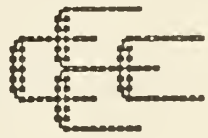
NBSIR 85-3181-3

Center for Electronics and Electrical Engineering



Technical Progress Bulletin

Covering Center Programs,
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1986 CEEE Events Calendar

December 1985

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National Engineering Laboratory
Gaithersburg, Maryland 20899

INTRODUCTION TO DECEMBER 1985 ISSUE OF THE CEEE TECHNICAL PROGRESS BULLETIN

This is the eleventh issue of a quarterly publication providing information on the technical work of the National Bureau of Standards Center for Electronics and Electrical Engineering. This issue of the CEEE Technical Progress Bulletin covers the second quarter of calendar year 1985.

Organization of Bulletin: This issue contains abstracts for all Center papers released for publication by NBS in the quarter and citations and abstracts for Center 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 Unpublished papers appear under the subheading "Released for Publication".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 now planned for fiscal year 1986, an announcement of recently issued 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 Electronics Division (formerly 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. To request a subscription or for more information on the Bulletin, write to CEEE Technical Progress Bulletin, National Bureau of Standards, Metrology Building, Room B-358, Gaithersburg, MD 20899 or call (301) 921-3357.

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 20.

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.

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SEMICONDUCTOR TECHNOLOGY PROGRAM

Silicon Materials

Released for Publication

Forman, R.A., Bell, M.I., Myers, D.R., and Chandler-Horowitz, D., **The Raman Spectrum of Carbon in Silicon.**

Raman spectroscopy is used to characterize carbon-doped silicon samples prepared by ion implantation and pulsed laser annealing. Sharp lines are observed in the Raman spectra due to the ^{12}C local mode at 604 ± 1 cm^{-1} and the ^{13}C local mode at 589 ± 1 cm^{-1}. At the highest carbon densities, these local modes broaden considerably. Identical spectra are obtained from a given carbon implant whether it is annealed using a 10-ns pulsed ruby laser or a 1-μs pulsed rhodium-6G dye laser. It is shown that Raman spectroscopy has sufficient sensitivity to detect striated carbon distributions in as-grown commercial silicon. Finally, at high carbon density in the implanted and laser-annealed samples, a disorder-induced first-order Raman spectrum is observed produced by the mass defect of the substitutional carbon.
[Contact: (301) 921-3786]

Mayo, S., Lowney, J.R., and Bell, M.I., **Evidence of Lattice Relaxation in Platinum-Doped Silicon,** to be published in the Proceedings of the Materials Research Society 1985 Spring Meeting, San Francisco, CA, April 15-18, 1985.

The photoionization cross section of the platinum-acceptor level in silicon was measured (in relative units) as a function of photon energy. Capacitance transients due to electron emission from this level were studied in a p^+n gated photodiode at temperatures of 40, 60, and 80 K. Measurements were made over the wavelength range of 2 to 5 μm with light from a prism monochromator with a constant bandpass of 10 meV. The platinum density in the diode was about 10^{14} cm^{-3}, providing a ratio of deep to shallow (phosphorus) levels of about 0.1. The data are in good agreement with the Ridley-Amato lattice-coupling model when a Huang-Rhys parameter of S = 0.3 is used, corresponding to a Frank-Condon shift of 15 meV if an average phonon energy of 50 meV is assumed. The electronic energy of the acceptor level was 226 ± 5 meV below the conduction band, independent of temperature and in agreement with previous studies of thermal ionization. The present results provide the first clear experimental evidence of lattice relaxation associated with a deep level in silicon. However, the observed Huang-Rhys parameter is smaller than the theoretical estimates of Lowther ($S \cong 1$), suggesting that multiphonon emission may not be the only mechanism for carrier recombination involving this level.
[Contact: (301) 921-3786]

Analysis Techniques

Released for Publication

Baghdadi, A., and Gladden, W.K., **ADC Errors in Quantitative FT-IR Spectroscopy,** to be published in the Proceedings of the 1985 International Conference on Fourier and Computerized IR Spectroscopy, Proc. SPIE - The International Society for Optical Engineering, P.O. Box 10, Bellingham, WA 98227-0010 [paper given at Conference, Ottawa, Ontario, June 24-28, 1985].

Analog-to-digital converters (ADCs) are the interface between the analog data actually collected by a Fourier transform infrared (FT-IR) spectrophotometer and the digital computer which processes these data. In the typical case of absorption spectra obtained using a broadband source, interferograms with a very wide dynamic range (typically on the order of 10^6:1) are required in order to produce spectra with adequate signal-to-noise ratios. This is a very demanding application, especially for a high-speed ADC. A numerical model of the effect of ADC errors, of ±1 least significant bit (LSB) shows that they can

Analysis Techniques, cont'd.

nificant bit (LSB) shows that they can produce errors as large as 50% on the height of peaks in an absorbance spectrum at low signal levels. This result is consistent with our experimental observations. We tested four ADC circuit boards (all the same model) in our FT-IR spectrometer. At low signal levels, the disagreement between peak heights in spectra collected using the different ADC boards ranged as high as 30%, even though none of them produced the low-wavenumber distortions characteristic of inadequate ADC performance. The static transfer characteristics of each of the ADCs was determined using an automated test facility at the National Bureau of Standards. These tests showed that the boards produced errors ranging only up to 2 LSBs, in qualitative agreement with our numerical model.
[Contact: (301) 921-3786]

Recently Published

Forman, R. A., and Mayo, S., **In Situ Alignment for X-Ray Topography**, J. Appl. Crystallography, Vol. 18, pp. 106-109 (1985).

A simple method for in situ alignment of samples in a double-crystal x-ray topography system is described. This method permits a specific crystallographic axis to be made coincident with the sample rotation axis used to set the Bragg angle. Surface reflections from approximately orthogonal crystallographic planes are required, and tables of such planes suitable for alignment of cubic crystals are given. This procedure allows rapid setup for the other accessible surface reflection or transmission topographs.
[Contact: (301) 921-3786]

Gallium Arsenide Materials

Recently Published

Imhoff, E.A., Bell, M.I., and Forman, R.A., **Hot Photoluminescence in Beryllium-Doped Gallium Arsenide**, Solid State Communications, Vol. 54, No. 10, pp. 845-848 (1985).

Hot photoluminecence in GaAs:Be is reported for the first time. The emission from a sample with $p = 6.5 \times 10^{16}$ cm^{-3} at 10 K consists of a shoulder at 1.803 ± 0.002 eV followed by a series of broad peaks at 1.781, 1.742, 1.704, 1.666, and 1.628 eV (all ±0.003 eV). Analysis of the results supports a decay model involving hot electron-acceptor recombination and implies an L-Γ splitting of 320 ± 4 meV in the conduction band at 0 K.
[Contact: Michael I. Bell, (301) 921-3786]

Power Devices

Recently Published

Blackburn, D.L., **Turn-Off Failure of Power MOSFETs**, Proceedings of the 1985 IEEE Power Electronic Specialists Conference, Toulouse, France, June 24-28, 1985, pp. 429-435.

