



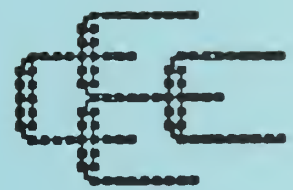
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Reference

NBS PUBLICATIONS

NBSIR 84-2877-1

CENTER FOR ELECTRONICS AND ELECTRICAL ENGINEERING



TECHNICAL PROGRESS BULLETIN

U.S. DEPARTMENT OF COMMERCE National Bureau of Standards National Engineering Laboratory Center for Electronics and Electrical Engineering Gaithersburg, Maryland 20899

Covering Center Programs, January - March 1984 with 1984 CEEE Events Calendar

May 1984



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## INTRODUCTION TO MAY 1984 ISSUE OF THE CEEE TECHNICAL PROGRESS BULLETIN

This is the sixth issue of a quarterly abstract journal covering the work of the National Bureau of Standards Center for Electronics and Electrical Engineering. This issue of the CEEE Technical Progress Bulletin covers the first quarter of calendar year 1984.

Organization of Bulletin: This issue contains abstracts for all papers released for publication by NBS in the quarter and citations and abstracts for 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 Unpublished papers appear under the subheading "Released for Publication". Papers published in the quarter appear under the subheading "Recently Published". Following each abstract is the telephone number of the individual to contact for more information on the topic; unless otherwise noted, this person is the first author. This issue also includes a calendar of Center conferences and workshops for the remainder of calendar year 1984, an announcement of newly released standard reference materials, and a list of sponsors of the work.

Center for Electronics and Electrical Engineering: Center 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 Center is divided into two major programs: the Semiconductor Technology Program, carried out by the Semiconductor Materials and Processes and Semiconductor Devices and Circuits Divisions in Gaithersburg, MD, and the Signals and Systems Metrology Program, carried out by the Electrosystems Division in Gaithersburg and the Electromagnetic Fields and Electromagnetic Technology Divisions in Boulder, CO. Key contacts in the Center are given on the back cover; readers are encouraged to contact any of these individuals for further information.

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

Note on Publication Lists: Guides to earlier as well as recent work are the publication lists covering the work of each division. These lists are revised and reissued on an approximately annual basis and are available from the originating division [publications from the Semiconductor Technology Program are covered in a single list, available from either Semiconductor Division].

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**SEMICONDUCTOR TECHNOLOGY PROGRAM**Silicon Materials

Released for Publication

Baghdadi, A., **The Effects of Instrumental Artifacts on the Quantitative Determination in Silicon by FTIR**, to be published in *Semiconductor Processing*, ASTM Special Technical Publication 850, ASTM 1916 Race Street, Philadelphia, PA 19103 [paper given at Silicon Processing Symposium, San Jose, CA, February 6-9, 1984].

The evolution of silicon processing technologies towards greater reliance on internal gettering by oxygen precipitates has led to the need for greater precision in the measurement of the interstitial oxygen content of silicon slices. This measurement is presently being carried out with the use of Fourier Transform Infrared (FTIR) spectrophotometers. This paper concerns the investigation of the effects of changing the apodization function and beam geometry on the quantitative determination of oxygen in silicon by FTIR. The apodization functions used include boxcar, cosine, Happ-Genzel, and triangular functions. The beam geometry is varied by placing apertures between the interferometer and the silicon specimen. The effects of beam polarization and detector nonlinearity were also investigated. [(301) 921-3625]

Ehrstein, J.R., Downing, R.G., Stallard, B.R., Simons, D.S., and Fleming, R.F., **Comparison Depth Profiling of  $^{10}\text{B}$  in Silicon Using Spreading Resistance Profiling, Secondary Ion Mass Spectrometry, and Neutron Depth Profiling**, to be published in *Semiconductor Processing*, ASTM Special Technical Publication 850, ASTM, 1916 Race Street, Philadelphia, PA 19103 [paper given at Silicon Processing Symposium, San Jose, CA, February 6-9, 1984].

Depth profiling of intentional dopants is an important measurement in the semiconductor industry both for process and device modeling and for process control. A comparison of  $^{10}\text{B}$  implants into silicon as measured by spreading resistance profiling, secondary ion mass spectrometry, and by neutron depth profiling is presented. The boron implantations were done at several fluences and energies into bare silicon and through several thicknesses of thermally grown oxides. Sources of error and their relation to observed differences among the techniques are discussed. [(301) 921-3625]

Thurber, W.R. and Lowney, J.R., **Electrical Transport Properties of Silicon**, to be published in book, *VLSI Handbook*, Academic Press, 111 Fifth Avenue, New York, NY 10003.

This short review of the electrical transport properties of silicon was written as a chapter for a VLSI handbook. The titles of the seven sections are: (1) Definition of Transport, Transport Equation; (2) Conversion Between Resistivity and Dopant Density; (3) Mobility of Charge Carriers; (4) Temperature Dependence of Resistivity and Mobility; (5) Dependence of Drift Velocity on Electric Field; (6) Minority-Carrier Mobility, Lifetime, and Diffusion Length; and (7) Mobility in an MOS Inversion Layer. The chapter includes five tables, seven figures, and 35 references. [(301) 921-3625]

Thurber, W.R., Lowney, J.R., and Phillips, W.E., **Measurement Techniques for High Power Semiconductor Materials and Devices: Annual Report, January 1, 1982 to March 31, 1983**, to be published as NBSIR 84-2838.

This annual report is the final one in a series which describes NBS research to develop procedures for the effective utilization of deep-level measurements to detect and characterize defects which reduce lifetime or contribute to leakage

Silicon Materials, cont'd.

current in power-device-grade silicon. During this reporting period, the previously written computer program for predicting excess-carrier lifetime was revised to calculate more accurately lifetimes for high or low injection conditions and in space-charge regions. Comparisons were made between lifetime measurements on platinum-doped silicon diodes and the predictions of the computer model. As part of the effort to extend the procedures to analyze data from nonexponential transient capacitance measurements, the time dependence of the capacitance-voltage relationship of a heavily platinum-doped silicon diode was measured as a function of bias voltage. Included as appendices are three recent publications resulting from the work. A listing of the lifetime-predicting computer program is also an appendix.

