Thursday Afternoon, November 5, 1998

Applied Surface Science Division

Room 307 - Session AS-ThA

SIMS - Depth Profiling and Molecular Surface Analysis Moderator: D. Simons, National Institute of Standards and Technology

2:00pm AS-ThA1 Sputtering Rate Change and Surface Roughening in SIMS Measurements Using Oblique and Normal Incidence Oxygen Bombardment, With and Without Oxygen Flooding, *C.W. Magee*, Evans East; *S.P. Smith, G.R. Mount*, Charles Evans and Associates; *H.-J. Gossmann, B. Herner*, Bell Laboratories, Lucent Technologies

Measuring depth profiles for ultra-low energy ion implants in Si requires accurate analyses within the top 1 to 10 nanometers of the sample surface where the "surface transient" affects secondary ion yields. Flooding the Si surface with oxygen during analysis is an accepted method for reducing the magnitude of the surface transient effect. However, a recent study by Wittmaack and Corcoran@footnote 1@ suggests that flooding with oxygen when using 2 keV oblique incidence O2 bombardment will result in an unavoidable change in the sputtering rate for the first 20-40 nanometers of the depth profile. Another recent study, this one by Jiang and Alkemade@footnote 2@, substantiated the claims of Wittmaack and Corcoran. Jiang and Alkemade used 1keV O2 bombardment instead of 2 keV, and they found that the depth of sputter rate change extended less than 11.7 nanometers. The study of Jiang and Alkemade used a Si sample in which contained internal Ge delta layers which were grown by MBE at intervals of 11.9 nanometers. This sample allowed them to compare unambiguously the apparent depth of the Ge layers to the known depths, thus exposing any changes in sputtering rate throughout the structure of 10 equally spaced Ge delta layers. The weakness of the Jiang and Alkemade experiment lay in the rather wide spacing of the delta layers (11.9 nanometers) as well as the fact that different energies and angles of primary ion incidence were not tried. This present study is an extension of the Jiang and Alkemade work. It involves using a similar MBE sample with internal marker layers to also determine, unambiguously, enhancements in initial sputter rates and the depths to which the enhanced initial sputter rates extend. Most importantly, we have investigated a large portion of the energy-angle of incidence parameter space and have found several sets of conditions of oblique incidence with oxygen bombardment which show virtually no enhanced sputter rate at the beginning of the analysis. Data will also be shown which duplicates the sputtering conditions of the experiments shown in reference 1. We will show that some of the conclusions drawn by the authors of reference 1 are not supported by our data. @FootnoteText@ @footnote 1@K. Wittmaack and S.F. Corcoran, J.V.S.T. B 16(1), 272 (1998). @footnote 2@ Z.X. Jiang and P.F.A. Alkemade, Proc. 11th Annn. Conf. On SIMS, edited by G. Gillen, R. Lareau, J. Bennett and F. Stevie, John Wiley & Sons, (1998).

2:20pm AS-ThA2 Secondary Ion Mass Spectrometry of Deep Trench Capacitors in Dynamic Random Access Memory, C.C. Parks, IBM Analytical Services; H. Glawischnig, Siemens AG, Germany; M. Levy, IBM Burlington; Chr. Dieseldorff, Siemens at International Sematech

Secondary Ion Mass Spectrometry (SIMS) supported the development of deep trench capacitors in Dynamic Random Access Memory (DRAM). SIMS is done efficiently by analyzing thousands of cells in parallel and the approach described in this paper is scalable to the multi-Gbit generation. By projecting out fundamental values using geometrical formalisms, the behavior of contaminants and dopants in sub-micrometer geometries is understood without the need for small-area measurements. Contamination aspects are addressed: quantifying and partitioning of halogen, alkali, and transition-metal residues among deep trench and other processing sectors. The deposition of self-limiting layers of arsenic during polysilicon fill of the deep trench is explored in detail. The doping of the trench side-walls, either through angle ion implants or by drive-in of doped-glass deposition, is quantified.