Experimental results of the failure of power MOSFETs during turn-off are discussed. It is shown that the electrical characteristics of these devices during failure are identical to those of a bipolar transistor undergoing second breakdown. Other comparisons of the power MOSFET failure and bipolar second breakdown are made. A nondestructive measurement system is used allowing repeated measurements of the failure characteristics as a function of various parameters to be made on single devices. It is shown that practical, commercial power MOSFETs do not fail as a result of dV(DS)/dt currents. Drain voltage slew rates up to 22 V/ns were studied. Other measurements show that the drain voltage at which failure occurs increases with temperature, the critical current above which failure occurs decreases with temperature, and the magnitude of the load inductance has no effect on the

Power Devices, cont'd.

failure. The results of this study are consistent with the theory that activation of the parasitic bipolar transistor initiates the power MOSFET failure.
[Contact: (301) 921-3621]

Integrated Circuit Test Structures

Released for Publication

Lie, L., Pramanik, D., Saxena, A.N., Mazer, J.A., and Linholm, L.W., **Contact Resistance of Aℓ-1%Si-0.5%Cu and Aℓ/TiW/PtSi Metallization,** to be published in the Proceedings of the 1985 IEEE VLSI Multilevel Interconnection Conference, Santa Clara, CA, June 24-26, 1985.

The specific contact resistivity, ρ_c, has been measured using six-terminal Kelvin contact resistor test structures with contacts of varying sizes. Values of ρ_c were determined for Aℓ-1%Si-0.5%Cu metallizations to n^+ and p^+ silicon junctions having different surface concentrations, C_o. The magnitude of ρ_c was found to decrease with increasing C_o. Values of ρ_c were also determined for PtSi/TiW/Aℓ contact metallizations to n^+ and p^+ and were found to be at least two times lower than that for Aℓ-Si metallization. Also, the variation of ρ_c across the wafer for PtSi was found to be less than that for Aℓ-Si. This indicates that PtSi/TiW/Aℓ metallizations offer advantages when compared to Aℓ-Si metallization and can contribute to improved performance of future VLSI circuits.
[Contact: Mazer (301) 921-3801]

Schafft, H.A., and Saxena, A.N., **Electromigration Test Methodology and Characterization,** to be published in the Proceedings of the 3d IBM Electromigration Symposium, Poughkeepsie, NY, April 1, 1985.

The accuracy of electromigration characterizations of metallizations may be affected significantly by the design of the electromigration test structure and by the conditions and procedures used in testing these structures. This is shown with a thermal analysis of a straight-line test structure and its packaging. The analysis uses a thermal model for an electromigration test structure from which equations are derived to calculate the temperature profile along the structure. It also uses experimental evidence to validate the thermal model and the use of a series of thermal resistance and capacitance networks to model the heat flow from the metallization through the silicon chip, package, and heat sink, and on to the oven environment.
[Contact: (301) 921-3801]

Recently Published

Roenker, K.P., Harner, B.L., and Linholm, L.W., **An NMOS Test Chip for Instruction in Semiconductor Parameter Measurements,** Proceedings of the Sixth Biennial University/Government/Industry Microelectronics Symposium, Auburn, AL, June 11-13, 1985, pp. 100-105.

This paper describes an NMOS test chip, NBS-40, designed for use in a graduate-level course in the measurement of semiconductor parameters using test structures. The rationale and objectives of a parameter measurements course are discussed and the organization and results of a course offered at the University of Cincinnati are described. The test chip layout and test structures are briefly described and parameter measurements using the test structures are discussed. An NBS technical report describing the test chip has been prepared and is available as a student reference. Examples of recent measurement results obtained on chips fabricated through the MOSIS service are provided to demonstrate the functionality of the chip.
[Contact: Loren W. Linholm, (301) 921-3801]

Schafft, H.A., Grant, T.C., Saxena, A.N., and Kao, C.Y., **Electromigration**

IC Test Structures, cont'd.

and the Current-Density Dependence, Proceedings of the International Reliability Physics Symposium, Orlando, FL, March 26, 1985, pp. 93-99.

The empirical expression used to predict metallization resistance to electromigration failure involves the current density to a power of n. A value for n of 1.5 was obtained from stressing unpassivated Al-1% Si metallization test structures over a range of current densities of from 0.5 to 2.5 MA/cm^2. The steps taken to ensure an accurate estimate of the metallization stress conditions of temperature current density to obtain this value are described in detail.
[Contact: (301) 921-3801]

Process and Device Modeling

Released for Publication

Albers, J., **Monte Carlo Calculation of One- and Two-Dimensional Particle and Damage Distributions for Ion-Implanted Dopants in Silicon,** to be published in a joint issue of the IEEE Transactions on Electron Devices and Computer-Aided Design.

The two-dimensional distributions of particles, primary damage, Frenkel pairs, and electronic and nuclear energy loss were calculated for implantation of a line source into silicon targets by using the TRIM Monte Carlo code. These allowed for the calculation of the one-dimensional distributions of these quantities for implantation into unmasked targets. The two-dimensional distributions of particles and Frenkel pairs for implantation past a mask edge were constructed by means of superposition. The results are important for understanding the mass, energy, and dose dependence of implantation and the associated displacement damage.
[Contact: (301) 921-3621]

Bennett, H.S., Gaitan, M., Roitman, P., Russell, T.J., and Suehle, J.S., **Modeling MOS Capacitors to Extract $Si-SiO_2$ Interface Trap Densities in the Presence of Arbitrary Silicon Doping Profiles.**

The MOS capacitor model in SEDAN has been modified to include the effects of an energy dependent $Si-SiO_2$ interface trap density and arbitrary silicon substrate doping profiles. These modifications have been used to calculate the quasi-static C-V characteristics of MOS capacitors and to compare them with those measured by the Kuhn technique for as-received and for gamma-irradiated p-well and n-type silicon MOS capacitors. The average substrate doping is obtained from high frequency C-V curves. For the n-type substrate, the dopant redistribution was estimated with SUPREM II. Experimental and theoretical C-V curves were made to agree by varying the voltage offset due to fixed oxide charge and both the magnitude and the energy distribution of interface trapped charge. The distributions of interface traps which gave the best fits between experiment and theory have peaks near mid gap for the p-well and n-type silicon MOS capacitors.
[Contact: (301) 921-3621]

Wachnik, R.A., and Lowney, J.R., **A Model for the Charge-Pumping Current Based on Small Rectangular Voltage Pulses.**

A charge-pumping current results from recombination associated with the SiO_2-Si interface traps under the gate of a MOSFET when a voltage pulse is applied to the gate. A model is proposed which predicts this current as a function of the frequency, amplitude, and average voltage of pulses with peak-to-peak amplitudes less than the difference between the flatband and inversion voltages and with pulse transitions fast enough so that negligible capture or emission occurs during the transition.