[(301) 921-3625]

## Recently Published

Lowney, J.R. and Thurber, W.R., **Evidence of Band-Gap Narrowing in the Space-Charge Layer of Heavily Doped Silicon Diodes**, Electronics Letters 20, No. 3, pp. 142-143 (February 1984).

The gradient voltage has been measured for seven heavily doped, graded-junction silicon diodes at 300 K. Experimental values up to nearly 0.5 V lower than theoretical predictions have been observed. The lowering is attributed to band-gap narrowing in the space-charge region. This narrowing is expected to be much larger than in neutral material of the same doping density because of the absence of free-carrier screening.

[(301) 921-3786]

Forman, R.A., Bell, M.I., Mayo, S., and Kahn, A.H., **Effect of Spatial Averaging on the Compositional Analysis of Crystals by Absorption Spectroscopy**, J. Applied Physics, 55, No. 2, pp. 547-554 (January 1984).

Calculations of optical absorption based on a model of a single crystal containing spatially periodic compositional variations are presented. These variations can contribute a significant source of systematic error in the analysis of composition by optical or surface techniques. The model is most appropriate for melt-grown crystals, in particular for striated semiconductor crystals, and the surface concentration profile which it predicts is confirmed by comparison with a published x-ray topographic study of silicon. Implications of the results for optical absorption studies of impurities in silicon crystals are discussed, and it is shown that significant measurement errors may occur.

[(301) 921-3625]

Integrated Circuit Test Structures

## Released for Publication

Mazer, J.A., Linholm, L.W., and Saxena, A.N., **An Improved Test Structure and Kelvin-Measurement Method for the Determination of Integrated Circuit Front Contact Resistance.**

The use of an improved microelectronic test structure and associated Kelvin measurement method for determining front contact resistance (circuit-loading resistance) of a metal/semiconductor ohmic contact is described. The values of front contact resistance for aluminum/silicon contacts are determined using this Kelvin-cross structure and are compared with values determined by a two-terminal contact chain method and with values determined by a Kelvin voltage divider method. The values of front contact resistance using the Kelvin-cross structure and associated measurement method are shown to be less sensitive to photolithographic process variations and electrical measurement errors than those determined using the other two structures and measurement methods.

[(301) 921-3621]



Integrated Circuit Test Struc., cont'd.

Roenker, K.P. and Linholm, L.W., **An NMOS Test Chip for a Course in Semiconductor Parameter Measurements**, to be published as NBSIR 84-2822.

This report describes an NMOS test chip, NBS-40, which was developed to be used in graduate level electronics engineering courses involving semiconductor parameter measurements associated with the fabrication of integrated circuits. The 35 test structures included in the test chip and their use in materials, device, and process parameter measurements are described. Details of the silicon gate NMOS process used in the chip fabrication are also provided. [Contact: Linholm, (301) 921-3541]

## Recently Published

Cassard, J.M., **A Sensitivity Analysis of SPICE Parameters Using an Eleven-Stage Ring Oscillator**, IEEE Trans. Electron Devices, ED-31, pp. 264-269 and IEEE J. Solid State Circuits, SC-19, pp. 130-135 (February 1984).

SPICE is a circuit simulator which predicts node voltages and currents as a function of time from device model parameters. Model parameters are determined by the manufacturing process. Process-induced variations in these parameters occur within a chip or from chip to chip and cause corresponding variations in circuit performance. Values for the model parameters used in simulators are usually obtained from measurements on test structures which are found along the periphery of the circuit or in test chips located at several sites on the product wafer. Because of the spatial separation between test structures and the circuits of interest, differences between measured and simulated performance can occur. This paper presents examples of how well model parameters extracted from a test chip can predict the ac response of a dynamic circuit element on the same wafer. Simulation results show which

model parameters are critical to performance. A comparison between measurement and simulation results is given and the importance of intra-chip and intra-wafer parameter variations is discussed. For the samples tested, the polysilicon gate linewidth variation was determined to be the primary cause of the ring oscillator frequency variation. [(301) 921-3621]

Suehle, J.S., Linholm, L.W., and Kafadar, K., **Minimum Test Chip Sample Size Selection for Characterizing Process Parameters**, IEEE Trans. Electron Devices, ED-31, pp. 257-264 and IEEE J. Solid State Circuits, SC-19, pp. 122-129 (February 1984).

A method for determining a test chip sample size to estimate effectively the electrical parameter distributions on an integrated circuit wafer is presented. This method gives relations among sample size and the figure of merit for four statistical techniques (trimmed mean, biweighted mean, median, and arithmetic mean) by which estimates are calculated. To demonstrate the use of this method, it has been applied to the evaluation of a CMOS fabrication process. Measurements on wafers completely patterned with identical test chips were used to determine actual parameter distributions for an entire wafer (true parameter values). Estimates of true parameters were determined using a site selection plan which is representative of sampling plans employed in industry. The above four statistical techniques were used to compute estimates for electrical parameters and their respective figures of merit. These estimates were compared with the true parameter values determined from testing all test chips on the wafer. When this method is used in conjunction with other criteria for test chip sample size, it enables judgments to be made on the effectiveness of sampling strategies for various processes and process technologies. The results, reported in this paper for CMOS processes, are interpreted for the case when only criteria concerning the slope

Integrated Circuit Test Struc., cont'd.

of the figure of merit with the sample size are considered.

[(301) 921-3621]

Yen, D. and Linholm, L.W., **Using Linewidth Measurement Test Structures to Evaluate Lithographic Processes and Equipment**, Test & Measurement World, 4, No. 3, pp. 48-61 (March 1984).

Test structures included on the wafer during semiconductor fabrication can help the process engineer evaluate semiconductor materials, process control and process equipment. One of the most important test methods used is the measurement of linewidth. In many cases, the results from electrical measurements on a cross-bridge sheet resistor can be used to determine the electrical linewidth of a conducting layer. Test chips that contain arrays of identical cross bridges can also help determine the uniformity of a lithographic process.

[(301) 921-3621]

Process & Device Modeling

Released for Publication

Albers, J., Wilson, C.L., and Blue, J.L., **The Effect of Bevel Angle and Number of Points on Spreading Resistance Data Analysis**, to be published in Extended Abstracts of the Electrochemical Society [paper to be given at Society conference, New Orleans, LA, October 7-12, 1984].

