SYMPOSIUM AA
Millimeter/Submillimeter-Wave Technology—Materials, Devices, and Diagnostics
April 24, 2000

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*Invited paper
SESSION A1: CHARACTERIZATION AND DIAGNOSIS
Chair: S. K. Sundaram, Paul P. Wasow
Monday Morning, April 24, 2000
Salon 15 (Marriott)

8:30 AM *AA1.1 MILLIMETER AND SUBMILLIMETER WAVE COMPONENTS FOR FUTURE DIAGNOSTIC INSTRUMENTATION. Chiara Mann.

The Birkbeck Appleton Laboratory, Chilton, Oxfordshire, UNITED KINGDOM.

Until very recently, cost and availability of millimeter and submillimeter components has restricted their use to applications such as Remote Sensing, Radio Astronomy and Plasma Diagnostics. Exploratory research aimed at demonstrating new potential applications such as material diagnostics, process control and medical imaging has suffered from a lack of sources and detectors which form the basic building blocks for new instrumentation are now becoming much more readily available. Such devices are likely to incorporate active devices in an integrated “flip chip” configuration rather than the “wiskered” device that has been the mainstay for so many years. Novel fabrication approaches have resulted in the lithographic realization of RF circuitry to 2.5THz and beyond. The arrival of the Heterostructure Barrier Varactor (HBV) for frequency multiplication promises solid state power in the 10% of millimeter level for the submillimeter region. New accurate circuit simulators have allowed the development of very high performance, compact, subharmonic frontends, offering high instantaneous bandwidth and low noise, room temperature operation. These can be used in conjunction with digitally swept Backward Wave Oscillators, ultra broadband fixed tuned HBV multipliers to carry out fast, swept frequency measurements. Finally, new manufacturing approaches such as micromachining and casting offer both a dramatic reduction in cost and more complex circuit/system implementation. This talk aims to describe the latest developments in millimeter and submillimeter component technology.

9:00 AM AA1.2 ACTIVE MILLIMETER-WAVE PYROMETER TEMPERATURE AND EMISSIVITY MEASUREMENTS. David Y. Rice.
Integrated Environmental Technologies, LLC, Richland, WA; John S. Muchnick and Paul P. Wasow, MIT, Plasma Science and Fusion Center, Cambridge, MA.

Millimeter-wave pyrometers can be used reliably for non-contact temperature measurements in harsh environments that are inaccessible by conventional infrared and thermocouple sensors. Millimeter-waves are long enough to see through dusty, smoky, and optically obscure propagation paths, but short enough for useful spatial resolution. Additional advantages include the ability to use refractory materials for waveguide and optics components, wide dynamic range for temperature measurement, and fractional degree relative accuracy to the highest temperatures. In addition, simultaneous surface emissivity measurements are possible when the viewing geometry can monitor a specular return reflection, which is more readily attainable at millimeter wavelengths than at shorter wavelengths. The capability to monitor thermal emission and reflection not only improves temperature measurement accuracy, but also can provide additional information on the properties of the materials being monitored. Such properties include material conductivity and fluidity. A 134-139 GHz heterodyne radiometer has been used on a plasma arc furnace for temperature measurements from room temperature to as high as 2290°C and on an electric resistance heated furnace to study molten glass. Relative temperature measurement sensitivity of 0.3°C for one-second time resolution was achieved throughout the temperature measurement range. Graphite or Inconel waveguides were used to efficiently access the inside of the furnace. In the graphite, a waveguide was rotated for scanning the interior furnace temperature profile with a 5-cm spatial resolution. The combined profile and emissivity information allowed the correction of furnace thermal gradients for non-ideal blackbody conditions. Coherent reflection signals clearly showed molten glass displacements due to turbulence and fluid flow with less than 1-mm spatial resolution.

9:15 AM *AA1.3 110 TO 325 GHZ VECTOR NETWORK ANALYSIS CALIBRATION PROBLEMS CAUSED BY COMMON WAVEGUIDE COMPONENT IRREGULARITIES. Charles Oleson, Anthony Denning, Oleson Microwave Labs, Moorhead Hill, CA.

