Materials Characterization in the Semiconductor Industry Focus Topic
Room: Hall D - Session MC-TuP

Poster Session for all areas of Materials Characterization in the Semiconductor Industry

MC-TuP1 Volumetric and Surface Chemistry of SF_6/C_4F_8/Ar Gas Mixture, ***Robert Bates***, *M.J. Goeckner, P.L.S. Thamban, L.J. Overzet*, University of Texas at Dallas

While plasmas using mixtures of SF_6, C_4F_8 and Ar are widely used in deep silicon etching, very few studies have linked the discharge parameters to etching results. We measured the optical emission intensities of lines from Ar, F, S, SF_x, CF_2, C_2, C_3 and CS as a function of the percentage C_4F_8 in the gas flow, the total gas flow rate and the bias power. In addition, the ion current density and electron temperature were measured using a floating Langmuir Probe. For comparison, trenches were etched of various widths and the trench profiles were measured. The addition of C_4F_8 to an SF_6/Ar plasma acts to reduce the availability of F as well as increase the deposition of passivation film. Sulfur combines with carbon in the plasma efficiently to create a large optical emission of CS and suppress optical emissions from C_2 and C_3. At low fractional flows of C_4F_8, the etch process appears to be controlled by the ion flux more so than by the F density. At large C_4F_8 fractional flows the etch process appears to be controlled more by the F density than by the ion flux or deposition rate of passivation film. CF_2 and C_2 do not appear to cause deposition from the plasma, but CS and other carbon containing molecules as well as ions do.

Financial Support Acknowledgement: TI/SRC Award #2261.001

MC-TuP3 SIMS Measurements of Impurities and Alloying Elements in Cu Films used for BEOL Processes, ***Steven Novak***, *T. Laursen*, SUNY College of Nanoscale Science and Engineering, *M. Rizzolo*, IBM Albany Nanotech Center, *B. O'brien*, SUNY College of Nanoscale Science and Engineering

Significant recent work has concentrated on the impurity contents of electroplated copper and how they affect the crystallization of copper interconnects. Plating bath additives cause elevated impurity contents in electroplated Cu films that have been thought to pin grain boundaries and strongly affect the recrystallized grain structure of the Cu. SIMS is among the most utilized technique to measure impurity contents in electrochemically deposited Cu however SIMS data is typically only given as relative comparative data. We present quantitative measurements for C, O, S and Cl contents in ECD Cu using both TOF-SIMS (IonTof V) and quadrupole (Phi 6650) SIMS instruments. Using ion-implanted standards we have found that detection limits for impurity elements are typically well below the required limit for ECD Cu. Detection limits are typically one order of magnitude lower using dynamic SIMS compared to TOF-SIMS. The high mass resolution available for TOF-SIMS allows unambiguous quantitative measurement of impurities like S, which experiences mass interference from the O2 molecular ion. Quantitative SIMS analyses show linear increases in impurity contents within plated Cu films as the additive content increases in the plating bath. Although impurity elements are commonly cited as a major effect on the grain size of recrystallized Cu films, recent experiments with intentionally layered Cu samples, having impurity content differences of 2-3X, show that the impurity content has little effect on ultimate crystallite size. Impurity measurements in Cu trenches have been a goal for SIMS for some time. Ion imaging of Cu trenches 450-35nm wide has been carried out using the Bi LMIG gun of the IonTOF V instrument. This instrument is capable of 200nm image resolution. Depth profile analysis of Cu trenches show higher impurity contents within clearly-resolved 450nm wide trenches and suggest even higher contents within smaller trenches, when compared to the Cu overburden. Detection limits in image mode are at least one order of magnitude higher than standard depth profile mode. Alloying Cu with other metals has been proposed as a means of minimizing electromigration within plated Cu lines. Presently Mn is used as an alloy element in seed Cu layers. In addition to Mn, we have studied ion implants of Ag, Co and Ni in Cu as standards for quantifying these elements in seed Cu layers. The alloying element will be present below 1 at percent, less than can be reliably measure with other surface analytical techniques. SIMS analytical methodology and detection limits will be presented for each of these elements in Cu.

MC-TuP4 Growth and Characterization of β-Tungsten Films, ***Avyaya Jayanthinarasimham***, *M. Medikonda, A. Matsubayashi, A.C. Diebold, R. Matyi, V.P. LaBella*, SUNY Albany, *P. Khare, H. Chong*, College of Nanoscale Science and Engineering

The giant spin Hall effect (GSHE) is caused by spin orbit interactions in a semiconductor [1] or metal [2] that result in a spin current that is transverse to charge current. Recent spin Hall effect studies in the beta phase of metals such as Ta and W produce transverse spin currents strong enough to switch an adjacent magnetic layer [3]

The metastable β-W is known to exhibit giant spin Hall effect [8]. Deposition conditions selective to β phase of W need to be understood for the large scale fabrication of devices that utilize GSHE. The growth of α and β phases of Tungsten are strongly governed by thickness [4], base pressure [5] and oxygen availability [6] [7]..