2:40pm AS-ThA3 TOF-SIMS Depth Profiling of Novel Si Devices, J.G.M. van Berkum, P.C. Zalm, Philips CFT - Materials Analysis, The Netherlands INVITED

Since about two years, concentration depth profiles of dopants in e.g. Si are not only measured with magnetic-sector SIMS or quadrupole SIMS, but also with time-of-flight (TOF) SIMS. In this technique, two ion sources are operated alternatingly: (i) a short-pulsed high-energy 'analysis' beam (typically 800 ps 11 keV Ar@super +@) produces secondary ion mass spectra and (ii) in between the pulses a low-energy 'sputter' beam (typically <1 keV O@sub 2@@super +@ or Cs@super +@) erodes the surface. The ion beam mixing is (almost) completely determined by the

energy of the sputter beam. Therefore, a very good depth resolution can be obtained without concessions to the analysis beam. High mass resolution (up to M/@DELTA@M=10.000) can be maintained due to the short pulse length and imaging during the depth profile with a lateral resolution down to 100 nm is possible. Thanks to the simultaneous mass detection, TOF-SIMS is particularly useful for devices with ultra-steep dopant profiles in the presence of other dopants or in devices with oxide layers or SiGe hetero-epitaxial layers. For example, for understanding the electrical behaviour of Schottky diodes or tunnel diodes with a high concentration of one or two dopants in an ultra-thin SiGe layer, it is essential to measure the dopant and the Ge concentrations at exactly the same depth. The same holds for CMOS devices with SiGe channel (typically a few nm's of SiGe at a few nm's distance from the gate oxide) or bipolar transistors with hetero-epitaxial base. The optimum condition for such measurements may differ from the optimum conditions for the elements separately. For B, P, As and Ge in Si, we often use O@sub 2@@super +@ primary ions, positive secondary ions and oxygen flooding to enhance the ion yields and suppress the pre-equilibrium effects. The segregation of Ge due to oxygen flooding is quantified by comparative measurements using different measurement conditions.

3:40pm AS-ThA6 Nitrogen Incorporation and Trace Element Analysis of Nanocrystalline Diamond Thin Films by SIMS, *D. Zhou*, University of Central Florida; *F.A. Stevie, J. Mckinley*, Cirent Semiconductor; *H. Gnaser*, University of Kaiserslautern, Germany

Nitrogen has been recognized as an important impurity in diamond, and the nature of its electronic states has been a central concern in elucidating the electronic and the optical properties of both natural and synthetically grown diamond. Although substitutional nitrogen in diamond is a deep donor impurity, it can affect that optical transparency, thermal conductivity, and electron field emission characteristics of diamond. We report that nitrogen has been successfully incorporated into nanodiamond films produced from a N@sub 2@/CH@sub 4@ microwave plasma enhanced CVD. High mass resolution SIMS (with a Cs@super +@ source) characterization shows that the concentration of the incorporated nitrogen, monitored via CN@super -@ (26.0031 amu), can be as high as 10@super 21@ atoms/cm@super 3@ depending on the ratio of N@sub 2@ to CH@sub 4@ in the reactant gas and on the substrate temperature used for the film preparation. The SIMS depth profile demonstrates that the incorporated nitrogen is uniform through the diamond films (about 1 micron thick) except for the surface and the interface between the film and substrate. Furthermore, SIMS (with an O@sub 2@@super +@ source) analysis reveals that alkali elements such as Na, K and Li appear to be the major trace metallic impurities and/or contamination for the diamond thin films produced from CH@sub 4@/N@sub 2@, CH@sub 4@/Ar, or CH@sub 4@/H@sub 2@ discharge, but they are the bulk impurities only for the thin films prepared from CH@sub 4@/N@sub 2@ plasma. These alkali impurities could also play important roles in electronic properties such as electron field emission of nanodiamond thin films. The authors would like to acknowledge the support from the Advanced Materials Processing and Analysis Center and UCF/Cirent Materials Characterization Facility at University of Central Florida. D. Zhou also specially acknowledge valuable discussion with D. M. Gruen and A. R. Krauss at Argonne National Laboratory.