The semiconductor equations are used to obtain the carrier profile along a beveled structure. The spreading resistance is calculated on a scale much finer than the present experimental resolution of the technique. Spreading resistance algorithms are used on data spaced at the present experimental resolution. The difference between atomic and carrier densities along the bevel and the errors inherent in finite-layer algorithms are investigated. This is meant to provide insight into limita-

tions of spreading resistance due to these sources.

[(301) 921-3621]

## Recently Published

Albers, J. and Berkowitz, H.L., **The Relation Between Two-Probe and Four-Probe Resistances on Nonuniform Structures**, J. Electrochemical Society, 131, No. 2, pp. 392-398 (February 1984).

A general relation between the two-probe resistance (spreading resistance) and the four-probe resistance on nonuniform structures is derived. In addition, an expression is derived for the derivative of the spreading resistance with respect to the logarithm of the probe spacing, and discussed for the evaluation of these equations for nonuniform structures. The relation between the four-probe resistance,  $Z(x,S)$ , and the incremental sheet resistance,  $R(x)$ , is shown to arise in the limit as the probe spacing becomes large compared to the distance to an insulating boundary. Specific examples are drawn from calculations on implant-type structures into substrates having insulating boundaries near the end of the implanted region (junction isolation) as well as those where the insulating boundary is far from the implanted region (emulating the back surface of a same conductivity type substrate). Also presented is a method for the self-consistent calibration of spreading resistance profiles utilizing  $Z(x,S)$ .

[(301) 921-3621]

Brodfehrer, B.P., Galloway, K.F., and Wilson, C.L., **Comparison of Simple Approximations and Numerical Solutions for the Threshold Voltage of Ion-Implanted Long-Channel MOSFETs**, IEEE Trans. Education, E-27, No.1, pp. 3-6 (February 1984).

The very simple approximations used for calculating the threshold voltage shifts for ion-implanted long-channel MOSFETs in classroom discussions are compared



Process & Device Modeling, contd.

measurements are compared with the calculated threshold voltage shifts.  
[Contact: Galloway, (301) 921-3541]

Power Devices

Released for Publication

Berning, D.W., **Effects of Very Fast Drain Voltage Transitions on Power MOSFETs.**

Radio frequency energy was applied to the drains of high voltage power MOSFETs to examine possible effects of high slew rates, such as those that may be encountered in switching applications, on these devices. Evidence of partial turn-on of the parasitic bipolar transistor was observed.  
[(301) 921-3621]

Packaging

Recently Published

Oettinger, F.F., **Thermal Evaluation of VLSI Packages Using Test Chips -- A Critical Review**, Solid State Technology, 27, No. 2, pp. 169-179 (February 1984).

The design, analysis, and utilization of test chips for the thermal evaluation of VLSI packages are discussed. The factors that determine the thermal performance of microelectronic devices are the circuit type, the fabrication technology, the die size, the die attachment method, the package and heat dissipater design, and the ambient environment. Thermal test chips are extensively used in characterizing new package designs for VLSI chips in the 1- to 10-W range. The information discussed should allow the engineer to rationally choose a particular test chip design and to understand the implications of measurements to thermally characterize a particular chip-package system.  
[(301) 921-3541]

Other Semiconductor Metrology

Released for Publication

Schafft, H.A., Younkins, C.D., Grant, T.C., Kao, C-Y., and Saxena, A.N., **Effect of Passivation and Passivation Defects on Electromigration Failure in Aluminum Metallization**, to be published in Proc. International Reliability Physics Symposium [paper given at Symposium, Las Vegas, NV, April 5, 1984].

Metal line structures with intentional defects in the passivation, to simulate cracks or pin holes, were used in electromigration studies. Results show that the stress changes in the metallization caused by these defects are not as important as the restraining action of the passivation in affecting a metallization's resistance to electromigration failure. Also, the observed effects of restorative forces acting on the metallization suggests that continuous monitoring for open-circuit failure may be necessary to obtain an accurate measure of the mean-time-to-failure.  
[(301) 921-3621]

**FAST SIGNAL ACQUISITION, PROCESSING, AND TRANSMISSION**Waveform Metrology

Released for Publication

Oldham, N.M., **Power Calibration Standard Based on Digitally Synthesized Sinewaves.**

The unit of electric power at 60 Hz is often derived using impedance bridge techniques in which the alternating voltage is referred to the direct voltage standard through a thermal converter. An alternative calibration technique is described in which the ac to dc transfer is made through digital-to-analog converters (DACs) in the form of a dual-channel digital sinewave generator. The power is calculated from



Waveform Metrology, cont'd.

measurements of voltage, current, and phase angle, all of which rely on the accuracy of the digital generator and ultimately on the accuracy of the DACs. Measurement uncertainties of less than 100 ppm have been achieved.  
[(301) 921-2727]

**Schoenwetter, H.K., A Programmable Precision Voltage-Step Generator for Testing Waveform Recorders.**

A pulse generator for testing the approximate step-response of waveform recorders is described. The initial and final levels of voltage steps are each programmable within the range of  $\pm 1$  V for a 50-ohm termination and within  $\pm 5$  V for a high-impedance load. Voltage steps within these ranges settle to within  $\pm 0.02\%$  of full-scale range in less than 30 and 40 ns, respectively, for a load capacitance of  $< 30$  pF. The corresponding 10-90 percent transition durations are approximately 7 and 12 ns.  
[(301) 921-2727]

## Recently Published

Lawton, R.A., Nahman, N.N., and Bigelow, J.M., **A Solid State Reference Waveform Standard**, Proc. IEEE Instrumentation and Measurement Technology Conference, pp. 74-76 (1984) [Conference Long Beach, CA, January 17-18, 1984; extended version in preparation for publication in 1984.

