Material Characterization
Room 207 - Session MC+NS-FrM
Characterization of Interfaces and Thin Films

Moderator: L.A. Giannuzzi, University of Central Florida

8:20am **MC+NS-FrM1 RBS, AFM, and AES Characterization of Pt Films Deposited by Ion Assisted CVD***, **B. Rogers**, K.A. Telari, H. Fang, L. Shen, R.A. Weller,* Vanderbilt University*; D. Braski,* Oak Ridge National Laboratory

The semiconductor industry has used focussed ion beam (FIB) systems for several years to create site specific transmission electron microscopy (TEM) and secondary electron microscopy (SEM) cross sections, repair lithography masks, and to reroute electrical current by cutting and creating current carrying paths for circuit testing. The FIB systems' capability to both etch and deposit material in defined areas makes them good candidates for use as flexible processing systems for the development of specialized circuits. For example, metal patterns deposited in a FIB system could be used to form electrical connections and sensors on micro-electromechanical systems (MEMs) devices. Properties of the deposited material as well as the process by which it is deposited must be well characterized in order for the material to be successfully used in this type of development program. This work presents results from characterization of the ion assisted chemical vapor deposition of Pt from trimethyl(methylcyclopentadienyl)platinum [C@sub 9@H@sub 16@Pt]. Films were deposited in squares ranging from 50µm on a side to 400 µm on a side. Process parameters, including precursor temperature, dwell time, and ion beam current were varied to investigate their affect on the composition of the deposited films. A specially designed sample holder and Be mask enabled Rutherford backscattering spectrometry (RBS) determination and comparison of the Pt areal densities in these small features. Atomic force microscopy was used to determine the thickness and surface morphology of the deposited films. Scanning Auger electron microscopy was used to analyze the films for oxygen and carbon. Results show that the films contain a large amount of carbon and gallium in addition to the desired platinum. The presentation will conclude with a discussion of the effects of process parameters on the films' composition and possible pathways to maximize the platinum content of the films.

8:40am **MC+NS-FrM2 Material and Interface Characterization of Locally Deposited Dielectrics and Metals Fabricated with a Focused Ion Beam (FIB)***, **H.D. Wanzenboeck**, H. Langfischer, E. Bertagnolli, H. Stoeri, M. Gritsch, H. Hutter,* Vienna University of Technology, Austria

A chemical vapor deposition process was performed under vacuum conditions utilizing a focused ion beam (FIB) tool confining the deposition on a selected area in the Âµm down to the deep sub-Âµm range. The direct fabrication by FIB offers a versatile approach for rapid development and instant testing of novel microelectronic devices. The electrical properties of devices are influenced by the bulk attributes of the material. For complex multilayer structures the interface between 2 materials is of crucial importance. A focused Ga ion beam with diameter down to 5 nm was applied to induce decomposition of selected metalorganic species and siliconorganic compounds adsorbed on the sample surface. Deposition of metals was achieved by using metalcarbonyls such as W(CO)6 as precursors. Dielectrics such as siliconoxides were deposited by coadsorption of siloxane and pure oxygene. For siliconoxide the mixture ratio of the volatile precursor gases was found to be decisive for the chemical composition and electrical properties. For material characterization multilayer structuresof dielectric and metal have been investigated. Auger-Spectroscopy revealed a correlation between the chemical composition of the FIB-deposited layers their electric characteristics and the process parameters chosen. Images of the X-section of the surface and interface deposited layers showed a homogeneous bulk density and a satisfactory surface roughness. Although the interface between FIB-deposited metal and dielectric layer is clearly visible in the secondary electron image depth profiling by secondary ion mass spectroscopy (SIMS) suggests an altered layer due to atomic mixing by the ion beam in a typical range up to 100 nm. The refined comprehension allowed to optimize the process parameters foraer improved material properties.

