Applied Surface Science Division
Room 307 - Session AS+VT-FrM

Application of Surface Analysis Techniques to Semiconductor Technology
Moderator: F.A. Stevie, Cirent Semiconductor

8:20am **AS+VT-FrM1 An Overview of the Applications of Surface Analysis Techniques in Semiconductor Technology**, ***B.R. Rogers****, R. Gregory, G. Harris, D. Werho, W. Chen,* Motorola, Inc. **INVITED**

Over the years the role of surfaces and interfaces has become increasingly important in determining the performance of semiconductor based microelectronic circuits. Consequently, the use of both new and traditional surface analysis techniques in the development of materials and processes as well as in manufacturing metrology and trouble shooting has become more and more popular. This presentation will review the strengths and weaknesses of the more common surface analysis techniques, such as Auger electron spectroscopy, Rutherford backscattering spectrometry, secondary ion mass spectrometry, total reflection x-ray fluorescence, and atomic force microscopy. Some of the newer scanning probe based techniques, such as scanning thermal microscopy and scanning capacitance microscopy, will be introduced. Several application examples will be presented to highlight the strengths and complimentary nature of these techniques. These examples will include: analysis of barrier metal composition as a function of depth into device features, two dimensional dopant profiling, measurement of ion implantation damage in SiC, analysis of fluorinated silicon dioxide film stability, development of wafer cleaning techniques, and the optimization of chemical mechanical polishing processes.

9:00am **AS+VT-FrM3 An Evaluation of SIMS Analytical Capabilities For Sub-0.25 Micron Implant Technology**, ***V.K.F. Chia****,* Charles Evans & Associates

The applications of SIMS (secondary ion mass spectrometry) to the microelectronics industry are very diverse. In the ion implantation sector SIMS is perhaps the most widely used analytical technique. This is not too surprising because SIMS can detect all elements, produce high precision profiles, and provide elemental surface and bulk information with excellent detection sensitivity. As the design rule continues to shrink the question that arises is, "Can SIMS still be a valuable tool?". This paper addresses this question and reviews advances made in protocol development. For example, SIMS can perform high precision implant characterization (HPIC) to match the dose delivered by two different implanters to within <1% (67% confidence interval) during process replication or transfer, and for initial implanter qualification during fab start-ups. A better understanding of near-surface profiling phenomena has led to more accurate depth profiling of ultra-low energy ion implants (e.g. <1 keV B). SurfaceSIMS was developed to monitor and accurately quantify unintentional contamination that occurs during ion implantation, for example dopant cross-contamination in multi-purpose implanters, and to monitor inadvertent contamination related to sputter erosion or outgassing of implanter construction materials. As device dimensions shrink in size the need to perform ion implant characterization in small areas with high sensitivity becomes increasingly important. One solution is to interleave reactive primary ion species with high current density probes. This procedure enables 12 µm x 12 µm areas to be depth profiled with a sensitivity similar to analyzing a 180 µm x 180 µm area using Cs primary ions alone. In view of these advancements, SIMS appears to be well positioned to continue its primary role in ion implant characterization beyond the year 2000.

9:20am **AS+VT-FrM4 Accurate Dynamic Secondary Ion Mass Spectrometry (SIMS) and Auger Electron Spectroscopy (AES) Characterization of SiGe Stoichiometry and Hetero-Junction Bipolar Transistor (HBT) Dopant Levels**, ***T.H. Büyüklimanli****, J.T. Mayer, M.S. Denker, R.L. Moore, C.W. Magee,* Evans East

The recent growth of the consumer microwave electronics market has spurred the development of SiGe HBTs. There are several physical and chemical properties of the device that affect performance and most importantly bandwidth. This has prompted us to take a fresh look at the acquisition and quantification of the SIMS and AES data. This paper investigates the characterization of two parameters of device fabrication: first the stoichiometry of the Ge-doped base layer, second the dopant (typically B) and impurity (typically O) concentration and distribution in the base layer. SIMS and AES were used to characterize a sample set ranging from 5-45 atomic percent Ge. Each sample was ion implanted with B, P, C and O. Differences in sputter rates, recommended analytical protocols (SIMS), data post-processing and changes in relative sensitivity factors will be addressed.

