid, nondestructive means.
[Contact: Robert K. Hickernell, (303) 497-3455]

Complex System Testing

Stenbakken, G.N., and Souders, T.M., **Developing Linear Error Models for Analog Devices**, IEEE Transactions on Instrumentation and Measurement, Vol. 43, No. 2, pp. 157-163 (April 1994).

Techniques are presented for developing linear error models for analog and mixed-signal devices. A simulation program developed to understand the modeling process is described, and results of simulations are presented. Methods for optimizing the size of empirical error models based on simulated error analyses are included. Once established, the models can be used in a comprehensive approach for optimizing the testing of the subject devices. Models are developed using data from a group of 13-bit A/D converters and compared with the simulation results.
[Contact: Gerard N. Stenbakken, (303) 497-2440]

ELECTRICAL SYSTEMS

Power Systems Metrology

Cookson, A.H., **Special Report of the CIGRÉ Session 1994 Study Group 15, Insulating Materials**, Proceedings of the 1994 Conference Internationale des Grands Rèseaux Électriques (CIGRÉ) (International Conference on Large High Voltage Electric Systems), Paris, France, August 28–September 3, 1994, pp. 1-4.

The special report reviews the nine papers accepted for the CIGRÉ General Session for Group 15 on Insulating Materials, and sets the question for the discussion period. The papers and discussions are divided into five groups: 1) partial discharge detection and analysis; 2) gas-insulated systems; 3) insulation for rotating machines; 4) polymeric materials and high voltage insulators; and 5) static electrification in transformer oil.
[Contact: Alan H. Cookson, (301) 975-2418]

von Glahn, P., and Van Brunt, R.J., **Performance Evaluation of New Digital Partial Discharge Recording and Analysis System**, Conference Record of the 1994 IEEE International Symposium on Electrical Insulation, Pittsburgh, Pennsylvania, June 5-8, 1994, pp. 12-16.

We describe the design and performance evaluation of a new digital partial discharge (PD) recording system capable of real-time recording of PD pulse trains for later off-line computerized stochastic analysis. The new recording system consists of a custom two-channel PD digitizer coupled to a new 16-bit parallel digital interface installed in a personal computer. The digitizer is under software control with the resulting data being stored in binary files on the computer's hard disk. Since post-test analysis software run on the computer provides the needed stochastic analysis of the data files, the new system offers a unique capability to perform stochastic analysis on nonstationary PD data such as found in aging studies. By way of illustration, measurements were made of the time-varying stochastic behavior of ac-generated PDs in point-to-dielectric gaps in air where the insulation material was cast epoxy with aluminum oxide filler, extending the work reported previously. Sample analysis results are presented, demonstrating that the new system provides analysis results comparable with the results achieved by the existing NIST analog PD stochastic analysis system. Sample stochastic analysis results are presented, demonstrating the additional insights possible with the new system.
[Contact: Peter von Glahn, (301) 975-2427]

Magnetic Materials and Measurements

Thompson, C.A., Cross, R.W., and Kos, A.B., **Micromagnetic Scanning Microprobe System**, Review of Scientific Instruments, Vol. 65, No. 2, pp. 383-389 (February 1994).

We describe the apparatus, instrumentation, and data acquisition techniques which make up the Micromagnetic Scanning Microprobe System (MSMS). This system was developed to study magnetoresistive (MR) thin films used in magnetic recording read heads. It uses a dc, four-probe resistance measurement technique coupled with two pairs of orthogonal field sources. Voltage contacts to the thin film are made with microprobe tips 0.1 μm in diameter on local edge and central regions of the film. Horizontal and vertical microscopes are used to verify tip placement. Results from magnetoresistance measurements of the dynamic response of a MR read head film are shown to demonstrate system operation and performance. The bulk and local magnetoresistance of a 10 μm x 10 μm NiFe thin film was measured as a function of applied field and angle. Significant variations in MR responses were seen across the width of the device because of local domain formation. The MSMS is an effective tool for characterizing the effects of domain formation on the output of a MR read head.
[Contact: Curtis A. Thompson, (303) 497-5206]

Superconductors

Coffey, M.W., **Aspects of a Deformable Superconductor Model for the Vortex Mass**, Journal of Low Temperature Physics, Vol. 96, Nos. 1/2, pp. 80-89 (1994).