Full waveguide band vector network analysis measurements are now being achieved in the 110 to 140 and 140 to 225 GHz waveguide bands. These measurements can now be accomplished in a non-linear rail and setup and calibration. To achieve optimum results a working knowledge of the available calibration procedures is necessary. The characterization of the vector network analysis equipment requires the use of a precision waveguide based calibration kit. This same calibration kit is used for the characterization of waveguide components and systems. Semi-conductor characterization requires the use of substrate based calibration artifacts. The most productive semi-conductor test systems are characterized first at the equipment level, then to the device probe interface flange, and then through the device probe to the substrate calibration artifacts. During the development of these specific waveguide calibration kits many unexpected problems were encountered which are discussed. The required tolerances of the waveguide dimensions becomes more exact as the frequency increases. Physical deformations often found in waveguides above 110 GHz, such as improper corner radius, poor surface finish and the lack of waveguide rectangularity, serve to shift the waveguide cutoff frequency and it's effective phase length. At these frequencies the use of waveguide dimensional tolerances found in industry standards most often leads to improper physical constants being entered into the calibration routines of the automated vector network analyzer. The ceramic nominal and angular nominal surface finish of the waveguide flange interfaces employed also impact the quality of the calibration achieved. Various waveguide irregularities, their impacts, and some often-overlooked nuances are examined. The need for physical measurement and vector network analysis of physical constants of each of the components in the test system is summarized.

10:15 AM AA1.4 WAVEGUIDE FOR HIGH TEMPERATURE MATERIALS CHARACTERIZATION USING MILLIMETER-WAVE TECHNOLOGY. S.K. Sundaram, Pacific Northwest National Laboratory, Richland, WA; Paul Wasow and J.S. Muchnick, Plasma Science and Fusion Center, Massachusetts Institute of Technology, Cambridge, MA.

Millimeter-wave technology was applied to measure reflectivity or absorption of representative materials at high temperatures (1000-1300°F) for development of materials characterization and process diagnostics. The selected surfaces were simulated Waste glass, aluminum, Inconel, and silicon carbide. A heterodyne receiver operating at a frequency of 1.37 GHz was tested. A scalar horn was used to convert the receiver antenna mode to a fundamental HE11 mode so that quasi-optical waveguide techniques could be applied for optimum coupling of the receiver view to the material surface. As an external calibration reference, a modified waveguide was necessary to support the propagation of an HE11 mode, an inconel 690 corrugated waveguide was fabricated and tested for views into the hot interior of a furnace. The performance of inconel 690 as a millimeter-wave waveguide in a high temperature environment was evaluated. Approximately a 26cm length of a 56 cm long Inconel waveguide was inserted into the furnace to view the material surface that would act as a return reflector of the millimeter-wave LO beam and incoherent blackbody emission. The return signals were monitored. Changes in return reflection were computed with theoretical calculations. The performance of the waveguide in terms of reproducibility and signal deterioration due to cycling effect will be presented. The millimeter-wave and selected surfaces and their potential applications will also be presented.

10:30 AM AA1.5 MULTI-CHANNEL RADIOMETRY IN MMW IMAGING SYSTEMS. Vladimir Albyuzov, Vladimir Abramov, Vladimir Lyubchenko, Kadir Mouradzhalov, Sergey Turygin, Inst. Radioeng. and Electron., Russian Acad. Sci., Moscow, RUSSIA.