9:00am **MC+NS-FrM3 Three-Dimensional Material Characterization using Focused Ion Beams (FIB)***, **R.J. Young**,* FEI Company **INVITED**

The focused ion beam (FIB) system is integral to the manufacture of semiconductor and data storage devices. Systems are now found throughout the manufacturing process, from the research laboratory to the production line. The ability of the FIB to image at high resolution, and to locally sputter and add material, provides capabilities not obtainable with optical and scanning electron microscope (SEM) techniques alone. FIB techniques include cross-sectioning, gas-assisted etching and deposition, circuit editing, ion channeling imaging, secondary ion mass spectroscopy (SIMS), and transmission electron microscope (TEM) thin film preparation. In addition, combining together the FIB and SEM in a single instrument (a "dual beam") produces an extremely powerful and flexible materials characterization system, providing unique three-dimensional subsurface metrology and analysis capabilities. In particular, the electron beam can be used to image the face of the cross section as it is being milled by the ion beam. This greatly aids in the location of very small defect sites. Further, the use of in-situ delineation etching allows the whole process of sample preparation to final imaging to be carried out in a single instrument. It should also be noted that SEM and FIB images and analysis techniques are in many ways complementary, the different contrast mechanism in each case giving additional information about the sample. Many of the FIB and dual beam techniques used in the analysis and sample preparation of microelectronic devices apply equally to other disciplines. In particular, the ability to locate, expose and then analyze submicron or unique defects has a wide applicability within material and biological sciences. This paper reviews the capabilities of focused ion beam systems, illustrating these with a number of case studies.

9:40am **MC+NS-FrM5 Visualizing Interfacial Structure at Non-Common-Atom Heterojunctions with Cross-Sectional Scanning Tunneling Microscopy@footnote 1@***, **J. Steinshnider**, M. Weimer,* Texas A&M University*; R. Kaspi,* Air Force Research Laboratory*; G.W. Turner,* Lincoln Laboratory, M.I.T.

We describe how scanning tunneling microscopy (STM) may be used to image the interfacial bonding across the nearly-lattice-matched, non-common-atom GaSb / InAs heterojunction with atomic-scale precision. An ideal, compositionally-abrupt GaSb / InAs interface introduces new bonds - either InSb-like or GaAs-like - whose natural lengths differ from those in the surrounding host materials. These bond length differences are readily distinguished following (110) cleavage of the heterojunction, which locally relieves the out-of-plane compressive or tensile strain otherwise accommodated by a lattice-mismatched interface. The method is equally applicable to AlSb / InAs and suggests how it might be possible to determine the interfacial structure of such non-common-atom heterojunctions from atomic-resolution STM data.@FootnoteText@@footnote 1@Work supported by the National Science Foundation, Division of Materials Research, and the Air Force Research Laboratory

10:00am **MC+NS-FrM6 Atomic Resolved Spectroscopic Study of AlGaAs/GaAs/InGaAs by Cross-sectional Scanning Tunneling Microscope***, **J. Yu**, L. Liu, J. Li, J.W. Lyding,* University of Illinois

An atomic resolved cross-sectional STM spectroscopic study has been performed on UHV-cleaved AlGaAs/GaAs/InGaAs heterostructures. Current imaging tunneling spectroscopy (CITS) results demonstrate significant electronic structure contrast between the column III and V sublattices as well as for the different compositional regions. The resulting images reveal surface structures not always evident in topographic images. Using a pattern recognition algorithm derived from the VERI analysis developed at Sandia,@footnote 1@ the image pixels can be grouped into classes according to similar electronic structure. This technique can be applied to automatically identify the spatial distribution of various elements during semiconductor growth. A detailed analysis and physical explanation of the spectra will be presented. @FootnoteText@@footnote 1@Bouchard, A. M., Osbourn, G. C., and Swartzentruber, B. S., Surf. Sci. 321, 276 (1994).

10:20am **MC+NS-FrM7 Scanning Spreading Resistance Microscopy of MOCVD Grown InP Structures***, **St.J. Dixon-Warren**, S. Ingrey,* Nortel Networks, Canada

Scanning spreading resistance microscopy (SSRM) is a new probe microscopy technique that provides localized resistance profiling over a semiconductor surface. The technique, which is based on contact-mode atomic force microscopy (AFM), provides information on the two dimensional distribution of charge carriers and on the position of pn junctions in semiconductor structures. We have used SSRM to examine the cleaved edge of a number of MOCVD grown InP structures, including multi-quantum well layers and buried heterojunction laser structures. Information on the spatial distribution of dopants in the InP epitaxial layers was obtained. The effect of the applied tip voltage was investigated. We found that the active region of the laser structure, where the band gap is lowest, could be identified in the voltage dependence of the SSRM images. The effect of scanning rate, surface preparation and tip choice will also be discussed.