A deformable superconductor model for the vortex mass per unit length μ_d in a type-II superconductor is discussed. A new identity for the inertial vortex mass in this model is presented which holds for an arbitrary quasiparticle fraction when the ionic displacement is irrotational. This result is used to show unphysical behavior in the temperature dependance of the ionic-strain-field vortex mass and is key in resolving this difficulty. A possibility for the experimental observation of the strain field mechanism is discussed.
[Contact: Mark W. Coffey, (301) 975-5303]

Goodrich, L.F., Srivastava, A.N., Stauffer, T.C., Roshko, A., and Vale, L.R., **High Current Pressure Contacts to Ag Pads on Thin Film Superconductors**, IEEE Transactions on Applied Superconductivity, Vol. 4, No. 2, pp. 61-64 (June 1994).

High-current, low-resistance, nonmagnetic, and nondestructive pressure contacts to Ag pads on $YBa_2Cu_3O_{7-\delta}$ (YBCO) thin-film superconductors were developed in this study. The contact resistance reported here includes the resistance of the current lead/Ag pad interface, the Ag pad/YBCO interface, and the bulk resistance of the contact material. This total contact resistance is the relevant parameter which determines power dissipation during critical-current measurements. It was found that regardless of the optimization of the Ag pad/YBCO interface through annealing, a pressure contact can yield a lower total resistance than a soldered contact. The lowest resistance obtained was 3 $\mu\Omega$ (for a 2 x 4 mm^2 contact). These contacts may be useful for many different high-temperature superconductor studies where high-current contacts with low heating are needed.
[Contact: Loren F. Goodrich, (303) 497-3143]

Xu, J.-H., Zheng, G.-G., Grishin, A.M., Moon, B.M., Rao, K.V., and Moreland, J., **Novel $YBa_2Cu_3O_{7-x}$ and $YBa_2Cu_3O_{7-x}/Y_4Ba_3O_9$ Multilayer Films by Bias-Masked "On-Axis" Magnetron Sputtering**, Applied Physics Letters, Vol. 64, No. 14, pp. 1874-1876 (4 April 1994).

In-situ $YBa_2Cu_3O_{7-x}$ (YBCO) films have been fabricated on $SrTiO_3$ (001) and $LaAlO_3$ (001) substrates by on-axis biased-radio-frequency magnetron sputtering in Ar-10% O_2 at total pressures as low as 3 Pa (3 x 10^{-2} mbar) and a deposition rate 210 nm/h. Negative oxygen ion-resputtering has been considerably reduced by introducing a biased copper mask between the substrate and target. The surface morphology and physical properties of the films are greatly improved on applying a *positive* dc substrate bias with respect to the grounded deposition chamber. We have obtained superconducting YBCO films with transport critical current as high as 10^6 A/cm^2 at 77 K and low normal-state resistivity by this approach. Scanning tunneling microscopy analyses of the films with the best superconducting properties reveal a spiral growth mechanism. However, films deposited

by *negative* dc bias under identical sputtering conditions are *insulating*. From X-ray θ-2θ and rocking curve measurements, we identify the insulating films to be *c*-axis oriented $Y_4Ba_3O_9$ (YBO) films. Furthermore, YBCO films could be grown on the YBO layers without any degradation of T_C and *c*-axis orientation. This novel bias sputtering feature gives us a unique opportunity to produce superconductor/insulator, YBCO/YBO, multilayers from a single YBCO target.
[Contact: John Moreland, (303) 497-3641]

ELECTROMAGNETIC INTERFERENCE

Radiated EMI

Blejer, D.J., Wittmann, R.C., and Yaghjian, A.D., **On-Axis Fields from a Circular Uniform Surface Current**, chapter in Ultra-Wideband, Short-Pulse Electromagnetics (Plenum Press, New York, New York, 1993), pp. 285-292. [Also published in the Proceedings of the International Conference on Ultra-Wideband Short-Pulse Electromagnetics, Brooklyn, New York, October 8-10, 1992.]