MMW imaging is becoming an attractive option for remote sensing because millimeter waves have the advantage of penetrating adverse weather or atmospheric obscuration, and to some extent becomes of MMW becomes ability to penetrate material, while retaining reasonable spatial resolution. Civilian applications of this technology are emerging, however there has been no real-time imaging demonstration of a civilian application. Potential applications include detection of oil spills, autonomous landing guidance for both night and fog, fire detection, automotive traffic monitoring, hidden object detection at security checkpoints, etc. Use of a single, high sensitive MMW receiver with a rapidly scanning antenna makes a MMW imaging system more readily achievable. However, imaging speed of such systems is rather low. On the other hand, focal plane arrays with large number of 94 GHz receivers were recently developed (TRW) and used to demonstrate the feasibility of real-time passive MMW imaging with enough sensitivity to provide real-time imagery at video rate. However, such focal plane arrays will remain very expensive for a long time. Use of focal plane arrays with moderate number of high sensitive MMW receivers with a array of simple though reasonable alternative for both - single scanning radiometer and multielement focal plane array. Such focal plane array 1x1 of 94 GHz receivers has been developed and tested with scanning offset parabolic antenna of 11.4 cm aperture. 16 superhet/receiver modules 16 square law detectors, 16 DC amplifiers, 16 zero-compensators formed array of 16 identical total-power radiometers. Each radiometer operates with
input brightness temperature range of 10K to 50K. Sensitivity of
each radiometer is estimated as about 0.02K with integration time 1s.
DC signal from output of DC amplifier corresponds to input brightness temperature of 100K, +5V output DC
corresponds to input brightness temperature of 500K.

10:45 AM *AA1.6
MILLIMETER-WAVE MILLIMETER VECTOR MEASUREMENTS IN FREE SPACE, AND IN RESONANT STRUCTURES
APPLICATION TO DIELECTRICS CHARACTERIZATION.
Philippe Gay, Michel Gross, Sylvain Carcenac, Ab Millimetre, Paris, FRANCE; John Milsa, Jussi Tuvoninen, Millimetre Wave Laboratory of Hiltunen, MTT ESA external laboratory, Helsinki University of Technology, Radio Laboratory, Hilt, FINLAND; Alain Marestri, Submillimeter Waves Advanced Technology Group, J.P.L., Pasadena, CA; Giuseppe Aminio, Maria Fitziagdi, Massimo Martellini, Istituto di Fisica Atomica e Molecolare, CNR, Pisa, ITALY.
A vector network analyzer has been created since 1989, based on a very simple principle, patented: there is a PLL link between the source LO and the detector LO, and this link gives the necessary reference to the vector receiver. This analyzer offers the capability of making vector measurements in the full 8 to 1000 GHz frequency interval. The 8-200 GHz coverage is obtained thanks to harmonic generation and a low LO common carrier. The 200-1000 GHz frequency interval can be covered by using a pair of extensions based on widely tunable Gunn oscillators feeding Schottky devices (harmonic generator, and harmonic mixer). It is well known that wideband mixing can become difficult at ultrawide submillimeter frequencies. On the contrary, free space propagation is quite possible. The microwave devices can be associated to small horn antennas to emit and receive waves. It is possible to refocus the diverging waves by means of lenses, mirrors, etc., according to the Quasi-Optical techniques. When introducing a dielectric sample in the wave path, the vector detector can give the material loss, from the wave amplitude attenuation, and also the material permittivity, from the wave phase rotation. This method is extremely simple to describe. The quality of the measurement will be limited by spurious standing waves effects. Besides, it is not possible to determine very low losses. In this last case, it is preferable to make use of the open cavity. A Fabry-Perot cavity, with an horizontal plane mirror below and a spherical mirror above, can be characterized in the unloaded state, then in the loaded state, after introduction of the sample, placed on the plane mirror. The comparison between the resonances positions and widths, with and without the sample, gives an accurate value of the permittivity, and of the loss. The observed vector signal describes a circle in the polar plane, at resonance, and permits unambiguous fitting. However, this simple cavity method cannot be precise enough for loss determination, in the case of extremely low losses. The last technique which will be described is the characterization of whispering gallery modes of the cavity made from the dielectric itself. This technique is the most precise, and the easiest, and it is particularly suitable for extremely low loss materials. A very same sample (small disk) can be characterized from 100 GHz to 800 GHz in the same set-up.