A solid-state reference waveform filter has been developed which uses the Maxwell-Wagner capacitor effect. This filter is realized in a stripline configuration with a lossy dielectric consisting of a thick (5- $\mu$ m) layer of SiO<sub>2</sub> on Si. The equivalent circuit of this filter is equivalent to that for previously developed filters which used a lossy liquid dielectric. A preliminary design has been completed and a filter fabricated for which the design characteristic impedance, 38  $\Omega$ , and transition duration (rise time), 350 ps, agree with

measured values to within 2% and 3%, respectively. The temperature dependence of the filter transition duration has been estimated from the temperature dependence of the filter conductance to be about 1% per degree Celsius.  
[(303) 497-3339]

Cryoelectronic Metrology

## Released for Publication

**Niemeyer, J., Hinken, J.H., and Kautz, R.L., Microwave-Induced Constant-Voltage Steps at One Volt from a Series Array of Josephson Junctions.**

It is demonstrated that a series array of 1474 Josephson junctions can produce quantized voltages up to 1.2 V when driven by microwaves at 90 GHz in the absence of a dc bias. This result brings closer the possibility of a practical Josephson voltage standard at the 1-V level.  
[Contact: Kautz, (303) 497-3391]

## Recently Published

**McDonald, D.G., Power Gain of a SQUID Amplifier**, Applied Physics Letters, 44, No. 5, pp. 556-558 (March 1984).

The power gain of a dc superconducting quantum interference device (SQUID) amplifier, with tuned input and output circuits, is computed as a function of the current and magnetic biases. A gain of 20300 is found at 1.5 GHz and 3470 at 3.0 GHz, implying a frequency dependence to the gain of approximately  $\omega^{-2}$ . The gain, as derived from the resistively shunted junction model, is compared with the gain of a simplified model based on the dc magnetic response  $V\phi$ . This comparison shows that the  $V\phi$  description of the SQUID can lead to large errors.  
[(303) 497-5113]

Antenna Metrology

## Released for Publication

**Hill, David A., Antennas for**

Antenna Metrology, cont'd.

**Geophysical Applications**, to be published as chapter in book, Handbook on Antenna Theory and Design, Eds. Y.T. Lo and S.W. Lee [publisher, Howard W. Sams and Company].

This chapter is part of the Handbook section on Applications; other sections, with some 40 chapters in all, deal with Fundamentals, Antenna Theory, and Related Topics. The chapter discusses a number of antennas which are used for subsurface probing of the earth. The two most commonly used antennas are grounded wires and loops, and they are covered in detail for both time-harmonic and transient excitations. Emphasis is placed on the extremely low frequency (ELF) portion of the spectrum where it is possible to probe the earth to depths of several hundred meters.

[(303) 497-3472]

**Wittman, R.C., Probe Correction in Spherical Near-Field Scanning, Viewed as an Ideal Probe Measuring an Effective Field** [paper to be given at IEEE Antennas and Propagation Society Meeting, Boston, MA, June 1984].

In order to reduce measurement and computation complexity, most probe-corrected, spherical near-field scanning facilities use a special "symmetric" probe, the output of which exhibits a  $\sin \chi$  --  $\cos \chi$  dependence as the probe is rotated about its axis by an angle  $\chi$ . We show here that such a probe is mathematically equivalent to ideal dipole probes measuring an effective field. Computational efficiency and structural simplicity result, since much of the effort concerns the calculation of the effective field, and this may be accomplished with a no-probe correction algorithm.

[(303) 497-3326]

Noise Metrology

Recently Published

**Counas, G.J., NBS 2.0 GHz to 4.0 GHz Automated Radiometer Operation and Service Manual**, NBSIR 83-1697 (January 1984).

The equipment described by this manual is the 2.0 to 4.0 GHz subsystem of the automated radiometer. This section of the multiband automated radiometer is a coaxial total power radiometer which implements a six-port reflectometer for impedance characterization and correction and utilizes a newly developed broadband cryogenic noise standard. NBS noise measurement capability in this frequency band has been expanded by the addition of this system which adds continuous frequency coverage to existing services along with the capability to measure cryogenic noise sources. The manual includes operation and service information.

[(303) 497-3546]

**Daywitt, W.C., A Coaxial Noise Standard for the 1 GHz to 12.4 GHz Frequency Range**, NBS Technical Note 1074 (March 1984).

This note describes the design and construction of a coaxial thermal noise standard. The standard is designed to operate at the boiling point of liquid nitrogen with a noise temperature accurate to  $\pm 1$  K in the frequency range from 1 GHz to 12.4 GHz.

[(303) 497-3720]

Optical Fiber Metrology

Released for Publication

**Rodhe, P.M., Intramodal Part of the Transfer Function for an Optical Fiber.**

Intramodal contributions in measurements of optical fiber bandwidth are investigated theoretically and experimentally in the quasimonochromatic case. A relation is established between the intramodal transfer function and a possibly non-Gaussian source spectrum, which may also vary with modulation frequency. By considering the latter



Optical Fiber Metrology, cont'd.

variation in particular, we are able to predict the intramodal length dependence and show how it may deviate from that of a conventional approach.

[Contact: Sanders, (303) 497-5341]

**Rodhe, P.M., The Bandwidth of a Multimode Fiber Chain.**

We propose a new method for evaluating the baseband transmission in a multimode fiber chain. Carnevale and Paek [Bell Syst. Tech. J., Vol. 62, pp. 1415-1431 (1983)] stated that errors in the fiber manufacturing process will randomly distort a desired index profile, presumably of power-law type. We extend their discussion to the bandwidths of concatenated fibers, by considering Gaussian approximations to actual transfer functions. The bandwidth can thus be separated into two parts, one of which is due to the over- and undercompensation of individual, idealized power-law profiles and the other which refers to random profile distortions as well as possible mode coupling within mode groups. The former part should normally dominate the length dependence of longer chains. The latter part may be replaced by an expectation value, typical for the actual manufacturing process. A remarkably good agreement is achieved between experimental and predicted bandwidths for various chain configurations.

[Contact: Sanders, (303) 497-5341]

Other Fast Signal Topics

Released for Publication

**Sanders, A.A., Some Future Trends in Optical Electronic Metrology**, to be published in Proc. 1984 Measurement Science Conference [paper given at Conference, Los Angeles, CA, January 19-20, 1984].