9:40am **AS+VT-FrM5 A Comparison Auger and TOF-SIMS Depth Profiling of Silicon Oxide Nitride Multilayers Using Low Incident Ion Energy**, ***S.E. Molis****, R.E. Davis,* IBM Corporation, East Fishkill Facility*; D.W. Kisker,* IBM Research Division*; D. Paul,* Physical Electronics

The ever-shrinking dimensions of semiconductor devices have placed steadily more difficult challenges in front of analytical instruments and methods as well as fabrication tools and processing. In the future, this shrinkage will have a proportionally greater impact on the vertical dimensions. The SIA Technology Roadmap lists for example a gate oxide thickness equivalent of 2-3 nm by the year 2001, and a phasing out of SiO2 in favor of alternative dielectric materials. The difficulty of this analytical challenge makes it likely that no single technique will be able to tackle any type of complex process problem alone. Rather, a synergistic approach involving the strengths of each will be called for. New techniques are needed, and the current limits of current techniques must be extended. This paper describes one approach, teaming TOF-SIMS and Auger electron spectroscopy, with sputter ion gun designs which can provide adequate sputter rates at impact energies of less than 500 eV, to improve depth resolution. A Ni-Cr multilayer standard of thicker dimensions was used to measure and optimize experimental conditions. A set of various thin oxide and nitride single films and multilayers wa examined by both techniques, to mutual advantage. The TOF-SIMS approach generally gave superior depth resolution compared to Auger, although not as good as the structural view of X-TEM. The SIMS matrix effect was interpreted by comparison to the Auger profiles. TOF-SIMS was able to give some insight into the question of hydrogen content of the films. The propensity for thermal damage was also studied.

10:00am **AS+VT-FrM6 A New High Performance TOF-SIMS Instrument for 300 mm Wafer Inspection**, ***E. Niehuis****, C. Bendel, D. Rading,* ION-TOF GmbH, Germany

We have developed a high performance TOF-SIMS instrument for the analysis of wafers up to 300 mm diameter. It includes a new sample stage with 5 axis and interferometric x,y position control for ultimate navigation accuracy. The instrument is equipped with a Ga liquid metal ion gun for surface analysis and imaging, and a flexible dual source gun with electron impact and Cs source for dual beam depth profiling. In a production environment high sample throughput, high reproducibility and ease of use are most important. To meet these requirements, we implemented complete instrument automation to setup the instrument for a specific task, to find a specific area on a wafer and to acquire and analyze the data. The navigation part includes the import of coordinates from other inspection tools, an auto-heigth-adjustment and optical pattern recognition. For the interpretation of the spectra we make use of a high mass resolution SIMS database for automated compound identification. In this paper we will describe the instrument performance and discuss the various applications of this tool in IC production. TOF-SIMS can be used for the screening of various surface contaminants like trace metals (alkali, transition metals), small inorganic molecules (e.g. sulfates) as well as organic contaminants (e.g. photoresist residues, cleaning agents, plasticizers from storage containers). The technique also offers depth profiling with excellent depth resolution for the characterization of gate oxides and ultra-shallow implants. In defect review TOF-SIMS provides high lateral resolution and detailed chemical information on sub-micron particles.

10:20am **AS+VT-FrM7 Automated Process Monitoring Using ESCA and Numerical Methods**, ***D.J. Hook****, J.F. Moulder, J.S. Hammond,* Physical Electronics, Inc.

There currently exists a need in the electronics industry for automated process control to increase product yield and reliability. An example of this is the hard disk industries' push to higher media storage density that has placed increasingly stringent requirements on the lubrication media needed for disk surfaces. Similarly, uniformity of oxide thickness on silicon wafers is an important property that can affect the finished device and in turn overall production capability of a semi-conductor facility. The ability to obtain quantitative ESCA results over large areas and present information in an easy to understand visual format can provide feedback for the production environment. The combination of totally automated process monitoring with Graphical User Interface (GUI) driven film thickness calculations and large area mapping software is a new development in ESCA which can address this need. Examples of automatically collected lube thickness measurements on new and used hard disks and oxide thickness maps on cleaned 200 mm silicon wafers will be presented.