10:40am **MC+NS-FrM8 XPS Analysis of Interfacial WO@sub x@ using Linear Least Squares and Standard Curve Fitting Routines***, D.K. Fillmore,* Micron Technology, Inc.

X-ray photoelectron spectroscopy (XPS) has proven itself extremely useful in determining the chemical states of various materials. These chemical state identifications are primarily inferred from characteristic peak shapes and energy shifts along with the correlating presence of other elements and a previous knowledge of typical chemical compounds. When several chemical species are present in a particular sample, standard curve fitting routines are employed to extract the individual spectral components from multi-component spectra. This entails significant care in assigning each of the individual component peak energies, relative intensities and characteristic widths. The problem is exacerbated when ion sputtering is employed which results in sputtering-induced decomposition of components. From the curve-resolved data, atomic concentrations of individual components in a multi-component sample may be obtained. By making certain assumptions in specific circumstances, linear least squares (LLS) analysis routines may be able to quickly extract similar atomic concentration data from multi-component spectra without explicitly identifying individual spectral component peaks. This paper will discuss and compare analyses of interfacial WO@sub x@ found between a surface SiO@sub 2@ layer and underlying elemental W using both LLS and standard curve fitting analysis routines. Specific advantages and disadvantages of each approach will be covered.

11:00am **MC+NS-FrM9 Investigations into the Chemical Nature of the Interfaces of Cu and Ta with SiN***, **J.F. Bernard**, E. Adem, S. Avanzino, M.-V. Ngo,* Advanced Micro Devices

Surface chemistry is typically related to film properties such as adhesion, wetability, etc. For Cu interconnects the surface mobility of of Cu ions can affect electromigration and line-to-line leakage in damascene structures.@footnote 1@ The surface treatment of Cu after CMP planarization will effect the chemical nature of the interface with the capping material as well as the interface of any liners with the cap. The chemical nature of the interface of Cu with SiN has been determined through XPS and AES compositional and chemical state depth profile analyses. The effect of plasma treatments on the Cu surface and resulting interfaces with the SiN capping layer is detailed. A mechanism for the Cu° catalyzed generation of the observed interfacial non-N bonded Si resulting from a silane based SiN deposition is proposed. Additionally, the interface of SiN with Ta is investigated to explore the effects of Cu treatments on the liner/cap interface. The basic outgassing behaviors of Cu and Ta are also discussed relative to the effects observed at the interface with the SiN capping layer. @FootnoteText@ @footnote 1@ Noguchi, J., "TDDB Improvement in Cu Metallization under Bias Stress"; International Relaiabilty Physics Symposium 2000.

11:20am **MC+NS-FrM10 On the Organic Content and Outgassing Behavior of Organometallic-based CVD-TiN Films***, J.F. Bernard, **E. Adem**,* Advanced Micro Devices

The drive to smaller IC geometries has led to an increasing use of organometallic precursor based chemical vapor depositions of TiN barrier films. The CVD-TiN process yields more uniform step coverage in high aspect ratio features. The CVD process also presents challenges in generating a consistently high quality TiN film. At lower temperatures both organometallic and metal halide precursors yield a lower density film with high resistivity and low N conents. A N-based treatment process has been widely employed to i)reduce the organic component and ii)increase the N content of the films resulting from the use of TDMAT or TDEAT organometallics. The remaining C in the film has been shown to be present as a cabide of Ti. The chemical state of this remaining C has been further examined through the use of depth profiling, FT/IR, and wet chemical etching techniques. Deviations in the plasma treatment or the as deposited thickness can have a significant effect on the film quality. The affinity for O exhibited by uncapped PVD-TiN is higher still for untreated CVD films. The evolved gas profiles for a low resistivity film are dominated by H/H@sub2@ outgassings. Films with a deviation in plasma conditions exhibited higher resistivity beyond spec limits and outgassings dominated by OH.

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