The use of optical related devices in high technology is expanding at a dramatic rate. Applications include the

expanding use of optical fibers in telecommunications and sensors, lasers in industrial processing and medicine, optical storage devices, directed energy weapons for defensive purposes, non-destructive testing, -- the list goes on and on. The Optical Electronics Metrology Group of the National Bureau of Standards has the responsibility for developing the standards, measurement data, and methodology infrastructure for supporting much of this expanding technology. This paper will review some of the ongoing research conducted by this Group and some of the perceived important technological applications in this area for the next few years. It will discuss Group plans for developing the measurement infrastructure to support these innovations. The intent is to generate a dialogue to improve the Group's planning process and help sort out the most pressing priorities for optical measurements.

[(303) 497-5341]

**ELECTRICAL SYSTEMS**Power Systems Metrology

Released for Publication

**Hebner, R.E. and Kelley, E.F., Electro-Optic Electric-Field Measurements Near Oil-Pressboard Interfaces**, to be published in Conf. Record of 1984 International Symposium on Electrical Insulation [paper to be given at Symposium, Montreal, Canada, June 11-13, 1984].

Electro-optical Kerr-effect measurements are made to characterize the electric field in the vicinity of pressboard interfaces in transformer oil. The interfaces are placed between parallel plate electrodes and are oriented parallel to the field direction and in contact with both electrodes. The electric field enhancement in the liquid alone (due to space charge) is compared with the enhancement with

Power Systems Metrology, cont'd.

interfaces installed. These results serve to better define the roles of space charge and interfacial surface charging in pressboard/transformer-oil high-voltage systems.

[(301) 921-3121]

Hebner, R.E., Kelley, E.F., Fitzpatrick, G.J., and Forster, E.O., **The Effect of Aromatic Impurities on the Positive Streamer Growth in Marcol 70**, to be published in Conf. Record of 1984 International Symposium on Electrical Insulation [paper to be given at Symposium, Montreal, Canada, June 11-13, 1984].

The growth of positive streamers has been photographed in Marcol 70 in the presence and the absence of dimethylaniline (DMA). Marcol 70 is a fluid which is chemically similar to transformer oil, but with the aromatic components removed. This combination has been studied previously by other authors, and was chosen for this work because it was expected to provide useful information on the contribution of aromatic components to the electrical properties of transformer oil. As in earlier studies, it was noted that the positive streamers initially propagate at or near sonic speed. After the streamer has propagated some distance across the inter-electrode gap, a supersonic secondary streamer develops that leads to breakdown. The initiation of this second event is significantly delayed by DMA. As in earlier studies in n-hexane, the reason for this behavior is assumed to be structural changes in the streamers because of the low ionization potential of DMA. These structural changes, in turn, lead to a modification of the electric field distribution between the positive streamer tips and the plane cathode. Information derived from the photographs suggests that the field distribution changes from a very nonuniform to a more uniform one, which would lead to the observed higher breakdown voltages. The

data presented are not in complete agreement with those reported in the literature. This disagreement is believed to be attributable to experimental differences.

[(301) 921-3121]

Misakian, M., **Electrical Parameters in 60-Hz Biological Exposure Systems and Their Measurement: A Primer**, to be issued as NBS Technical Note.

This report presents material which is intended to provide assistance in the measurement of a number of electrical parameters that are of importance during bioeffects research involving 60-Hz electric and magnetic fields. The parameters that are considered are the electric field strength E, the magnetic induction or flux density B, field uniformity, harmonic content, phase relations between field components, and corona. Descriptions of the fields and methods for their laboratory generation are surveyed. The text is purposely elementary with references provided to aid the interested reader in obtaining a fuller understanding of many of the topics. It is shown that using relatively simple instrumentation, it is possible to characterize reasonably well the electric and magnetic fields used in animal exposure studies.

[(301) 921-3121]

Misakian, M., **Calibration of Flat 60-Hz Electric Field Probes.**

A parallel-plate apparatus which is suitable for calibration of flat 60-Hz electric field probes used in bioeffects studies is described.

[(301) 921-3121]

Van Brunt, R.J., Anderson, W.E., and Lazo, T.C., **Production Rates for Discharge Generated SOF<sub>2</sub>, SO<sub>2</sub>F<sub>2</sub> in SF<sub>6</sub> and SF<sub>6</sub>/H<sub>2</sub>O Mixtures**, to be published in Proc. Fourth International Symposium on Gaseous Dielectrics [paper given at Symposium, Knoxville, TN, April 30 - May 3, 1984].



Power Systems Metrology, cont'd.

Production rates for  $\text{SO}_2\text{F}_2$ ,  $\text{SO}_2\text{F}_2$ , and  $\text{SO}_2$  have been measured by quantitative gas analysis during continuous corona discharges in compressed  $\text{SF}_6$  containing trace levels (10 to 200 ppm) of water vapor for total gas pressures between 100 and 300 kPa. The rates are expressed both in terms of moles-per-unit of energy dissipated in the discharge, and in moles-per-unit of charge transported in the gap. Variations in the absolute and relative concentrations of  $\text{H}_2\text{O}$  and  $\text{SO}_2\text{F}_2$ , respectively, were also monitored. Determinations were made of the polarity, power, and pressure dependences of these rates. The time rates-of-production for  $\text{SO}_2\text{F}_2$  and  $\text{SO}_2$  are more nearly proportional to the discharge current than to the power dissipation. The results indicate that the equilibrium concentration of  $\text{H}_2\text{O}$  is significantly affected by the discharge. The influence of  $\text{O}_2$  and  $\text{H}_2\text{O}$  on oxyfluoride production is discussed. [(301) 921-3121]

## Recently Published

Hebner, R.E., **Development of Power System Measurements -- Quarterly Report April 1, 1983 to June 30, 1983**, NBSIR 84-2809 (February 1984).