Process & Device Modeling, cont'd.

The model is based on Shockley-Read-Hall traps segregated by energy and capture cross section into traps which capture only and traps which tend to emit before capture. It predicts the dominant behavior of the measured current, and, with the inclusion of surface potential fluctuations and a distribution of cross sections it agrees very well with experiment. Thus, the charge pumping current due to these small rectangular pulses can be used to determine the density, the electron capture cross section, and the hole capture cross section of interface traps near midgap.
[Contact: Jeremiah R. Lowney, (301) 921-3786]

Wilson, C.L., and Blue, J.L., **Accurate Current Calculation in Two-Dimensional MOSFET Models,** IEEE Transactions on Electron Devices.

Two-dimensional simulations of MOSFETs are widely used for the design of short-channel transistors used in VLSI circuits. These models use low-order methods of discretization of solution variables. In this paper, a method of current calculation is presented which works with these methods and yields good accuracy. The method uses integration of the solution variables, rather than differentiation, and is similar to applying Ohm's law in two dimensions.
[Contact: (301) 921-3621]

Witte, L.C., **CSFIT: A FORTRAN Program for Charge-Sheet Model Fitting of MOSFET Data,** to be published as NBSIR 85-3145.

A FORTRAN program, CSFIT, has been developed for fitting an expression for the current-voltage (I-V) characteristics of a long-channel MOSFET to experimental I-V curves. The one-dimensional charge-sheet model developed by Brews provides the basis for the I-V characteristics. The I-V characteristics given by this model are optimized with respect to a set of experimental data using the flatband voltage and the mobility as the only adjustable parameters. The program is written so that multiple sets of I-V data can be fit simultaneously if desired. The user must supply, in specified formats, a current-voltage data file, a device parameter file, and a starting value file.
[Contact: Kenneth F. Galloway, (301) 921-3541]

Recently Published

Bennett, H.S., **Band Structure and Density of States Changes for Doped Gallium Arsenide,** paper in NBS Special Publication 697, OM85, Basic Properties of Optical Materials, Summaries of Papers [given at the Topical Conference, Gaithersburg, MD, May 7-9, 1985], pp. 194-197 (April 1985).

Optical absorption measurements on doped GaAs are interpreted in terms of distorted band structures. Such data provide values for the many-body interactions which are essential in calculations on the operation of lasers and opto-electronic devices.
[Contact: (301) 921-3621]

Wilson, C.L., and Blue, J.L., **Semiconductor Measurement Technology: MOS1: A Program for Two-Dimensional Analysis of Si MOSFETs,** NBS Special Publication 400-77 (April 1985).

The MOS1 program is a portable FORTRAN 77 program suitable for analysis of currents and fields in VLSI devices. The program solves three coupled nonlinear elliptic partial differential semiconductor device equations in two dimensions. Historically, these equations have been solved using a special-purpose program and batch runs on a large, fast computer. We use a general-purpose program which runs on a large minicomputer or scientific workstation. This report discusses the physical formulation of the semiconductor equations and the methods used to select the solution strategy.
[Contact: (301) 921-3621]

Radiation Effects

Released for Publication

Galloway, K.F., Wilson, C.L., and Witte, L.C., **Charge-Sheet Model Fitting to Extract Radiation-Induced Oxide and Interface Charge.**

A method for extracting values of oxide and interface charge from the current-voltage (I-V) characteristics of long-channel MOSFETs is described. The one-dimensional charge-sheet model developed by Brews provides the basis for the I-V characteristics. The I-V characteristics given by this model are optimized with respect to a set of experimental data for an irradiated device with the flatband voltage and the mobility the only free parameters. Simple relationships between these parameters and the radiation-induced interface and oxide charge are assumed.
[Contact: (301) 921-3541]

Recently Published

Galloway, K.F., Wilson, C.L., and Witte, L.C., **MOSFET Electrical Parameter Extraction from Charge-Sheet Model Fitting,** Proceedings of the Sixth Biennial University/Government/Industry Microelectronics Symposium, Auburn, AL, June 11-13, 1985, pp. 77-81.

A method for extracting the flatband voltage and the channel mobility from the current-voltage (I-V) characteristics of long-channel MOSFETs is described. The one-dimensional charge-sheet model developed by Brews provides the basis for the I-V characteristics. The I-V characteristics given by this model are optimized with respect to a set of experimental data with the flatband voltage and the mobility the only free parameters. A computer program, CSFIT, has been developed for this purpose. The choice of parameters is usually appropriate for a device subjected to a stress condition (e.g., hot-carrier injection or ionizing radiation). To illustrate the application of this method and CSFIT, the flatband voltage and mobility for an n-channel enhancement-mode device subjected to ionizing radiation are determined from the I-V curves and the changes of these parameters with radiation dose are tracked.
[Contact: (301) 921-3541]

FAST SIGNAL ACQUISITION, PROCESSING, AND TRANSMISSION

Waveform Metrology

Released for Publication

Flach, D.R., **Characterization of Waveform Recorders,** to be published in the Proceedings of the Seminar on Digital Methods in Waveform Metrology, Gaithersburg, MD, October 18-19, 1983, NBS Special Publication 707.

Transient waveform recorders have been in use for more than 15 years with no commonly accepted test procedures for measuring the performance of these instruments with dynamic input signals. One test procedure that has been increasingly used by manufacturers and others in recent years involves the application of steady-state sinusoidal waveforms to measure the dynamic characteristics of these instruments. These tests measure integral and differential linearity errors, missing codes, signal-to-noise ratios (effective number of bits) and aperture uncertainty.

Described are sine wave tests that use non-linear, least-square curve fit procedures to measure the waveform recorder's noise, and thus the signal-to-noise ratio. This approach yields a "global" description of the recorder's errors. A sine wave test where the data are evaluated using a Fast Fourier Transform is described. This test is particularly useful to measure the integral linearity errors of the waveform recorder. A histogram test, which measures differential linearity errors and missing codes, is described. Results are given for the above tests. A method for measuring aperture uncertainty is briefly mentioned.

Waveform Metrology, cont'd.