11:15 AM AA1.7
OPEN RESONATOR TECHNIQUE FOR MEASUREMENT OF THIN FILM DIELECTRICS ON OPTICALLY DENSE SUBSTRATES.
Sergey Dudarenko, Dmitrii Lisobzhchenko, John Milsa, Jussi
tuvoninen, Antti V. Riihinen, Millim, HUT Radio Laboratory, Espoo, FINLAND; Millim, VTT Information Technology.
Dielectric materials are nowadays widely employed in millimeter and submillimeter wave applications. Dielectric waveguides are attractive alternatives to be used instead of metallic single-mode waveguides and could be compatible with optoelectronics and microwave integrated circuits, if made using low loss GaAs or Si epitaxial layers on dielectric substrates. Recently, new promising materials are being developed. For example, GaN and AlN epitaxial layers on seminsulating GaAs or Si are attractive. The problem is that these layers are not only thin as compared with the wavelength, but also that their permittivity is close to the substrate permittivity. Therefore the problem of precise measurement of their properties is challenging. One of the most accurate methods of measurement of dielectric properties is an open resonator technique, which have been developed by several authors mostly for other sample shape measurements, and recently the multilayers were studied as well. In this work, we have developed this technique for applications with layered dielectrics in which one layer is thin in comparison with a wavelength. The general theory for the case of multilayer dielectric is well developed by Sheng, Long (1982), when one of the two layers is very thin, i.e. \( n_2 k_2 \rho < 2 \), where \( \rho \) is the thickness of the thin film, we have simplified these equations. The principle of the determination of the properties of the thin film is obtained by comparing the resonant frequencies and quality factors of the resonator containing the substrate and without thin film. Recently, we have obtained a good accuracy (error 1-2%) in refractive index between the tests and simplified approach described above for a thin GaAs layer on a sapphire substrate.

11:30 AM AA1.8
SUBSURFACE DAMAGE CHARACTERIZATION OF HYDROGEN IMPLANTED SILICON WAFER WITH UV/MILLIMETER-WAVE TECHNIQUE. Yoichi Ogiwa, Ken-Ichi Kobayashi, Kangawa Inst. Tech., Dept. Electrical & Electronic Engineering, Kangawa, JAPAN; Hideyuki Kondo, Takeo Kanai, Mitsubishi Materials Corp., Silicon Research Center, Saitama, JAPAN.
As gate oxide thickness of MOS devices in ULSI is thinner, subsurface damage induced by mirror polishing in Si wafers degrades gate oxide integrity. However, it is hard to detect this damage because of very slight damage, its existence in a nearby surface, and influence of a surface property. A photoconductivity measurement with an ultraviolet irradiation and a millimeter detection (UV/Millimeter-Wave Technique) has characterized subsurface property in chemical mechanical polished Si wafers. However, whether the technique reflects the subsurface and very slight damage has not necessarily been confirmed. The purpose of this study is to show that UV/Millimeter-Wave Technique reflects information of very slight damage induced by hydrogen ion implantation in the subsurface. A dinitrogen laser with 20 nm penetration-depth and a millimeter-wave with 100 nm were employed in UV/Millimeter-Wave Technique. The photoconductivity amplitude (PCA) and recovere (the recovery) were measured for two kinds of sample: 1) 100 cm-thick p-type Si wafers with hydrogen ion implantation dose of 0 to 10^16 cm^-2, and 2) 100 cm-thick p-type Si wafers with hydrogen ion implantation energy of 0 to 200 keV. The problem of implantation damage existed at 226 nm depth regarded as a nearby surface. The dose dependence of PCA measured showed drastic decrease with dose increase. Measured PCA decreased depending the implantation energy. However, time reached carrier lifetimes measured in a nearby region were varied depending on the implantation energy. This means that PCA signal reflects shift of the damage layer accompany with ion implantation energy increase. As the conclusion, it has been confirmed that UV/Millimeter-Wave Technique well reflects subsurface property and very slight damage.