4:00pm AS-ThA7 Quantitative ToF-SIMS Analysis of Industrial Polymers, A.A. Galuska, D.W. Abmayr, Exxon Chemical Co. INVITED

In recent years, ToF-SIMS has been developed as a tool for surface (top 10 Å) and microscopic (= $60 \ \mu m$) polymer analysis. The technique is most commonly used to qualitatively identify chemical species on polymer surfaces. However, quantitative methods can also be routinely performed on polymer articles. In fact, much of the real power of the technique for industrial polymer analysis is associated with the quantitative information that can be obtained from the ToF-SIMS mass spectra. In this presentation, we will discuss quantitative ToF-SIMS methods for the analysis of comonomers, sequence distributions, MWs, and trace elements in various polymers. Issues associated with microscopic bulk analysis will also be discussed. When possible, quantitative methods will be demonstrated using industrially meaningful analyses.

4:40pm AS-ThA9 Secondary Ion Emission from Molecular Surfaces and Overlayers under Noble Gas and Molecular Primary Ion Bombardment, D. Stapel, A. Benninghoven, Universität Münster, Germany

By changing from atomic to molecular primary ions, considerable increases in secondary ion yields Y(X@sub i@@super q@) are achieved, in particular for molecular surfaces and overlayers. In an earlier paper@footnote 1@ we

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report on yield increases up to a factor of 1000 for polymer surfaces under 10 keV SF@sub 5@@super +@ bombardment. The corresponding increase of damage cross sections @sigma@(X@sub i@@super q@) is relatively small, so that the increase in ionization efficiencies E(X@sub i@@super q@) = Y(X@sub i@@super q@)/@sigma@(X@sub i@@super q@) remains high. This has important consequences for the analytical application of molecular SIMS - for spectroscopy as well as for imaging and microarea analysis. For further yield optimization and for a better understanding of this yield enhancement by the use of molecular primary ions, we carried out systematic investigations for different polymers, metals and semiconductor materials, covered by a variety of molecular overlayers as biomolecules, additives, LB- and SA-layers, etc. Comparing molecular (SF@sub 5@@super +@, C@sub 7@H@sub 7@@super +@, C@sub 10@H@sub 10@@super +@, ...) and atomic (Ar@super +@, Kr@super +@, Xe@super +@) primary ion bombardment we found for nearly all of the investigated molecular surfaces and overlayers a strong increase in molecular ion yields, a much smaller increase in the corresponding damage cross sections, and smaller secondary ion emission depths. Experimental results will be presented and will be compared with model calculations. @FootnoteText@ @footnote 1@ F. Kötter, A. Benninghoven, Appl. Surf. Sci., in press

5:00pm AS-ThA10 Coincidence Counting in Highly Charged Ion Based Time-of-Flight Secondary Ion Mass Spectrometry, A.V. Hamza, T. Schenkel, A.V. Barnes, D.H. Schneider, Lawrence Livermore National Laboratory

The high (>1) secondary ion yield per incident primary ion, which is produced when slow, highly charged ions impinge on a surface, affords the collection of time-of-flight secondary ion mass spectra in coincidence mode. In coincidence mode a spectrum may be acquired in which a particular secondary ion is required for each recorded primary ion event. Primary ion events that do not exhibit the required secondary ion are discarded. Since the primary highly charged ion induces the emission of secondary ions from a localized area of ~20 nm, the coincidence measurement insures that secondary ion emission be from within 20 nm of the coincident secondary ion emission. Hence localized (20nm scale) chemical information is obtained. An example of the power of this technique with highly charged ions is presented for a tungsten/SiO@sub 2@ patterned silicon sample wafer. Details of the wafer processing steps can be discerned from the coincidence spectra. By this coincidence method trace impurities can be associated with tungsten features. This work was performed under the auspices of the U.S. Department of Energy at Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

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