Two NBS-developed test procedures, a single period transient sinusoidal test, and the voltage-step generator, are also described, and test results are given.
[Contact: (301) 921-2727]

Kanada, T., and Franzen, D.L., **Optical Waveform Measurement by Optical Sampling/Crosscorrelation with a Modelocked Laser Diode.**

Optical pulses from a GaAlAs buried heterostructure (BH) laser diode directly modulated at a frequency f_0 (971.5 MHz) are mixed in a $LiIO_3$ crystal with 20 ps wide optical sampling pulses at a frequency of f_0-10 Hz from a second modelocked, GaAlAs BH laser diode. The optical signal obtained by sum frequency mixing in the crystal is observed with a photomultiplier and an oscilloscope. The original pulse waveform is reproduced clearly with a temporal resolution of about 20 ps and at a repetition frequency of 10 Hz.
[Contact: (303) 497-5342]

Oldham, N.M., **Digital Waveform Synthesis Techniques,** to be published in the Proceedings of the Seminar on Digital Methods in Waveform Metrology, Gaithersburg, MD, October 18-19, 1983, NBS Special Publication 707.

The theory of digital waveform synthesis, including hardware implementations and practical limitations are discussed. The generation of sinewaves as well as arbitrary waveforms using zero-order-hold and linear-point-connector reconstruction techniques is analyzed. An NBS-developed sinewave generator which provides a high accuracy (50 ppm) signal from dc to 50 kHz is also described.
[Contact: (301) 921-2727]

Schoenwetter, H.K., **Settling Time Measurements,** to be published in the Proceedings of the Seminar on Digital Methods in Waveform Metrology, Gaithersburg, MD, October 18-19, 1983, NBS Special Publication 707.

Methods are described for measuring the settling times (STs) and other dynamic characteristics of D/A converters, operational amplifiers, and precision voltage-step generators. The measurement of device STs from 5 μs to less than 20 ns with corresponding accuracies of 1 ppm and 0.1% is described.
[Contact: (301) 921-2727]

Souders, T.M., **Data Converter Test Methods,** to be published in the Proceedings of the Seminar on Digital Methods in Waveform Metrology, Gaithersburg, MD, October 18-19, 1983, NBS Special Publication 707.

Data converter test methods pertinent to measurement or control instrumentation applications are reviewed. Methods ranging from simple manual techniques to comprehensive fully automated approaches are discussed for both digital-to-analog and analog-to-digital converters. Strengths and weaknesses, major applications, and pertinent references are presented for each.
[Contact: (301) 921-2727]

Souders, T.M., Flach, D.R., and Schoenwetter, H.K., **Transient Response Characterization of Waveform Recorders,** to be published in the Proceedings of the 5th IEEE Pulsed Power Conference, Crystal City, VA, June 10-12, 1985.

Test methods for characterizing the transient response of waveform recorders are presented, together with typical test results. The methods, based on the use of a precision, programmable step generator developed at NBS, are suitable for recorders having up to 10-bit resolution and 100-MHz bandwidth.
[Contact: (301) 921-2727]

Stenbakken, G.N., **Dual-Channel Sampling Systems,** to be published in the Proceedings of the Seminar on Digital Methods in Waveform Metrology, Gaithersburg, MD, October 18-19, 1983, NBS Special Publication 707.

Measuring two signals simultaneously

Waveform Metrology, cont'd.

with a dual-channel sampling system allows for the calculation of many signal parameters not easily obtained with single-channel instruments. This paper concentrates on the use of dual-channel sampling for the measurement of power and phase angles. The theoretical relationships are developed between the sampled data, the measured quantities, and the error sources. Both hardware and software errors are described. Calibration techniques are given for quantifying many of the error sources.
[Contact: (301) 921-2727]

Turgel, R.S., **Phase Angle Standards and Calibration Methods,** to be published in the Proceedings of the Seminar on Digital Methods in Waveform Metrology, Gaithersburg, MD, October 18-19, 1983, NBS Special Publication 707.

Measurement of phase angles in the audio frequency range is discussed with emphasis on precision phase meters and their calibration using an NBS-developed Phase Angle Calibration Standard.
[Contact: (301) 921-2727]

Turgel, R.S., **A Precision Phase Angle Calibration Standard for Frequencies up to 50 kHz.**

A phase angle calibration standard covering a frequency range from 2 Hz to 50 kHz has been designed and constructed. Digital waveform generation is used to provide sinusoidal analog outputs having precisely settable phase angles. Output voltages are independently adjustable from 0.5 to 100 volts rms on both channels. An auto-zero feed-back loop compensates for differential phase errors of the output amplifiers.
[Contact: (301) 921-2727]

Cryoelectronic Metrology

Released for Publication

Hamilton, C.A., Kautz, R.L., and Lloyd, F.L., **A Josephson Series Array Voltage Standard at One Volt,** to be published in the Proceedings of the 1985 NCSL Workshop and Symposium, Boulder, CO, July 15-18, 1985.

Josephson voltage standards have long been limited by their low 1-10 mV output level. A new method for operating 1000 or more Josephson junctions in series has produced a practical standard at the one-volt level. The junction array is in the form of a microstrip which is finline coupled to a waveguide at one end and is terminated at the other end. The whole circuit is fabricated on a 6 by 12 mm silicon substrate. With applied radiation at 72 GHz, the junction array produces up to 8000 quantized levels at the voltages nhf/2e. (In the U.S. 2e/h has an assigned value of 483593.420 GHz/V_{NBS}.) By selecting the level, n, and fine tuning the frequency, f, any voltage from 0.1 to 1.2 volts can be obtained. The high output voltage eliminates the need for a voltage divider and greatly reduces errors due to thermal voltages. When fully evaluated, the new standard is expected to have a precision of a few parts per billion.
[Contact: (303) 497-3740]

Kautz, R.L., and Macfarlane, J.C., **Onset of Chaos in the rf-Biased Josephson Junction.**

The onset of chaos in the rf-biased Josephson junction is studied through numerical simulations. It is shown that the chaotic region predicted by the method of Melnikov spans only a narrow region of rf amplitudes and consists of weakly chaotic solutions which maintain phase lock with the rf bias. The experimentally observed threshold of chaos is shown to coincide with the onset of unlocked chaotic behavior at higher rf amplitudes.
[Contact: (303) 497-3391]

McDonald, D.G., and Frederick, N.V., **Amplification by a Voltage Locked Array of Josephson Junctions.**

Cryoelectronic Metrology, cont'd.

We have studied a new type of Josephson junction amplifier which is based on a two-junction array; the junctions are mutually phase locked at the Josephson self-oscillation frequency. With this frequency at 82 GHz, the voltages of the junctions remain equal (locked) for a bias current range as large as 60% of the critical current. Over a much smaller bias range, with an applied signal frequency of 1 kHz, a small-signal power gain of 19 dB was measured, accompanied by a negative resistance input impedance. This performance is consistent with a quasi static theory of the amplifier.
[Contact: (303) 497-5113]

Recently Published

Zimmerman, J.E., **Design of Cryocoolers for Microwatt Superconducting Devices,** Proceedings of the Third Cryocooler Conference, Boulder, CO, September 17-18, 1984, pp. 2-9, NBS Special Publication 698 (May 1985).