11:45 AM AA1.9
SUBSURFACE DAMAGE PROFILE CHARACTERIZATION OF Si WAFERS WITH UV/MILLIMETER-WAVE TECHNIQUE AND LIGHT SCATTERING TOPOGRAPHY. Takeo Kanai, Hideyuki Kondo, Mitsubishi Materials Corp., Silicon Research Center, Saitama, JAPAN; Yoichi Ogiwa, Ken-Ichi Kobayashi, Masaki Kurokawa, Kangawa Inst. Tech., Dept. Electrical & Electronic Engineering, Kangawa, JAPAN.
We have characterized subsurface damage profiles of hydrogen ion implanted silicon wafers by means of non-contact UV/Millimeter-Wave Technique and Light Scattering Topography (LST). The subsurface damage profile of a hydrogen ion implanted wafers was clamped by chemical mechanical polishing after hydrogen ion implantation. The Photoconductivity Amplitude (PCA) signals measured by UV/Millimeter-Wave Technique drastically weakened and the haze values measured by LST increased on the area with subsurface damage. A clear correlation has been found between the peak depth of subsurface damage and the haze value. The spectral analysis of the surface images obtained by Atomic Force Microscopy (AFM) were carried out to separate the influences of surface micro roughness and subsurface damage on the haze value. The contribution of subsurface damage on the haze value can be formulated as convolution of the damage profile and the transparency function of the incident laser in silicon crystal.
devices are driving the growth of many new applications in materials science. Examples of various solid state devices will be presented, together with perspectives on the applications in which these devices may be utilized. Device examples and applications include the following. GaAs mixers have application in millimeter-wave detectors and receivers, and mixer arrays for millimeter-wave imaging. GaAs varactor diodes are large gain microwave frequency multiplier based sources, or be used in phased antenna array beam steering and high speed switching. Micro-electromechanical systems (MEMS) switches are exciting new devices with numerous applications. The low loss millimeter-wave switch, phase shifters and mechanically tunable structures.

2600 PM AA2.2
NANOFACTRICATED SiO$_2$-Si$_3$N$_4$ RESONANT TUNNELING 
DIODES. J.D. Fleming, E. Chow, Shao-Yu Lin, Sandra National 
Laboratories, Albuquerque, NM.

One possible approach to the generation and detection of millimeter wavelength radiation is the use of Resonance Tunneling Diodes (RTDs). These structures consist of a thin (nm scale) layer of high 
quality semiconductor material, sandwiched between two thin (nm 
node) barrier layers. These devices can exhibit negative differential 
resistance and extremely high-speed operation. RTDs have almost 
invariably been fabricated using epitaxial growth techniques. 
This restricts the possible combinations of materials that may be 
employed, typically to the II-VI or Si/Ge systems. In particular, there 
are few good choices for barrier materials and this limits device 
performance. Due to the overwhelming dominance of silicon in most 
areas of microelectronics and the maturity of Si processing techniques, 
SiO$_2$/Si$_3$N$_4$/Si structures are particularly promising. However, 
such a structure is impossible to fabricate using standard epitaxial 
techniques, due to the amorphous nature of SiO$_2$. In this paper we 
will describe a fundamentally different RTD fabrication approach, which 
makes use of novel combinations of well-known and controllable 
Si processing techniques. Single crystalline, parallel, and smooth, sheets of 
Si were synthesized using a combination of reactive ion etching and 
KOH wet etching of Si 110 substrates. The tunnel oxides were 
grown using processes developed for non-volatile memory applications.

These structures were integrated with modified IC fabrication 
processes to form trench isolation and electrodes. The finished devices are 
oriented perpendicular to the wafer surface and had active areas 
between one and two microns square. Using this approach we have 
been, to the best of our knowledge, the first to demonstrate negative 
differential resistance with SiO$_2$/Si$_3$N$_4$/Si$_3$O$_x$ structures. 

This work was supported by the United States Department of Energy 
under contract DE-AC04-94AL55000. Sandia is a multiprogram 
laboratory operated by Sandia Corporation, a Lockheed Martin 
Company, for the United States Department of Energy.

2:15 PM AA2.3
INTEGRATED ESA GAA DIO DIODE TECHNOLOGY FOR MILLIMETER 
AND SUBMILLIMETER-WAVE COMPONENTS AND SYSTEMS. Thomas M. Cumberlidge, L. Hedditch, D. M. E. 
Brown, Dept. of Electrical Engineering, University of Virginia; 
Richard F. Bradley, Saini Kaminjel, National Radio Astronomy 
Observatory; Steven M. Marnani, David W. Porterfield, Virginia 
Millimeter Wave Inc., Charlotteville, VA.