10:40am **AS+VT-FrM8 Measurement of Carrier Concentration and Lattice Absorption in Bulk and Epitaxial Silicon Carbide Using Infrared Ellipsometry***, **T.E. Tiwald**,* University of Nebraska, Lincoln*; S. Zollner,* Motorola Semiconductor Products Sector*; J.A. Woollam,* University of Nebraska, Lincoln*; J. Christiansen,* Motorola Semiconductor Products Sector*; P.G. Snyder,* University of Nebraska, Lincoln

We have measured the dielectric function of bulk nitrogen-doped 4H and 6H SiC substrates from 700 to 4000 cm@super -1@ using Fourier-transform infrared spectroscopic ellipsometry. We observe a strong reststrahlen band between 800 and 1000 cm@super -1@ due to photon absorption by transverse optical phonons. The shape of this band is influenced by plasma oscillations of free electrons, which can be described with the Drude model. A detailed analysis of the data allows the determination of the free electron concentration, which is between 10@super 18@ and 10@super 19@ cm@super -3@, in good agreement with electrical measurements. We were also able to determine the surface layer thickness for epitaxial 4H SiC (with an electron concentration of 10@super 16@ cm@super -3@) on heavily-doped bulk 4H SiC. Finally, we observe Berreman peaks near the longitudinal optical phonon energy in all samples. These interference effects are the result of carrier depletion and accumulation near the surface. The effect is strongest in the epitaxial sample and the more lightly doped substrates.

11:00am **AS+VT-FrM9 Si Dopant Site Within Ion Implanted GaN Lattice***, **H. Kobayashi**, W.M. Gibson,* State University of New York, Albany

There has been considerable interest in GaN for the fabrication of blue light emitting devices. In addition, this material is attractive for use in high temperature or high power electronic devices. Therefore, ion implantation for selective area doping is becoming more important for future Ga N device technology. It has been demonstrated that Si and Mg ion implantation and post-implant annealing are useful to obtain n-type and p-type GaN, respectively. However, there is still little information on actual lattice lo cation of impurities. We have investigated the Si dopant site in the GaN la ttice using ion channeling technique in combination with Rutherford backscattering spectrometry (RBS), particle induced X-ray emission (PIXE) and nuclear reaction analysis (NRA). Metalorganic chemical vapor deposition (MOCVD) grown GaN on a c-plane sapphire substrate implanted with @super 28@Si at a do se of 7x10@super 14@cm@super -2@ with post-implant annealing was investigated. Channeling measurements were performed by taking angular scans around the and axes and recording RBS, PIXE and NRA yields for Ga, Si and N, respectively. The channeling results indicate that almost 100 % of Si goes into the Ga site when the samples are annealed at 1100°C for 30 minutes while for annealing at 1050°C and below, Si is distributed almost randomly. This suggests that a drastic change of Si substitutionality takes place in a narrow temperature region near 1100°C. Our results directly indicate that the electrical activation of Si implanted GaN with post-implant annealing is due to the formation of substitutional Si at this temperature.

11:20am **AS+VT-FrM10 Laser Assisted Etching of InP Studied with XPS***, **D.M. Wieliczka**, J.M. Wrobel, C.E. Moffitt,* University of Missouri, Kansas City*; J.J. Dubowski,* National Research Council of Canada, Canada

X-ray Photoelectron Spectroscopy (XPS) and Scanning Electron Microscopy (SEM) have been used to study the surface chemistry and morphology of InP wafers after photo-chemical etching of the surface. The etching process employed 308 nm illumination from a XeCl excimer laser in conjunction with a low pressure atmosphere of 10%/90% Cl@sub 2@/ He mixture. The samples were exposed to laser radiation with fluences ranging from 73 mJ/cm@super 2@ to 210 mJ/cm@super 2@. The lower fluence is well below the ablation threshold for InP under vacuum conditions. The use of a Kratos AXIS-HS photoelectron spectrometer allowed for mapping the surface chemical composition within the illuminated region and in the vicinity with a 60 µm spot size. Photoelecron spectral lines from In, P, Cl, C, and O were monitored for determining the surface chemical composition and for creating surface maps of the illuminated regions. The results showed a distinct correlation between surface chemical composition and laser fluence. At high fluence levels, the surface composition changed dramatically between the illuminated region and the exterior. Evidence for In-Cl compounds was found within the crater with thermal processes occurring in the region near the crater. At low laser fluence, the etching process showed no thermal effects in the near crater region and produced a crater with minimal Cl incorporation. In addition to the chemical changes with fluence, the surface morphology is dramatically altered. At high fluence levels, SEM images indicate the etched surface was rough and deposits of ablated material were left in the vicinity of the crater. At low fluence the images indicate a better surface morphology. This work was supported by the University of Missouri Research Board.

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