The primary applications of the cryocoolers considered here are for cooling various Josephson devices such as SQUID magnetometers and amplifiers, voltage standards, and microwave mixers and detectors. The common feature of these devices is their extremely low inherent bias power requirement, of the order of 10^{-7} W (or sometimes much less) per junction. This provides the possibility, not yet fully exploited, of designing compact, low-power cryocoolers for these applications, the design criteria being totally different from those of any cryocoolers presently available. Several concepts have been explored and a number of laboratory model cryocoolers have been built. These include low-power non-magnetic regenerative machines of the Stirling or Gifford-McMahon type, three- or four-stage Joule-Thomson machines, liquid-helium dewars with integral small cryocoolers to reduce the evaporation rate, and liquid-helium dewars with integral continuously or intermittently operated small helium liquefiers to permit operation of cryogenic devices for indefinite time periods.
[Contact: Richard L. Harris, (303) 497-3901]

Antenna Metrology

Recently Published

Kanda, M., **Transients in a Resistively Loaded Loop Antenna,** Proceedings of the 1984 International Symposium on Electromagnetic Compatability [IEEE EMC Society], Tokyo, Japan, October 16-18, 1984, pp. 286-290.

Transient characteristics of a loop antenna loaded uniformly with a resistive material are analyzed. The current distribution of the antenna is obtained by the use of the Fourier series expansion technique. It is found that the distortion of the transient waveforms due to a resonance of a loop antenna can be reduced and the received transient waveforms can be tailored by resistive loading.
[Contact: (303) 497-5320]

Optical Fiber Metrology

Released for Publication

Danielson, B.L., **Optical Time-Domain Reflectometer Performance.**

From a researcher's as well as a user's point of view, it is highly desirable to adopt a common basis for specifying optical time-domain reflectometer performance parameters. This paper proposes some procedures and test methods which permit these devices to be characterized in a consistent way. We also describe passive test fixtures which may facilitate measurements of dynamic range and other reflectometer properties.
[Contact: (303) 497-5620]

Danielson, B.L., **Optical Time-Domain Reflectometer Signal Enhancement Using Extended Probe Pulse Methods.**

Other Fast Signal Topics, cont'd.

turns, deformation, and ferrite defects is described.
[Contact: (303) 497-3641]

Leedy, T.F., **An Approach to ATE Calibration Via Performance Verification at the System Interface,** Proceedings of the 1985 Measurement Science Conference, Sunnyvale, CA, January 17-18, 1985, pp. 198-201.

A method of verifying the performance of automatic test equipment (ATE) in its normal operating environment and configuration is presented as the best approach to achieving an overall system calibration. The method consists of the transport of well-characterized signal sources to the ATE station and the application of these electrical stimuli directly to a well-defined electrical interface on the test station. Data are presented on typical accuracies that have been obtained on limited parameters and ranges during the testing process, using calibrated commercial equipment.
[Contact: (301) 921-2727]

Sorrells, J.R., Palla, J.C., Meiselman, B., and Oravec, B.A., **Electrical and Electronic Metrology: A Bibliography of NBS Electrosystems Division's Publications,** NBS List of Publications 94 (March 1985).

This bibliography lists the publications of the Electrosystems Division, Center for Electronics and Electrical Engineering, NBS, and of its predecessor sections for the period January 1968 to March 1984. A brief description of the Division's technical program is given in the introduction.
[Contact: (301) 921-2727]

ELECTRICAL SYSTEMS

Power Systems Metrology

Released for Publication

Hebner, R.E., Kelley, E.F., FitzPatrick, G.J., and Forster, E.O., **Prebreakdown Cathode Processes in Liquid Hydrocarbons.**

Measurements are presented of the initiation of prebreakdown streamers at a point cathode in liquid hydrocarbons. Using a computer implementation of the method of images, the electric field is computed for selected geometries to demonstrate that the field strengths in the vicinity of these streamers are probably high enough so that electron multiplication processes can occur. In addition, it is shown that the primary streamer moves at about the same velocity that a solvated ion would move if it were placed in the electric field.
[Contact: (301) 921-3121]

McKnight, R.H., **Operation of an Ion Counter in the Ground Plane Under a Monopolar Line,** to be published in the Proceedings of the 23rd Hanford Life Sciences Symposium, Hanford, WA, October 22-24, 1985.

Studies have been made of the operation of an ion counter with the inlet located in the ground plane near a monopolar line. Electric field values at the ground plane ranged between 14.8 kV/m and 29.8 kV/m, while ion current densities varied from 0.1 to 0.43 $\mu A/m^2$. An observed variation in measured ion density with volumetric flow rate through the counter appears to be predominantly due to losses in the duct between the ground plane opening and the ion counter inlet.
[Contact: (301) 921-3121]

Misakian, M., **High Voltage Divider and Resistor Calibrations,** to be published as NBS Technical Note TN-1215.

An NBS calibration service for determining the ratio of high-voltage dc dividers and the resistance of high-voltage resistors is described. Calibrations are performed with a Wheatstone bridge apparatus with a simple guard system. Sources of systematic error are identified and methods for characterizing the

Power Systems Metrology, cont'd.

NBS standard high-voltage resistors are discussed. Ratio and resistance values can be determined between the voltages of 10 kV and 150 kV with an uncertainty of less than ±0.01%.
[Contact: (301) 921-3121]

Oldham, N.M., and Petersons, O., **Calibration of Standard Wattmeters Using a Capacitance Bridge and a Digital Generator.**

A method for calibrating high-accuracy wattmeters is described. The technique is a modification of a previously described approach that utilizes a power bridge based on a current comparator. In such a bridge the test current of the wattmeter is balanced with a known current that is proportional to the test voltage. The measurement circuit described employs a high-voltage capacitance bridge in place of a special current comparator that was used in the previous system. High sensitivity and large ratios of the capacitance bridge enable using high impedances, such as stable gas-dielectric capacitors and resistors having low power dissipation, for the generation of reference currents. The voltage on the standard impedances is adjusted with inductive dividers to obtain any power factor between zero and one, lead and lag. A digitally synthesized dual-channel signal source serves as a stable source of voltage and current, and thus of "phantom" power.
[Contact: (301) 921-2727]

Ramboz, J.D., and Petersons, O., **Emerging New Requirements for Electric Power And Energy Measurements**, to be published in the Proceedings of the 1985 NCSL Workshop and Symposium, Boulder, CO, July 15-18, 1985.