GaAs Schottky barrier diodes remain a workhorse technology for 
submillimeter-wave applications including radio astronomy, chemical 
spectroscopy, terahertz, THz, and other exotic studies, plasma diagnostics and compact 
range radars. This is because of the inherent speed of these devices and 
their ability to operate at room temperature. Although planar 
(flip-chip and back-lead) diodes are slowly replacing whisker 
contacted diodes throughout this frequency range, the handling 
and placement of such small GaAs chips limits performance and greatly 
increases component costs. Through the use of a novel wafer bonding 
process we have fabricated and tested submillimeter-wave components 
where the GaAs chip is integrated on a copper substrate with other 
circuit elements such as filters, probes and bias lines. This 
not only eliminates the need to handle small chips, but also greatly 
increases circuit performance. This is because the parasitic 
capacitance is integrated into the electronic circuitry. The GaAs 
substrate and the position of the Schottky diode relative to the other circuit 
elements is defined lithographically rather than by a skilled 
technician. Our wafer bonding process has been demonstrated through 
the fabrication of a fundamental mixer at 285 GHz 
[Tmix,dab]=(200K) and a 380 GHz subharmonically pumped mixer 
(Tmix,dab)=(100K). This paper will review the wafer bonding process 
and discuss how it is being extended to include additional circuit 
elements for submillimeter-wave mixers and frequency multipliers.

2:30 PM AA2.4
PLANAR THICK FILM MATERIALS FOR MILLIMETER-WAVE 
APPLICATIONS. S.W. McKnight, Northeastern Univ, Ctr for 
Electromagnetics Research, Dept of ECE, Boston, MA; S.A. Oliver, 
Northeastern Univ, Ctr for Electromagnetics Research, Boston, MA; 
H. How, EMA Corp, Boston, MA; C. Vittorio, Northeastern Univ, 
Dept of ECE, Boston, MA.

Magnetic oxide ferrites are the materials of choice for non-reciprocal 
functions in microwave and millimeter-wave circuits including 
isolators, circulators, and tunable phase-shifters. Techniques for the 
integration of planar ferrite devices into semiconductor integrated 
circuits have been sought for many years to supercede present hybrid 
technologies. Two paths have been investigated for fabricating thick 
ferroelectric films on semiconductor substrates: direct IC growth 
and low loss millimeter-wave switch, phase shifters and mechanically tunable structures.

Direct growth is hampered by the incompatibility of 
optimal ferrite fabrication temperatures (650-800°C) with 
semiconductor IC materials and processes. We have successfully 
transferred yttrium-iron-garnet epitaxial films from gadolinium-
gallium-garnet to silicon substrates to create non-reciprocal circulator 
devices at X-band (8-12 GHz). To extend these techniques to 
millimeter-wave frequencies, ferrite microfilm with large intrinsic 
magnetic anisotropies are required to overcome the need for large DC 
magnetic bias. Hexagonal ferrites have been widely used in sintered 
ceramics, but their magnetic losses are a limiting factor for 
high-frequency devices. We have fabricated thick-film millimeter-wave 
circulators that integrate ceramic barium hexaferrite and strontium 
hexaferrite die with dielectrics on silicon substrates and have achieved 
good non-reciprocal performance and insertion loss of less than 2 dB 
within 30 GHz. Approximately 60% of the insertion loss can be 
predicted from calculated magnetic losses consistent with measured 
ferromagnetic resonance line-widths. The technology for fabrication of 
high-quality hexagonal ferrite films for future planar 
integrated millimeter-wave devices is under development. We have grown 
epitaxial films of barium hexaferrite (BaFe$_2$O$_4$) and 
scandium-substituted barium hexaferrite (BaFe$_2$Sc$_x$O$_{4-x}$) 
on sapphire and MgO substrates by pulsed-laser deposition techniques. 
Adjacent thin films on heated substrates display a high degree of 
orientation with the (0001) normal to the film plane at thicknesses 
less than ~10μm, but for thicker films nucleation and growth of 
non-preferentially-oriented facets is a problem, as are the large 
thermally-induced stresses that arise upon cooling after deposition.

3:30 PM AA2.5
SILICON WAFER SUBSURFACE CHARACTERIZATION WITH 
UV/MILLIMETER-WAVE TECHNIQUE. Yoko-Ikuko Orito, 
Kouga Corp. Inst. Tech., Dept. Electrical & Electronic Engineering, 
Koigawa, JAPAN.