This report documents the progress on five technical investigations sponsored by the Department of Energy. Three were performed by the NBS Electrosystems Division, the fourth by the Department of Electrical Engineering of the University of Southern California, and the fifth by the College of Engineering at the University of South Carolina. The work described covers the period from April 1, 1983 to June 30, 1983. The report emphasizes the calibration of instruments designed to measure the 60-Hz electric field in biological exposure facilities, the effect of water on  $\text{SF}_6$  corona discharges, the measurement of failure mechanisms in liquid/solid and gas/solid insulating systems, and the development and behavior of active

insulators.  
[(301) 921-3121]

Hebner, R.E., **Development of Power System Measurements -- Quarterly Report July 1, 1983 to September 30, 1983**, NBSIR 84-2818 (February 1984)

This report documents the progress on three technical investigations sponsored by the Department of Energy and performed by the NBS Electrosystems Division. The work described covers the period from July 1, 1983 to September 30, 1983. The report emphasizes the measurement of the 60-Hz electric and magnetic field in biological exposure facilities, the measurement of water vapor, the production rates of oxyfluorides in  $\text{SF}_6$  corona discharges, and in the measurement of space charge in transformer oil. [(301) 921-3121]

Magnetic Materials and Measurements

Released for Publication

Cromar, M., Clark, A.F., and Fickett, F.R., **Monopole Detection Studies at NBS**, to be published in Proc. Monopole Detection by Induction Techniques Conference [paper given at Conference, Ann Arbor, MI, October 5-9, 1983].

Magnetic monopole detectors have been under study and evaluation at NBS for the past year. This paper describes some of the work. It is the written version of a brief workshop contribution made at the MONOPOLE '83 conference held at the University of Michigan. [(303) 497-5375]

Goldfarb, R.B. and Minervini, J.V., **Calibration of AC Susceptometer for Cylindrical Specimens.**

The absolute magnetic susceptibility of cylindrical specimens is obtained with an ac susceptometer whose calibration is based on a calculation of mutual inductance. [(303) 497-3650]

Magnetic Materials & Meas., cont'd.

Goldfarb, R.B., Rao, K.V., Chen, H.S.,  
**Magnetic Phase Diagram of the Amorphous  
 Pd-Fe-Si Ferroglass Alloy System: New  
 Analysis of Spinglass Measurements.**

The real (in-phase) and imaginary (quadrature) components of ac magnetic susceptibility were used to determine the Curie ( $T_C$ ) and spin-freezing ( $T_f$ ) temperatures, and hence the magnetic phase diagram, of the Pd-Fe-Si system. For increasing Fe concentration, this alloy goes from a simple spinglass (in which a paramagnetic-to-spinglass transition occurs as a function of decreasing temperature) to a ferroglass (defined as a spinglass in which there is an intervening ferromagnetic-like state). It is shown that the peak in the imaginary, or loss, component of susceptibility is especially useful in determining  $T_f$ . Such a determination is difficult in the case of ferroglasses when only the vector susceptibility is measured. In such cases,  $T_f$  is below the temperature of the vector susceptibility maximum. DC magnetization measurements of a ferroglass show that the field-cooled and zero-field-cooled curves bifurcate at  $T_f$ , below the peak temperature. The thermoremanent magnetization decays with increasing temperature until  $T_f$ , whereupon it levels off, finally dropping to zero at  $T_C$ . It is emphasized that spin freezing is a function of not only temperature, but also of time and field. Therefore, a phase diagram that purports to show  $T_f$ , based on ac susceptibility measurements as a function of temperature, is strictly valid only for the frequency and rms field specified. This caveat is most applicable to ferroglasses.

[(303) 497-3650]

Superconductors

Released for Publication

Ekin, J.W. and Hong, M., **Critical Parameters and Strain Effects in**

**Liquid-Infiltrated Nb-Ta/Sn Multifilamentary Superconductors.**

Data are presented on the strain dependence of the critical current and critical field of Nb-Ta/Sn superconductors fabricated by the liquid-tin infiltration process. The results show that liquid infiltrated Nb-Ta/Sn superconductors have several significant advantages over bronze-process Nb/Sn superconductors: an overall  $J_c$  that is 3 to 10 times higher for magnetic fields in the range 13 to 20 T, an irreversible (damage) strain limit twice as large, and a  $J_c$  elastic-strain sensitivity less than half as large at fields above about 16 T. These improved properties are attributed to several unique characteristics of the liquid infiltration process: a tough Nb-Ta matrix, fine equiaxial A15 grains, and a uniform stoichiometric Sn concentration.

[(303) 497-5448]

Tinkham, M., Beasley, M.R.,  
 Larbalestier, D.C., Clark, A.F., and  
 Finnemore, D.K., **Research  
 Opportunities in Superconductivity.**

Opportunities for research in the field of superconductivity are identified in this report of a "Workshop on Problems in Superconductivity" held at Copper Mountain, Colorado, August 22-23, 1983. Key problems in superconductivity, high payoff areas of research, barriers to progress, and the need for new facilities are outlined in the three areas of basic physics, materials, and devices.

[Contact: Clark, (303) 497-3253]

## Recently Published

Clark, A.F., Goodrich, L.F., and  
 Fickett, F.R., **Experience in  
 Standardizing Superconductor  
 Measurements**, Journal De Physique,  
 Colloque C1, supplement to Vol. 45, No.  
 1, pp. C1-379 - C1-372 (January 1984).

The research leading to standard measurement techniques for characterizing practical superconductors is described.



Superconductors, cont'd.

## Recently Published

Special attention is given to measuring critical current.  
[(303) 497-3253]

Other Electrical Systems Topics

## Recently Published

Bell, R.S., Jones, C.K., and Fickett, F.R., **Temperatures, Cryogenics**, pp. 31-35 (January 1984).

Interfaces between metals and polytetrafluoroethylene (TFE) are common in cryogenic systems. In this paper we present results from measurements of the temperature dependence of the dynamic coefficient of friction between commercially pure copper and TFE. The effect of the copper surface finish was also determined. The effects of load and speed were evaluated over a small range, but nearly all data were taken at a surface speed of  $5.4 \text{ cm}\cdot\text{s}^{-1}$  with a load of  $1.63 \text{ N}\cdot\text{cm}^{-2}$ . These values are typical of those encountered by the moving parts of some cryogenic machinery.

[Contact: Fickett, (303) 497-3785]

**ELECTROMAGNETIC INTERFERENCE**

## Released for Publication

Crawford, M.L. and Koepke, G.H., **Operational Considerations of a Reverberation Chamber for EMC Immunity Measurements, Some Experimental Results**, to be published in Proc., 1984 IEEE National Electromagnetic Compatibility Symposium [paper given at Symposium, San Antonio, TX, April 24-26, 1984].