Advances in electronic instrumentation technology have brought greater stability and precision to transducers that are utilized for measuring electric power and energy. An advantage of instruments based on electronic transducers is that they can be readily adapted to the measurement of other quantities such as current, voltage, reactive and apparent power, power factor, demand, time-of-day readings, etc. The increases in the cost of energy during the past decade have stimulated the acceptance of new instrument technology by the users associated with the electric power industry. The electronic instruments have especially found acceptance in metering installations for large loads and at interchange points between utilities. Modern instruments, because of their accuracy capabilities, are also advantageous in those applications where the efficiency of large equipment such as generators and transformers has to be measured. A large number of the instruments used as physical standards by the industry and submitted recently to the National Bureau of Standards (NBS) for calibration have been of the electronic type. The calibration accuracies requested from NBS for power and energy measurements have increased at least fivefold (uncertainty reduction from ±0.5% to ±0.1%) within the past several years. Calibrations for different quantities and values are being requested. These changing calibration requirements and the response of NBS to meet the requests of its calibration clientele are discussed.
[Contact: (301) 921-3121]

Recently Published

Hebner, R.E., Kelley, E.F., Forster, E.O., and FitzPatrick, G.J., **Observation of Prebreakdown and Breakdown Phenomena in Liquid Hydrocarbons II. Non-Uniform Field Conditions**, IEEE Transactions on Electrical Insulation, Vol. EI-20, No. 2, pp. 281-292 (April 1985).

The prebreakdown and breakdown processes have been recorded in n-hexane toluene and Marcol 70, both in a pure state and with selected impurities. The study was carried out using a point-plane geometry. A low ionization potential addi-

Power Systems Metrology, cont'd.

tive had only a small effect on the breakdown voltage or the streamer propagation speed but did significantly alter the shape of the prebreakdown streamer when the needle was positive, i.e., an anode. For a negative needle (cathode), chemical impurities affected the breakdown voltage. The significance of these findings is discussed in detail.
[Contact: (301) 921-3121]

Van Brunt, R.J., **Production Rates for Oxyfluorides SOF_2, SO_2F_2, and SOF_4 in SF_6 Corona Discharges**, NBS Journal of Research, Vol. 90, No. 3, pp. 229-253 (May-June 1985).

The most abundant, long-lived stable gaseous species generated by corona discharges in SF_6 gas containing trace levels of O_2 and H_2O are the oxyfluorides SOF_2, SO_2F_2, and SOF_4. Absolute energy and charge rates-of-production of these and the minor products SO_2, OCS, and CO_2 have been measured at different total gas pressures from 100 kPa to 300 kPa and for discharges of different current, power, and polarity. Oxyfluoride yields for SF_6/O_2 mixtures containing up to 10% O_2 have also been measured. The results indicate that oxyfluoride production is not controlled by the concentrations of either O_2 or H_2O at levels below about 1%, and the rate controlling factor is the dissociation rate of SF_6 in the discharge. The discharge current and time dependence of the production rates are discussed in terms of gas-phase mechanisms that have been proposed to explain previous observations of electrical, thermal, and laser-induced decomposition of SF_6 and SF_6/O_2 mixtures. Upper limits on the total SF_6 decomposition rate in low-current discharges have been estimated. Details of the chemical analysis procedures are given, and application of the results to the design of chemical diagnostics for SF_6-insulated, high-voltage apparatus is discussed.
[Contact: (301) 921-3121]

Pulse Power Metrology

Released for Publication

McKnight, R.H., Fenimore, C., and Lagnese, J., **The Use of Deconvolution Methods in Characterizing Electrical Sensors**, to be published in the Proceedings of the 5th IEEE Pulsed Power Conference, Crystal City, VA, June 10-12, 1985.

Deconvolution methods have been applied to measurements made with different electrical sensors including resistive and capacitive dividers. Deconvolved and directly measured waveforms have been compared with good results.
[Contact: (301) 921-3121]

Superconductors

Released for Publication

Fickett, F.R., **Research on Practical Superconductors at NBS**, to be published in the Proceedings of the Benelux Metallurgy Conference on Superconductors, Brussels, Belgium, May 8-9, 1985.

The National Bureau of Standards is engaged in a large number of research programs which have as their goals the evaluation of various properties of practical superconductors related to their application in large-magnet systems. The ability to have standard data, standard tests, and standard materials for evaluating the primary properties of superconductors and related measurement systems is essential to the increasing international commerce in these complicated conductors. The NBS work has concentrated on measurement of critical current, critical field, ac losses, and properties of the copper normally used as a stabilizing material. Many parameters must be considered in these investigations. An overview of these research efforts and a selection of recent results are presented. Particular emphasis is given to work per-

Superconductors, cont'd.

formed in cooperation with the International Copper Research Association (INCRA) on properties of oxygen-free copper.
[Contact: (303) 497-3785]

Goodrich, L.F., Minervini, J.V., Clark, A.F., Fickett, F.R., Ekin, J.W., and Pittman, E.S., **Development of Standards for Superconductors Interim Report, January 1982-December 1983,** to be published as NBSIR 85-3027.

A cooperative program with the Department of Energy, the National Bureau of Standards, and private industry is in progress to develop standard measurement practices for use in large scale applications of superconductivity. The goal is the adoption of voluntary standards for the critical parameters and other characterizations of practical superconductors. Progress for the period January 1982 through December 1983 is reported. The major effort was the procurement, selection, and certification of the first superconducting wire for critical current measurements as a Standard Reference Material (SRM 1457). Other work reported here includes: effect of geometry on current transfer, lap-joint resistance, and ac losses.
[Contact: (303) 497-3143]

Moreland, J., and Ekin, J.W., **Electron Tunneling Experiments Using Nb-Sn "Break" Junctions.**

An Nb-Sn filament mounted on a flexible glass beam can be broken to form an electron tunneling junction between the fracture elements. Breaking the filament in liquid helium prevents oxidation of the freshly-exposed fracture surfaces. A sharp superconducting energy gap in the I-V characteristics measured at 4 K indicates the formation of a high quality tunneling barrier between the fracture elements. The resistance of the junction between the fracture elements can be adjusted continuously by varying the surface bending strain of the beam.
[Contact: (303) 497-5477]

Recently Published

Fickett, F.R., **Standards for Measurement of the Critical Fields of Superconductors,** NBS Journal of Research, Vol. 90, No. 2, pp. 95-113 (March-April 1985).