Minimization of ULSI devices requires that MOS devices have 
finer oxide. This thinner oxide is causing breakdown in a gate oxide 
that is fabricated in the substrate of an silicon wafer. Therefore, a 
strict characterization of the substrates is needed. Photoconductivity 
measurements in silicon wafers using ultra violet irradiation and 
millimeter detection (UV/millimeter technique) has been proposed for 
characterizing a nearby surface of a silicon wafer and an epilayer on 
a silicon substrate. In this paper, we discuss millimeter skin effect 
reducing to interaction between millimeter wave and excess carriers 
transporting in a silicon wafer. We show both principles of epilayer 
characterization based on millimeter wave effect and of subsurface 
characterization based on extremely shallow photoconduction and 
extremely short carrier transport time. 10micron thick 
epilayers having Mo and Be contamination in silicon p/p+ and n/n+ 
substrates are characterized with carrier lifetimes obtained from 
photoconductivity decay measured using UV/millimeter wave 
technique. A slight damage induced in a nearby surface by hydrogen 
implantation is characterized based on implantation dose ( dose 
range: 0 to 1x10$^7$cm$^{-2}$) and energy (energy range: 0 to 120keV) 
dependencies of photoconductivity amplitudes and initial carrier 
lifetimes measured by the technique. Very slight damage as slight 
scratches induced in a silicon wafer substrate by chemical mechanical 
polishing as in a commercial level is characterized by 
photoconductivity amplitude signal measured by UV/millimeter-wave 
technique. For this range of parameters, the photoconductivity 
peak is not affected. Further, the technique makes it possible to detect a very slight 
damage induced by chemical mechanical polishing.

3:45 PM AA2.6
MILLIMETERWAVE AQUAMETR. Vinczels V. Meriski, 
Institute of Radioengineering and Electronics Russian Academy of 
Sciences, Pyrsinino Moscow Reg., RUSSIA.

The aim of this paper is to examine the peculiarities of the 
application of millimeter (MM) band (including long-wave 
submillimeter region) to water content measurement and moisture 
monitoring. The use of this frequency region (f = 30-300 GHz) 
for agriculture has some advantages:

1. MM waves ensure better spatial resolution and better sensitivity to
water than microwaves [attenuation of MM waves in water is more than 15 dB/mm and increases more rapidly with decreasing wavelength than in majority of host media].

2. MM waves are less sensitive than microwaves to conducting impurities.

3. MM waves can be used for water test [including nondestructive monitoring] in media that are opaque to optical and infrared radiation.

The report presents dielectric properties [complex permittivity and attenuation] of many materials and media as an object for aquamaetry.

a) Liquid media. There are water solutions and emulsions. The permittivity and attenuation depending on water concentration, frequency, temperature for water solutions of alcohol, sugar, and salts and emulsions water in crude oil were investigated.

b) Solid media. We have investigated dielectric properties of many solid materials. There are porous dielectrics and powders, building materials, natural materials, materials for common use, for clothes, furniture, food, etc.

There are many methods for water content determination in above mentioned media: measurements of transmission and reflection coefficients in quasiaquitational situation or in a waveguide filled with the monitored medium; measurement of wave propagation in guiding structure connected with the medium under test (sloted metal waveguide, waveguide supporting slow wave) when some part of power of this wave penetrates into material and in the transmission coefficient depends on surrounding medium. In the paper we consider examples of devices for water control in crude oil, alcohol, sugar, humidity of materials for common use, building and nature material, materials used in metalurgy [charge, bentonite]. Usually it is possible to measure moisture content in real time [including in flow] with uncertainty better than 0.1%.

4:45 PM AA2.9

BWO CHARACTERIZATION OF MATERIALS AND DEVICES AT FREQUENCIES 100-1000 GHz. Alexander Volkov, Inst. of General Physics, Russian Academy of Sciences, Department of Submillimeter Spectroscopy, Moscow, RUSSIA.