Exact closed-form expressions are derived for the on-axis electric and magnetic fields of a circular aperture excited by a uniform surface current with arbitrary time dependence. Corresponding expressions hold for a uniform magnetic or electric field exciting the circular aperture. Necessary and sufficient conditions on the current are given to overcome the usual l/z^2 far-field energy dependence.
[Contact: Ronald C. Wittmann, (303) 497-3326]

Hill, D.A., Crawford, M.L., Johnk, R.T., Ondrejka, A.R., and Camell, D.G., **Measurements of Shielding Effectiveness and Cavity Characteristics of Airplanes**, NISTIR 5023 (July 1994).

We present measured data for shielding effectiveness, cavity Q, and cavity time constant of three small (twin-engine) airplanes for frequencies from 400 MHz to 18 GHz. Both cw and time-domain measurement methods were used, but the time-domain method yields higher values of cavity Q. Both methods yield Q values below a theoretical upper bound determined by window leakage losses. The measured shielding effectiveness is variable, but averages about 15 dB. The measured time constants are also variable and average about 15 ns. This short time constant is a result of the low Q of the aircraft cavities.
[Contact: David A. Hill, (303) 497-3472]

PRODUCT DATA SYSTEMS

Goldstein, B.L.M., **Electronic Commerce for the Electronics Industry**, Proceedings of the 1994 Electro International Conference, Boston, Massachusetts, May 10-12, 1994, pp. 532-539.

This paper discusses the potential impact of an electronic marketplace on the electronics industry, the enabling technology needed to effectively migrate current business practices to take full advantage of such a highly networked environment, a few of the organizations participating in the creation and promotion of these technologies, and some of the challenges to migration.
[Contact: Barbara L. Maia Goldstein, (301) 975-2304]

McLay, M., **The Role of Standards in Vacuum Electronics**, Proceedings of the Vacuum Electronics Annual Review, Arlington, Virginia, June 29—July 1, 1993, pp. II 29-II 33.

The spectrum of physical characteristics that are critical in vacuum electronics design makes it a particularly challenging product category to model. However, a well integrated set of information exchange standards for vacuum electronics would provide an opportunity to reduce the cost of doing business and improve the quality of products sold. Use of existing standards and establishment of the necessary industry standards for microwave-tube design data will have significant impact on the future costs and effectiveness of maintaining and extending power-tube design systems such as Microwave and Millimeter-Wave Advanced Computational Environments.
[Contact: Michael McLay, (303) 497-4099]

Parks, C., **Demonstration: World Wide Web for Distribution of Users Group Information on Internet**, Proceedings of the 1994 IDEF Users Group Spring Conference, Richmond, Virginia, May 23-26, 1994, pp. 4-6.

Internet is rapidly becoming the primary means of

communication among millions of people including individuals, academia, government, and commercial organizations. This demonstration is an experimental use of an Internet "hypermedia document server and reader" facility to present information about the IDEF Users Group. Should the Users Group adopt the World Wide Web as one means for distributing information, the demonstration files are available for modification and hosting on a server so as to be available on the network. The Users Group demonstration includes links to the NIST FIPS documents on IDEF 0 and IDEF1X which are now available for access.
[Contact: Curtis Parks, (301) 975-3517]

VIDEO TECHNOLOGY

Fenimore, C., Field, B.F., Frank, H., Georg, E., Papillo, M., Reitmeier, G., Stackhouse, W., and Van Degrift, C., **Report on the Workshop on Advanced Digital Video in the National Information Infrastructure**, NISTIR 5457 (July 1994).

A workshop was held to highlight technical issues for industry and government decision makers with respect to Advanced Digital Video in the National Information Infrastructure (NII). The purpose of the Workshop was to: (1) define a vision of the role of digital video within the NII; (2) identify the architectural, scaling, and performance issues in realizing this vision, and (3) recommend the research, experiments, and steps to be taken to resolve these issues.