The origins, definitions, and measurement of the various critical magnetic fields associated with superconductors are reviewed. The potential need for an ASTM-type standard for the measurement of these fields is discussed. Measurement techniques as practiced both in industry and in the national laboratories are reviewed. Extrapolation techniques commonly used to determine the upper critical fields of the newer materials are evaluated as to their suitability for various applications. Sources of error in the experimental determination of critical fields are assessed for the various common techniques. A comprehensive bibliography of the modern literature on critical field measurement and interpretation is included.
[Contact: (303) 497-3785]

Goldfarb, R.B., and Clark, A.F., **Hysteretic Losses in Nb-Ti Superconductors,** J. Appl. Phys., Vol. 57, No. 1, pp. 3809-3811 (15 April 1985).

When subjected to transient magnetic fields, superconductors exhibit losses. At low frequencies, most of the dissipation is hysteretic. Magnetization was measured in an axial field for eight multifilamentary Nb-Ti superconducting wires with different filament sizes and different ratios of copper to superconductor. The full-penetration field H_p was estimated from the high-field ends of the hysteresis loops. The estimate of H_p provides a method to assess the critical current density J_c. There was good agreement between measured losses and those predicted from H_p and the peak applied field.
[Contact: (303) 497-3650]

Power Systems Metrology, cont'd.

tive had only a small effect on the breakdown voltage or the streamer propagation speed but did significantly alter the shape of the prebreakdown streamer when the needle was positive, i.e., an anode. For a negative needle (cathode), chemical impurities affected the breakdown voltage. The significance of these findings is discussed in detail.
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Superconductors, cont'd.

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[Contact: (303) 497-3650]

Superconductors, cont'd.

Goldfarb, R.B., and Clark, A.F., **Magnetic Hysteresis and Complex Susceptibility as Measures of AC Losses in a Multifilamentary NbTi Superconductor**, IEEE Transactions on Magnetics, Vol. MAG-21, No. 2, pp. 332-335 (March 1985).

Magnetization and ac susceptibility of a standard NbTi superconductor were measured as a function of longitudinal dc magnetic field. The ac-field-amplitude and frequency dependences of the complex susceptibility are examined. The magnetization is related to the susceptibility by means of a theoretical derivation based on the field dependence of the critical current density. Hysteresis losses, both obtained directly from dc hysteresis loops and derived theoretically from ac susceptibility and critical current density, were in reasonable agreement.
[Contact: (303) 497-3650]

Magnetic Materials and Measurements

Released for Publication

Capobianco, T.E., Moulder, J.C., and Fickett, F.R., **Flaw Detection with a Magnetic Field Gradiometer**, to be published in the Proceedings of the NTIAC 15th Symposium on NDE, San Antonio, TX, April 22-24, 1985.

When eddy currents are induced in a conductor, flaws deflect the eddy currents and perturb the associated electric and magnetic fields. In conventional eddy current testing, the perturbed fields associated with a flaw are detected as a change in the impedance of the test coil used to induce the eddy currents. More direct methods for detecting and characterizing flaw-perturbed fields, both electric and magnetic, have also been developed. We describe a method for determining the normal component of the magnetic field gradient caused by a flaw. A novel feature of the measurement system is the use of a Superconducting Quantum Interference Device (SQUID). The SQUID provides more sensitivity than conventional detection methods, and the possibility of calibration based on a fundamental physical quantity: the flux quantum. We report the results of a series of measurements on a fatigue crack and several manufactured defects in aluminum alloy specimens using this system. The effect of edge proximity compared to flaw signal and a figure of merit is also discussed.
[Contact: (303) 497-3641]

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

The magnetic phase diagram of amorphous $Pd_{80-x}Fe_xSi_{20}$ was examined. The peak in the imaginary component of ac susceptibility was used to determine the ferromagnetic-like/spin-glass transition temperatures T_{fg}. It was found that the T_{fg} line is highly field dependent and rises with increasing iron concentration.
[Contact: (303) 497-3650]

Recently Published

Fickett, F.R., and Capobianco, T.E., **Magnetic Field Mapping with a SQUID Device,** Proc. Review of Progress in Quantitative NDE, Vol. 4A (Plenum Press, New York, 1985), pp. 401-410. [paper given at Conference, University of California, San Diego, July 9-13, 1984]

Results of tests applying a SQUID (superconducting quantum interference device) system to measurement of the magnetic near field of commercial eddy current coils are reported. The SQUID system offers some significant advantages over more conventional techniques in that very small coils can be used and the calibration of the system is tied to the quantum of flux.
[Contact: (303) 497-3785]

Magnetic Materials & Meas., cont'd.

Goldfarb, R.B., Rao, K.V., and Chen, H.S., **Differences Between Spin Glasses and Ferroglasses: Pd-Fe-Si,** Solid State Communications, Vol. 54, No. 9, pp. 799-801 (1985).

Near the multicritical point in the magnetic phase diagram, some alloys that appear to be simple spin glasses actually have an intermediate ferro-magnetic-like state between the high-temperature paramagnetic and low-temperature spin-glass states. The temperature dependences of the imaginary component of ac susceptibility and dc magnetization are presented to illustrate the subtle experimental differences between spin glasses and these ferroglasses.
[Contact: (303) 497-3650]

Other Electrical Systems Topics

Recently Published

Sorrells, J.R., Palla, J.C., Meiselman, B., and Oravec, B.A., **Electrical and Electronic Metrology: A Bibliography of NBS Electrosystems Division's Publications**, NBS List of Publications 94 (March 1985).

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[Contact: (301) 921-2727]

1986 CEEE CALENDAR

January 27-31 (San Jose, CA)

The Fourth International Symposium on Semiconductor Processing. This Symposium is presented by American Society for Testing and Materials Committee F-1 on Electronics, the National Bureau of Standards, the Semiconductor Equipment and Materials Institute, Stanford University Center for Integrated Systems, and the Components, Hybrids, and Manufacturing Technology Society of the American Institute of Electrical and Electronics Engineers. Technical areas to be covered include crystal growth and material preparation technology, fabrication processes, lithography and patterning, interconnects and silicides,, material and process characterization, measurement and control of contaminants introduced during fabrication and particulates, equipment technology and automation, and manufacturing control systems to achieve improved product quality. Special in-depth sessions are also planned on the state of the art in dopant profiling techniques.
[Contact: Dinesh C. Gupta (Siliconix) (408) 988-8000]

February 17-18, 1986

IEEE VLSI Workshop on Test Structures. The IEEE Electron Devices Society is sponsoring a Workshop intended to bring together the designers and users of test chips to discuss new developments in microelectronic test chip/test structure research, implementation, and application. The Workshop will present papers covering such topics as: material and process characterization and diagnostics; device and circuit characterization; yield and reliability assessment; test structure utilization, data analysis, and data management; and advances in test equipment. Workshop proceedings will be published.
[Contact: Loren W. Linholm, (301) 921-3801]

March 5-7 (Gaithersburg, MD)