This poster will present our work on fabricating and characterizing tungsten films, dominated by the β-phase over a large thickness range by adjusting the oxygen content during the growth. Resistivity measurements as well as x-ray photoelectron spectroscopy and x-ray analysis are performed to determine the phase of the tungsten films.

Reference:

[1] Dyakonov, M.I.Perel, V.I.: Phys. Lett. A 35, 459 (1971)

[2] J.E. Hirsch, arXiv:cond-mat/9906160

[3] Luaiao Liu et al. Science 336, 555 (2012)

[4] D. Choi, et al. J. Vac Sci. Technol.A 29, 051512 9 (2011)

[5] S.M. Rossnagel et al. J.Vac. Sci. Technol. B20, 2047 (2002)

[6] S.Basavaiah Appl. Phys. Lett. 12, 259 (1968)

[7] T. Karabacak et al. Thin Solid Films 493 (2005) 293-293

[8] C.F.Pai et al. [http://arxiv.org/abs/1208.1711]

MC-TuP6 Some Experience in Characterizing Thin Films on Next Generation 450mm Wafer with Spectroscopic Ellipsometry, ***Richard Sun***, *N. Sun*, Angstrom Sun Technologies Inc.

Under guidance of International SEMATECH Manufacturing Initiative(ISMI), Angstrom Sun Technologies Inc developed the first tabletop spectroscopic ellipsometer for 450mm wafer application. A few challenges regarding wafer handling and small edge exclusion requirement will be discussed. With improved modeling, spectroscopic ellipsometry could also be used to determine EBR profile of photoresist by linear line scan near the wafer edge.

MC-TuP7 The Effect of Aberration Coefficients on Phase Shift in Electronic Optics, ***Chien-Nan Hsiao***, *J.S. Kao, F.Z. Chen, J.L.A. Yeh*, ITRC, NARL, Taiwan, Republic of China

The epitaxial SiGe/Simultiple quantum wells (MQWs) were grown by ultra-high vacuum chemical vapor deposition (UHV-CVD) on a single crystalline silicon (111) substrate. Aberration corrected scanning transmittance electron microscopy equipped the high bright electron gun, DCOR aberration corrector, high angle annular dark field (HAADF) detector, and EDS was used to analysis the atomic structure of SiGe/Si interface. The defocus (C1) and aberration coefficients of electronic optics system such as astigmatism (A1, A2, A3, A5), coma (B2, B4), spherical aberration (C3, C5), and star aberration (S3) were corrected preciously by changing the convergence angle of electron beam probe (18 and 25 mrad). It was found that the distance between dumbbell Si and Ge atoms could be directly measured by the HRSTEM HAADF image. The corresponding FFT shows the point resolution was shown higher point resolution. In addition, the effect of aberration coefficients on phase shift in electronic optic (phase plate) was investigated. Furthermore, the experimental results also demonstrated that simultaneously complementary atomic-resolution EDS line-scan signal in HRSTEM HAADF image. These results provide an effective approach to investigate structural chemical element image in real space at the atomic resolution.

MC-TuP8 Modification of Density of States in Iron Chloride Intercalated Epitaxial Graphene with Electric Bias, ***Taurean Groover***, *M.D. Williams*, Clark Atlanta University

Graphene, an atomic thick layer of carbon in a hexagonal lattice, has received a large amount of attention from researchers across many different scientific disciplines. Within the condensed matter physics community it is fairly well agreed that the electronic, optical, as well as structural properties of graphene are poised to revolutionize the semiconductor industry. This unique collection of properties proves promising but there are some obstacles that need to be addressed before these properties can be fully exploited. Graphene is a semimetal, which means that the conduction and valence bands touch at the Dirac point leaving no band gap to be utilized in semiconductor and optoelectronic devices. In this work we seek to investigate the electronic characteristics of epitaxial graphene, stage one and stage three ferric(III) chloride intercalated epitaxial graphene. We investigate the opening of a band gap in graphene through intercalation and in conjunction with the application of an appropriate electrical bias normal to the sample surface. Through theoretical calculations, we show that the electrical bias normal to the surface not only tunes the carrier concentration but also has the ability to switch the majority carriers from electrons to holes. The Walt de Heer Confinement Controlled Sublimation method was employed for the production of the epitaxial graphene samples and the two zone vapor transport method was employed for the intercalation of the samples. With the Confinement Controlled Sublimation growth method used, graphene is grown on SiC substrates which make these materials uniquely suited for a smooth integration into existing silicon based electronics. We observe, compare, and interpret the alteration of the density of states as well as the work functions of these samples upon the application of the electric field normal to the sample surface. Analyzing the band structure of these samples, we witness a change of the band structure from that of the AB stacking configuration to that of the decoupled AA stacking configuration. In conjunction with Raman spectroscopy, this confirms the electronic decoupling of graphene layers. Auger spectroscopy was employed to investigate the chemical environment of the near surface region of the samples and may be a viable method for stage number determination in intercalated materials. When intercalated with $FeCl_3$, the optical transparency of the sample is conserved and the resistivity drops tremendously which makes this material, in particular, uniquely suited for the production of transparent electrodes that can be utilized to improve the performance of Li-Ion batteries.

Authors Index

Bold page numbers indicate the presenter