This summary by the Program Committee reports on some of the important ideas expressed by the speakers and the conclusions reached by the breakout groups, and the recommendations from the Workshop as a whole. The reader is referred to the unedited Breakout Group Reports and speakers' slides, in Part 2 of the Report, for more details.
[Contact: Charles Fenimore, (301) 975-2428]

Field, B.F., Kelley, E.F., Fenimore, C.P., and Bennett, H.S., **Research on Flat Panel Display Measurements at the National Institute of Standards and Technology**, to be published in the Proceedings of SPIE (The International Society for Optical Engineering, P.O. Box 10, Bellingham, Washington 98227-0010), Vol. 2174, pp. 30-34 (1994).

The National Institute of Standards and Technology has initiated a new program on performance measurements for flat-panel displays. Prior to this program, NIST completed an assessment of industry needs for measurements and standards to assist in the development of high-resolution displays. As a result of this study, a new laboratory has been established to characterize the electrical and optical performance of flat-panel displays. The services of the laboratory will be available to commercial panel manufacturers and users. NIST, as a neutral third party, intends to provide technical assistance to the development of standards and measurement practices for flat-panel display characterization.
[Contact: Bruce F. Field, (301) 975-4230]

Herman, S., Field, B.F., and Boynton, P.A., **Quantification of Temporal Threshold Noise in TV Display**, Proceedings of the Society for Information Display Symposium, San Jose, California, June 12-14, 1994, pp. 869-872.

The time-varying speckle pattern due to temporal broadband noise presents an objectionable artifact in television viewing. This paper reports on research performed on a Princeton Engine video processing supercomputer. The research quantified the threshold signal-to-noise ratio (SNR) at which such temporal noise becomes visible, as a function of the mean and standard deviation of the background image. Data were taken using a large number of viewers, some trained, others untrained, observing both artificial and real TV images. It was found that the threshold SNR can vary between 29 and 39 dB, depending on the first two statistical moments of the background. Thus, signal processing that changes image luminance levels can sometimes impose a system SNR penalty of up to 10 dB.
[Contact: Bruce F. Field, (301) 975-4230]

Kelley, E.F., Field, B.F., Jones, G.R., and Boynton, P.A., **Display Modeling and an AMLCD Model on a Video Supercomputer**, Proceedings of the Society for Information Display International Symposium Digest of Technical Papers, San Jose, California, May 1994, Vol. XXV, pp. 779-782.

An active-matrix liquid crystal display (AMLCD) is simulated on a cathode ray tube display driven by a video supercomputer, the Princeton Engine. The supercomputer permits the use of real-time video in conducting human factors visualization tests. The display model produces a representation that visually matches an actual AMLCD display for a wide range of viewing angles.
[Contact: Edward F. Kelley, (301) 975-3842]

ADDITIONAL INFORMATION

Lists of Publications

Smith, A.J., **Metrology for Electromagnetic Technology: A Bibliography of NIST Publications**, NISTIR 5029 (September 1994).

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

Lyons, R.M., and Gibson, K.A., **A Bibliography of the NIST Electromagnetic Fields Division Publications**, NISTIR 5028 (September 1994).

This bibliography lists publications by the staff of the National Institute of Standards and Technology's Electromagnetic Fields Division for the period from January 1970 through July 1993. Selected earlier publications from the Division's predecessor organizations are included.
[Contact: Kathryn A. Gibson, (303) 497-3132]

Meiselman, B., **Electrical and Electronic Metrology: A Bibliography of NIST Electricity Division's Publications, NIST List of Publications 94** (January 1994).

This bibliography covers publications of the Electricity Division, Electronics and Electrical Engineering, Laboratory, NIST, and of its predecessor sections for the period January 1968 to December 1993. A brief description of the Division's technical program is given in the introduction.
[Contact: Katherine H. Magruder, (301) 975-2401]

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

The bibliography provides information on technology transfer in the field of microelectronics at NIST for the calendar years 1990 through 1993. Publications from groups specializing in semiconductor electronics are included, along with NIST-wide research now coordinated by the NIST Office of Microelectronics Programs which was established in 1991. Indices by topic area and by author are provided. Earlier reports of work performed during the period from 1962 through December 1989 are provided in NIST List of Publications 72.
[Contact: E. Jane Walters, (301) 975-2050]