On the basis of Backward-Wave Oscillators (BWOs) we have developed a highly efficient measurement technology for characterization of materials and devices in the millimeter and submillimeter wavelength spectral domain [1-3-3.3 mm, n=100-1000 GHz] [1-2]. Submillimeter BWOspectrometers are designed utilizing comprehensively unique features of BWO-radiation: wide range electronic tunability of frequency, high radiation intensity, monochromaticity and polarizability. The methods developed are of a hybrid type, combining features of both microwave technology and infrared spectrosopy: “high quality” radiation is treated by optical means in an open space. As a result, the information of the highest quality is obtainable rapidly in a real time scale, yielding spectra of both parts [real and imaginary] of the complex either transmission/reflectivity of devices or dielectric function [permittivity, absorptivity, conductivity, etc.] of material under study.

Using the described method we have performed a great body of researches on a) electrodynamic properties of various quasiaquitical MM-SBMM devices and b) dielectric properties of wide range of substances. Polarizers, attenuators, cut-off and band pass filters, phase shifters, etc., have been studied in the a) case. In the b) case we have studied single crystals and ceramics, glasses and polymers, powders, composites, liquids, films, fibers, etc. We have investigated fundamental regularities of the frequency-temperature behavior of the dielectric response function in simple dielectrics, ferroelectrics, ionic conductors, dipole glasses, incommensurate crystals, semiconductors, superconductors, low-dimensional conductors and antiferromagnets.

Many results of the performed measurements cannot be obtained at present by any other technique.


4:30 PM AA2.7

DEVELOPMENT IN MICROWAVE DIELECTRIC CERAMICS FOR COMMUNICATIONS APPLICATIONS. Robert Beer, Ferdos Azaigh, Colin Leach, Material Science Centre, University of Manchester/UMIST, Manchester, UNITED KINGDOM.

Five main families of microwave dielectric ceramics are currently available for communications applications. Most are titanates and relative permittivities are in the range 20-80. The properties depend upon processing, microstructure and composition. As a case study, specific attention will be paid to high permittivity ceramics of Ba0.875Sr0.125TiO3. Specimens have been prepared with the additions of MgO by the mixed oxide route, with both random polycrystalline and textured. The use of small amounts of MgO led to an enhancement of the dielectric Q values. Impedance spectroscopy has been used to investigate the behaviour of grains and grain boundaries. Static simulation studies of Ba0.875Sr0.125TiO3 ceramics successfully reproduced the structure and lattice parameters within 1-2%. Predicted relative permittivities are in satisfactory agreement with experimental data.

Methods to predict dielectric losses are being explored.

4:30 PM AA2.8

STRUCTURE AND CHEMICAL ANALYSIS OF As2S3 GLASSES USED FOR WAVEGUIDE APPLICATIONS. D.K. Venema, Advanced Materials Processing and Analysis Center & Mechanical Materials and Aerospace Engineering and CREOL, S. Seal, Advanced Materials Processing and Analysis Center & Mechanical Materials and Aerospace Engineering; C. Lopez, K.A. Richardson, School of Optics, CREOL, K. Zollinger, A. Graham, A. Schultz Department of Physics, University of Central Florida, Orlando, FL; K. Tureazte, J.M. Lasell, T. Galtiez and A. Villeneuve, Universite Laval, Centre d’Optique, Photique et Laser, Cite Universitaire, Pavillon A-Vachon, Quebec, CANADA.

Chalcogenide glasses based on As2S3 have been studied extensively due to their optical and electronic properties and have been examined recently for use in various waveguide components. This paper reports are results of ongoing research on their structural, chemical and optical properties. Structural and chemical variations imposed by processing conditions [film deposition] can lead to changes in linear and nonlinear optical properties. X-ray Photoelectron Spectroscopy (XPS) has been employed to study the exact chemical composition at the film surface as well as in bulk, and to investigate variations in the nature of chemical bonds, electronic structure etc. These data have been compared to results from Raman spectroscopy aimed at characterizing such changes in bonding between bulk glass specimens and glasses in film form. Effect of X-ray exposure, O2 contamination, and sample purity, is discussed, as well as changes introduced to the films during device processing. These results have been correlated with component linear and nonlinear optical properties.

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