This paper describes measurement procedures and results obtained from evaluation of a shielded chamber having dimensions (2.74 x 3.05 x 4.57) m modified into a mode-tuned reverberation

chamber. A brief description of the measurement setup and resonant cavity theory is given. The measurements described include an evaluation of the following chamber parameters: 1) excitation and receiving antennas' voltage standing wave ratio and efficiency, 2) mode tuner effectiveness, 3) loss, and 4) electromagnetic test field statistical characteristics. In addition, the measurement results of two techniques to determine the field strength in the reverberation chamber are compared. Results shown cover the frequency range 200 MHz to 18 GHz.  
[(303) 497-5497]

Daywitt, W.C., **Complex Permittivity of Beryllium Oxide Between 100 and 300 Kelvins at 9.3 Gigahertz.**

Measurement results at 9.3 GHz of the relative dielectric constant and loss tangent of ceramic beryllium oxide at 99, 145, 223, and 300 Kelvins are reported.  
[(303) 497-3720]

Driver, L.D. and Reeve, G.R., **Application of a Systematic Approach to an Investigation of HF Interference to a Shipboard Radar Set**, to be published in Proc. 1984 IEEE National Electromagnetic Compatibility Symposium [paper given at Symposium, San Antonio, TX, April 24-26, 1984].

This paper describes an investigation of electromagnetic interference to shipboard radar caused by a colocated HF, one kilowatt transmitter. The test procedures and analysis used to determine the points of EM field entry, the corrective measures taken, and a summary of the results achieved are described.  
[(303) 497-3557]

Kanda, M., **A Methodology for Evaluating Microwave Anechoic Chamber Measurements** [paper to be given at Sixth Zurich Symposium and Technical Exhibition on Electromagnetic Compatibility, Zurich, Switzerland, March 5-7, 1985].

Electromagnetic Interference, cont'd.

The anechoic chamber measurement is evaluated in terms of the net power delivered to a transmitting antenna, the near-zone gains of open-ended rectangular waveguides and rectangular pyramidal horns, and reflections from chamber walls. The on-axis field intensity of the standard transmitting horn in an anechoic chamber is calculated in terms of the net power delivered to the transmitting antenna. The resulting data can be used for estimating the overall uncertainty in the anechoic chamber measurements. The statistical control of the measurement process by use of transfer standard antennas will monitor the measurement uncertainties. This paper discusses the methodology for evaluating anechoic chamber measurements.

[(303) 497-5320]

Ondrejka, A.R. and Adams, J.W., **Shielding Effectiveness Measurement Techniques**, to be published in Proc. 1984 IEEE National Symposium on Electromagnetic Compatibility [paper given at Symposium, San Antonio, TX, April 24-26, 1984].

Five methods of measuring shielding effectiveness of a lossy material are compared. Comparative measurement data are shown, and insights are offered as to why the results of the different methods do or do not agree. This is a preliminary analysis, not a definitive work.

[(303) 497-3328]

Wilson, Perry F., **Small Aperture Analysis of the Dual TEM Cell**, to be published in Proc. 1984 IEEE National Symposium on Electromagnetic Compatibility [paper given at Symposium, San Antonio, TX, April 24-26, 1984].

This paper describes an analysis of dual TEM cell coupling based on Bethe's small aperture theory. This approach allows one to model a variety of possible aperture shapes (circular, elliptical,

square etc.), including material-loaded apertures of finite thickness. Measurements demonstrate that the theory accurately predicts coupling for an unloaded aperture.

[(303) 497-3842]

## Recently Published

Alspach, W.J., Miller, C.K.S., and Reeve, G.R., **An Assessment of Electromagnetic Interference and Electromagnetic Compatibility (EMC) Measurement Practices to Meet U.S. Army Aviation Research and Development Command EMI/EMC Requirements**, NBSIR 84-1698 (January 1984).

A survey of selected industrial contractors, airframe manufacturers, and electronic test and calibration firms was conducted during June - August 1982 by the NBS Electromagnetic Fields Division, to assess industrial and commercial testing and measurement practices used to meet electromagnetic interference/electromagnetic compatibility (EMI/EMC) requirements of the U.S. Army Aviation Research and Development Command (AVRADCOM). This survey addressed the cost of conducting EMI/EMC tests; whether or not electronic components, subassemblies, systems, and their testing met specified AVRADCOM EMI/EMC tests and requirements; and whether the test practices, test equipment, and EMI/EMC requirements are appropriate. The following conclusions were reached: (1) Victim-source testing, although limited, is the only current EMI test that is meaningful for whole system testing. (2) It is questionable whether electronic systems will perform satisfactorily in a battlefield electromagnetic environment. (3) There is no correlation in EMI/EMC test practices; it is possible that electronic systems are overdesigned, overbuilt, and overtested. (4) Future issues such as high-level field testing and electromagnetic pulse (EMP) need to be addressed.

[Contact: Reeve, (303) 497-3557]



Electromagnetic Interference, cont'd.

Hill, D.A., **Theory of Near-Field Phased Arrays for Electromagnetic Susceptibility Testing**, NBS Technical Note 1072 (February 1984).

The feasibility of using a near-field arrays for electromagnetic susceptibility testing is studied. The basic objective is to control the element weightings such that a plane wave is generated within the test volume. The basic theory is developed for arbitrary array geometries, and numerical results are obtained for finite planar arrays. A general near-field array synthesis technique is developed; this technique minimizes the mean square error in the test volume while constraining the array excitations. The constraint prevents large currents and is useful in minimizing the fields outside the test volume. The basic idea looks promising, but some practical considerations, such as bandwidth and angular scanning limitations, require further theoretical and experimental investigations.

[(303) 497-3472]

Jesch, R.L. and McLaughlin, R.H., **Dielectric Measurements of Oil Shale as Functions of Temperature and Frequency**, IEEE Trans. Geoscience and Remote Sensing, GE-22, No. 2, pp. 99-105 (March 1984)

A high-temperature sample holder designed by the National Bureau of Standards was used to determine the dielectric properties of approximately 40 oil shale samples as functions of temperature and frequency. A description of the sample holder characterization is given along with the measurement procedure and the sample preparation. Experimental results are given for different oil shale samples, varying in yield from 0.024 L/kg (6 gal/ton) to 0.338 L/kg (81 gal/ton), that were measured at room temperature (25°C) up to 500°C and within the frequency range of 5 to 1000 MHz.