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

This document is the successor to NISTIR 90-4260, *Emerging Technologies in Electronics ...and their Measurement Needs* [Second Edition]. The new *Measurements for Competitiveness in Electronics* identifies the measurement needs that are most critical to U.S. competitiveness, that would have the highest economic impact if met, and that are the most difficult for the broad range of individual companies to address. The document has two primary purposes: (1) to show the close relationship between U.S. measurement infrastructure and U.S. competitiveness, and show why improved measurement capability offers such high economic leverage and (2) to provide a consensus on the principal measurement needs affecting U.S. competitiveness, as the basis for an *action plan* to meet those needs and to improve U.S. competitiveness.

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

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

Measurement capability is critical to research and development, manufacturing, marketplace entry, and after-sales support of products. Thus, measurement capability affects the performance, quality, reliability, and cost of products. The result of this pervasive impact is that the level of U.S. measurement capability places an upper limit on the competitiveness of U.S. products.

At present, U.S. industry is experiencing a major shortfall in the measurement capability needed for competitiveness in electronic products. This document identifies the measurement needs that are most critical to U.S. competitiveness, that would have the highest economic impact if met, and that are the most difficult for the broad range of individual companies to address. The measurement needs are reviewed for nine important fields of electronics, including semiconductors, magnetics, superconductors, microwaves, lasers, optical-fiber communications, optical-fiber sensors, video, and electromagnetic compatibility. These fields of electronics underlie more than $300 billion of electronic and electrical products manufactured in the U.S. each year.

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

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

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

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

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

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

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

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

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

Each of these chapters contains four basic types of information:

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

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

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

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

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

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

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

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

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

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

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

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

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

Chapter 9, **Optical-Fiber Communications**, describes the highest-information-capacity cable technology. It provides the basis for national and international information highways of unprecedented performance and broad economic impact.

Optical-fiber systems will be linked with microwave systems to interconnect mobile and portable users and to backup cable systems.

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

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

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

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

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

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

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

1994/1995 Calendar of Events

January 27, 1995 (Gaithersburg, Maryland)

Ion Implant Users Group Meeting. One of the topics to be discussed will be Particles II: Improvement Programs and Monitoring Sensors. Additional topics will be announced at a later date.
[Contact: John Albers, (301) 975-2075]

January 30—February 2, 1995 (Gaithersburg, Maryland)

International Workshop on Semiconductor Materials Characterization: Present Status and Future Needs. Papers will be presented in all relevant fields of interest to materials characterization in semiconductor device manufacturing, growth, processing, diagnostics, in-situ, real-time control and monitoring, etc. Panel sessions organized by SEMI and NIST will provide for multiple inputs and interactive discussion on important issues related to the topics of the formal presentation sessions. A separate planning session for compound semiconductors is scheduled. The Workshop is sponsored by the Advanced Research Projects Agency (ARPA), SEMI, SEMATECH, NIST, and others. [Contact: David G. Seiler, (301) 975-2074]

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NIST SILICON RESISTIVITY SRMs

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

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

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

NIST SILICON BULK RESISTIVITY STANDARD REFERENCE MATERIALS

DATE UPDATED: 8 AUGUST 1994

Note: Problems in producing and certifying new SRMs have resulted in substantial delays. The first to become available, for 10 and 180 ohm · cm, are not likely to be ready until 1995.

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

The above table will be updated in future issues to reflect changes in availability. Every effort will be made to provide accurate statements of availability; NIST sells SRMS on an as-available basis. For technical information, contact James R. Ehrstein, (301) 975-2060; for ordering information, call the Standard Reference Materials Program Domestic Sales Office: (301) 975-6776.