Workshop on Measurement of Electrical Quantities in Pulse Power Systems - 11. This Workshop is intended to disseminate information on modern measurement techniques, define the state of the art of measurement of electrical quantities in pulse power systems, and identify areas

1986 CEEE Calendar, cont'd.

in which improvements in measurements are required. Papers are planned for the following three areas: (1) voltage, current, power, and energy measurements, including conventional and electro-optical techniques, beam and radiation methods, software corrections and modeling; (2) data acquisition and processing, including signal transmission, electro-optical links, electromagnetic interference and noise suppression, data recording, and diagnostics for large systems; and (3) calibration methods for laboratory and machine use. The Workshop proceedings will be published. [Contact: John R. Sorrells, (301) 921-2727 or Ronald H. McKnight, (301) 921-3121]

April 22-23 (Gaithersburg, MD)

Workshop on Test Procedures for Precision Instrumentation and ATE Systems. This Workshop is intended to provide a forum for the exchange of information among researchers, users, manufacturers, testing companies, and calibration laboratories on the procedures used in testing the performance of precision instrumentation and automatic test equipment systems. Technical topics planned include first-article and acceptance testing, bid-sample testing, maintenance and calibration testing, developing and writing specifications and procedures, "minimum-use" specifications, test accuracy ratios, economic tradeoffs of testing, case histories of specific test programs, optimum calibration strategies, and recommended practices. The Workshop proceedings will be published by the Institute of Electrical and Electronics Engineers. [Contact: John R. Sorrells, (301) 921-2727]

June 23-27 (Gaithersburg, MD)

1986 CPEM (Conference on Precision Electromagnetic Measurements). CPEM 86 is being sponsored by the U.S. National Bureau of Standards, the IEEE Instrumentation and Measurement Society, and the Union Radio Scientifique Internationale. The Conference will present papers covering the theory, design, performance, simulation, and application of electromagnetic standards, measurements, techniques, instruments, and systems. Sessions are tentatively planned to cover the following technical areas: electromagnetic-related fundamental constants and standards; direct current, low frequency, and radiofrequency; time, time interval, and frequency; antennas and fields; microwaves and millimeter waves; infrared, visible, and ultraviolet radiation; lasers; electro-optics and fiber optics; cryoelectronics; automated measurements; and technical calibration services. The Conference language will be English. [Contact: Sara Torrence, (301) 921-2721. (For technical information, contact John R. Sorrells, (301) 921-2727 or Norman B. Belecki, (301) 921-2715.)]

RECENTLY ISSUED STANDARD REFERENCE MATERIALS

The first practical superconducting standard reference material (SRM) has been released by the Electromagnetic Technology Division to the NBS Office of Standard Reference Materials for sale to the public. The certified parameter of SRM 1457, Superconducting Critical Current -- NbTi Wire, is critical current at magnetic fields of 2,4,6, and 8 tesla at a temperature of 4.2 K and an electric field criterion of 0.2 μV/cm. Information is given to permit the user to determine critical current for temperatures in the range 3.90 to 4.24 K and electric field criteria from 0.05 to 0.2 μV/cm.

SRM 1457 consists of a 2.2-m length of a multifilimentary, niobium-titanium, copper-stabilized wire, wound in a single layer on a spool having a core diameter of 8.7 cm. The wire is evaluated for 34 parameters relating to current,

Recently Issued SRM, cont'd.

voltage, magnetic field, temperature, strain, and physical specimen characteristics.

In conjunction with ASTM Standard Test Method B714-82, D-C Critical Current of Composite Superconductors, the new SRM is intended to provide means for calibrating apparatus used to measure key parameters of superconductor products and thus should be useful to buyers and sellers of superconductors, users of superconducting equipment, and researchers in superconducting technology.

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Center for Electronics and Electrical Engineering

10. SUPPLEMENTARY NOTES

All technical information included in this document has been approved for publication previously.

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

This is the eleventh issue of a quarterly publication providing information on the technical work of the National Bureau of Standards Center for Electronics and Electrical Engineering. This issue of the CEEE Technical Progress Bulletin covers the second quarter of calendar year 1985. Abstracts are provided by technical area for both published papers and papers approved by NBS for publication.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

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

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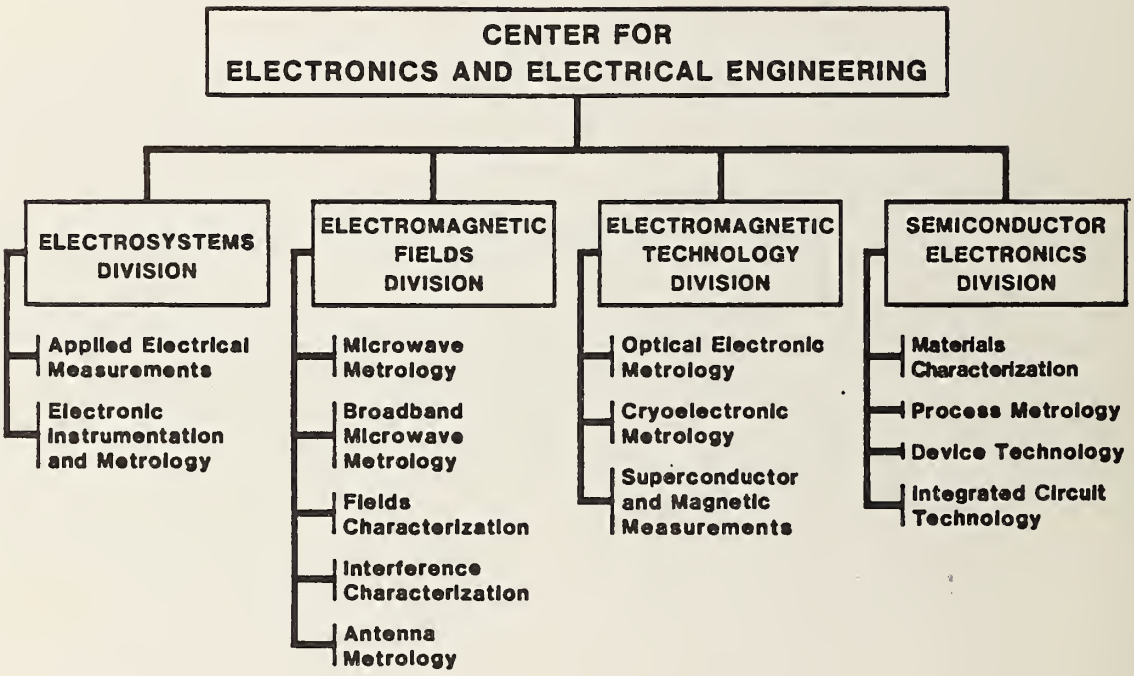

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