[(303) 497-3496]

**1984 CEEE CALENDAR**

June 18-21 (Gaithersburg, MD)

**Power Electronics Specialists Conference.** Co-sponsored by the the Power Electronics Council of the Institute of Electrical and Electronics Engineers and the National Bureau of Standards, the Conference is intended to provide a venue where specialists in circuits, systems, electron devices, magnetics, control theory, instrumentation, and power engineering may discuss new ideas, research, development, applications, and the latest advances in power electronics.

The Conference will incorporate six technical sessions (on converter circuits, converter systems, converter control, motor drives, power components, and modeling and analysis techniques), a one-day tutorial on Electromagnetic Compatibility in Power Systems, and three special "rap sessions" (EMI, RFI, and Noise: Fact or Fiction; Emerging Power Semiconductors: Positive and Negative Attributes; and Future Trends in Aircraft Power Electronics and Electrical Actuators).

[Contact: Sandra B. Kelley (301) 921-3541]

August 28-30 (Vail, CO)

**Short Course on Optical Fiber Measurements.** This course is addressed to scientists and engineers who are involved in fiber characterization. The course will emphasize concepts, techniques, and apparatus used in measuring the engineering parameters of telecommunication-grade fibers. A degree in electrical engineering or physics is assumed. The course will last three days with 18 hours of class time.

[Contact: Robert L. Gallawa (303) 497-3761]

## CEEE CALENDAR, cont'd.

October 15-17 (Boulder, CO)

**Symposium on Optical Materials for High Power Lasers.** The Symposium is the principal forum for the exchange of information on the physics and technology of materials for high-power lasers. Topics to be discussed include new materials, bulk damage phenomena, surface and thin film damage, design considerations for high-power systems, and fundamental mechanisms of laser-induced damage. The series of conference proceedings resulting from these annual symposia has collectively become the principal repository of information on optics for all aspects of high-power/high-energy lasers, including, in addition to the subjects given above, environmental degradation, durability, fabrication, material growth and deposition processes, and testing. [Contact: Aaron A. Sanders (303) 497-5341]

## NEW STANDARD REFERENCE MATERIALS

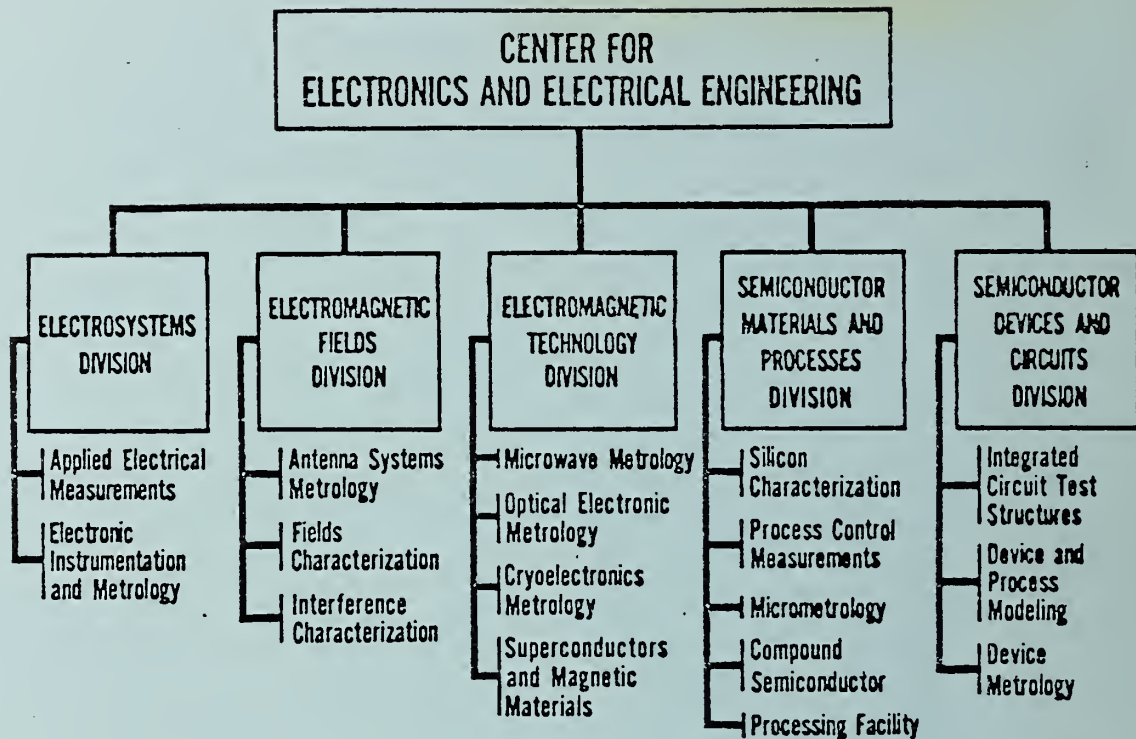
Two new Standard Reference Materials (SRMs) for calibrating equipment used to make spreading resistance measurements have been released by the Semiconductor Materials and Processes Division to the NBS Office of Standard Reference Materials for sale to the public. SRM 2526 applies to (111)-oriented p-type silicon surfaces and SRM 2527 to (111)-oriented n-type silicon surfaces. Each SRM consists of a set of about 15 specimens (number of specimens varies depending on availability of material of appropriate resistivities) of silicon, 6 x 12 mm in area and mounted on beveled metal blocks for convenient use in calibrating commercial spreading resistance equipment. These silicon chips have resistivities ranging from about 0.001 to 200  $\Omega \cdot \text{cm}$ . The uncertainties in resistivity range typically from 2 to 5 percent for p-type specimens and from 4 to 10 percent for n-type. Two companion SRMs for (110) silicon surfaces are about to be released (2528, p-type and 2529, n-type).

## SPONSORS OF WORK REPORTED IN THIS ISSUE

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