International Workshop on Semiconductor Characterization: Present Status and Future Needs

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

The International Workshop on Semiconductor Characterization: Present Status and Future Needs will be held Monday, January 30 through February 2, 1995, at NIST in Gaithersburg, Maryland. The Workshop provides a forum to present and discuss critical issues, problems and limits, evolving requirements and analysis needs, future directions, and key measurement principles, capabilities, applications, and limitations. It will be comprised of formal invited presentation sessions, poster sessions for contributed papers, and panel sessions. Invited sessions are planned on:

- Si Process Development and Manufacturing — The Drivers
- Analytical Technology and Metrology Requirements for Beyond 0.35 μm Technology
- Process and Characterization Issues
- Above-Si Processing
- Critical Analytical Methods
- Si and Compounds: In-Situ; Real-Time Diagnostics, Analysis, and Control
- Frontiers in Compound Semiconductors

Three panel sessions are being organized by Semiconductor Equipment and Materials International (SEMI) to provide for multiple inputs and interactive discussion on important issues related to the topics of the formal presentation sessions. On Friday, February 3, a separate planning session for compound semiconductors, jointly sponsored by SEMI and NIST, is scheduled.

Sponsors: The Advanced Research Projects Agency, SEMATECH, National Institute of Standards and Technology, Army Research Office, U.S. Department of Energy, National Science Foundation, and SEMI.

Conference Chair: David G. Seiler, NIST

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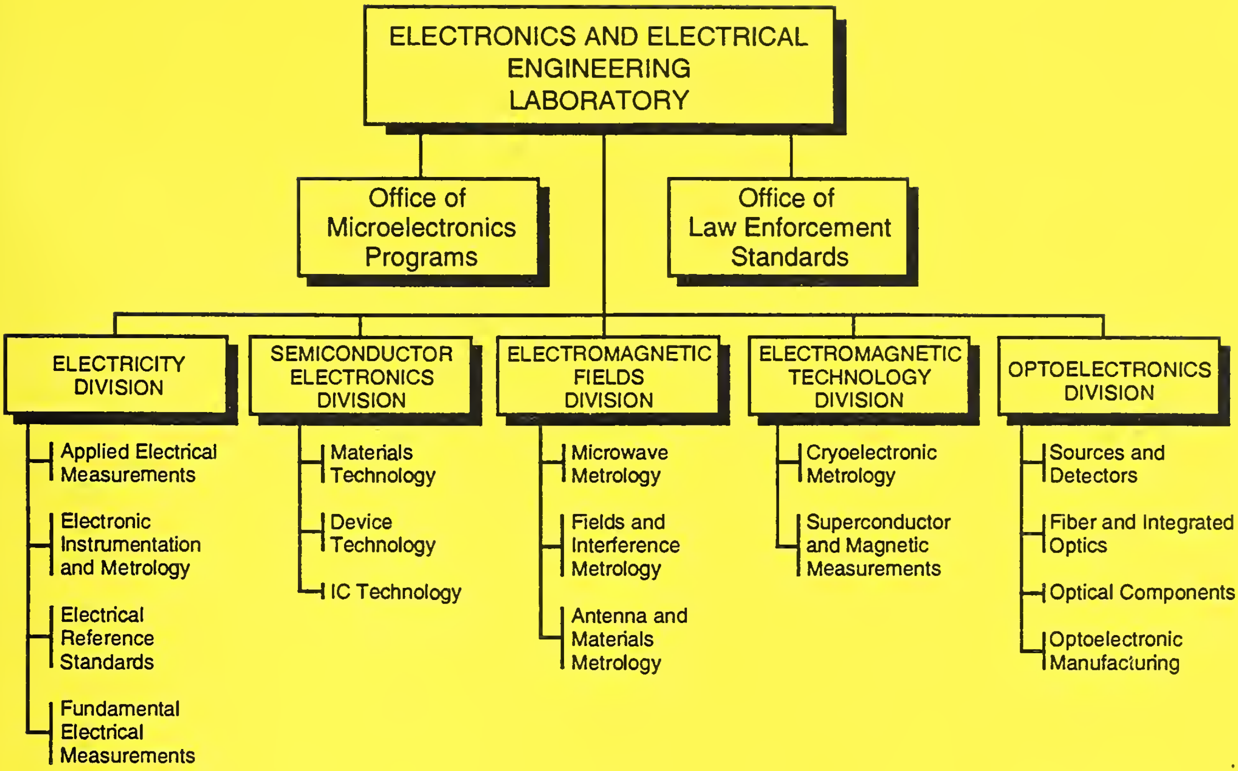

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