Applied Surface Science
Room: C-106 - Session AS-WeM

Optical Methods and High-k Dielectrics Characterization
Moderator: H.G. Tompkins

8:20am **AS-WeM1 Verification of Silicon Native Oxide Growth Models using Spectroscopic Ellipsometry**, ***D.W. Crunkleton***, *V. Pawar, Z. Song, R.D. Geil, B.R. Rogers*, Vanderbilt University

The need for atomically clean silicon surfaces in microelectronics processing has lead to several proposed kinetic models of native oxide growth on silicon. In this work, we present new data sets from which these models are analyzed. We have measured the room temperature silicon dioxide growth on Si (100) samples pre-treated with various fluoride, chloride, and hydroxide base etchants. The oxide thickness is determined with multiangle spectroscopic ellipsometry. Many of the proposed kinetic models fit the trends in our data well; yet several tend to underestimate the final native oxide thickness.

8:40am **AS-WeM2 Measurement of Semi-Isolated Poly-Silicon Gate Structure with Optical Critical Dimension Technique**, ***D. Shivaprasad***, *J. Hu, M. Tabet, R. Hoobler,* Nanometrics, Inc., *W. Liu, H. Sasano, C. Bencher, D. Mui*, Applied Materials

The ITRS predicts the production of sub-100 nm transistor gates by 2004 pushing further the limit of the size and speed posed by 180 nm gates which are currently in use. With decreases in gate length, it has become extremely critical to measure these dimensions accurately using non-destructive techniques. Optical Critical Dimension (OCD) measurements are emerging as one of the most promising CD measurement techniques for sub-0.1 micron device fabrication. Compared to CD-SEM and X-SEM, OCD measurements are non-destructive, relatively high throughput, sensitive to sidewall profiles, and sensitive to sub-100nm linewidths. In the OCD technique, a broadband polarized light beam is focused onto the grating surface, and the spectrum of the 0th order reflection is measured. The spectrum contains a signature of the grating profile that is analyzed in real time using Rigorous Coupled Wave Analysis (RCWA). The real time curve fitting algorithms, which do not require library generation, make the analysis simple and easy to extend to a variety of grating structures. Since the OCD technique is based on specular diffraction, a primary requirement for the OCD measurement target is to have periodical grating structures with a line to space ratio typically 1:5. In this paper, we report using the OCD technique to measure poly-silicon gate grating with line to space ratio as large as 1:20. Poly-silicon gate grating structures with critical dimensions of 30â€”40 nm were measured with line to space ratios of 1:10 and 1:20. In both cases, the measurement showed excellent sensitivity to linewidth variations and detailed profile changes, without deterioration of repeatability. Data from an un-cleaned wafer with the hard mask still remaining will also be presented. This study has significantly extended the measurement range of the OCD technique and its application to isolated line measurements.

9:00am **AS-WeM3 Progress in Spectroscopic Ellipsometry: Applications from Vacuum Ultraviolet to Infrared**, ***J.N. Hilfiker***, *C.L. Bungay, R.A. Synowicki, T.E. Tiwald, C.M. Herzinger, B. Johs, G. Pribil, J.A. Woollam*, J. A. Woollam Co., Inc. **INVITED**

Spectroscopic ellipsometry (SE) is a non-contact and non-destructive optical technique for thin film characterization. In the past ten years, it has migrated from the research laboratory into the semiconductor, data storage, display, communication, and optical coating industries. The wide acceptance of SE is a result of its flexibility to measure most material types: dielectrics, semiconductors, metals, superconductors, polymers, biological coatings, and even multi-layers of these materials. Measurement of anisotropic materials has also made huge strides in recent years. Traditional SE measurements cover the ultraviolet, visible, and near infrared wavelengths. This spectral range is now acquired within seconds with high accuracy due to innovative optical configurations and new CCD detection. In addition, the wavelength range has recently been expanded both into the vacuum ultraviolet (VUV) and the mid infrared. This wide spectral coverage was achieved by utilizing new optical elements and detections systems, along with UV or FTIR light sources. Modern instrumentation is now available with unprecedented flexibility promoting a new range of possible applications. For example, the VUV spectral region is uniquely capable of characterizing lithographic materials for 157nm photolithography. The VUV also provides increased sensitivity for thin layers (e.g. gate oxides or self-assembled monolayers) and allows investigation of high-energy electronic transitions. The infrared spectral region contains new information about semiconductor doping concentration, phonon absorption, and molecular bond vibrations. In this work, we review the latest progress in spectroscopic ellipsometry hardware and software. Areas of significant application in both research and industrial fields will also be surveyed.

9:40am **AS-WeM5 Application of Bragg Light Scattering Method for Studying of Spatial Dispersion Effects in Ferroelectrics**, ***F.R. Akhmedzhanov***, Samarkand State University, Uzbekistan

Bragg light scattering method for studying of spatial dispersion effects was applied to pure $LiNbO_3$ and Mg doped $LiNbO_3$ ferroelectrics. The examined samples of pure $LiNbO_3$ and $LiNbO_3$ with Mg impurity (10^{-2} mol. %) were oriented along the axis of the third order with the accuracy of 10'. Piezoelectric transducers of Lithium Niobate of appropriate cuts are used in order to excite the plane-polarized transverse acoustic waves with the frequencies of 0.4-1.5 GHz. Measurements of the dependence of the scattered light intensity from the distance to the piezotransducer along the direction of the acoustic wave propagation have been carried out in automatic regime. The scattered light intensity can be presented as function dependence of the light intensity I with respect to distance Z of acoustic wave shift: $I = I_0 \exp(-A*Z) \cos^2(D*Z + F)$, Here I_0 is the scattered light intensity near piezotransducer, A is the attenuation coefficient of the acoustic wave, D - the specific rotation angle of the polarization vector and F - the initial phase angle. The obtained values of the scattered light intensities have been used to calculate the quantity and frequency dependence of the attenuation and of the specific rotation of polarization vector in given acoustic wave by modeling of above-mentioned equation. The effective constants of acoustical activity along the investigated direction were determined from the experimental data simultaneously. There has been shown the high efficiency and trustworthiness of the results of simultaneous calculation of attenuation coefficient and specific rotation of the polarization plane in gyrotropic crystals, as well as possibility of speculation of experimental curves by varying factors, which are changed in a real experiment.

10:00am **AS-WeM6 Titanium Dioxide Thin Film Growth on Si(111) by Chemical Vapor Deposition of Titanium(IV) Isopropoxide**, ***A. Sandell***, Uppsala University, Sweden, *M.P. Andersson,* Lund University, Sweden, *Y. Alfredsson,* Uppsala University, Sweden, *M.K.-J. Johansson,* Lund University, Sweden, *J. Schnadt, H. Rensmo, H. Siegbahn*, Uppsala University, Sweden, *P. Uvdal*, Lund University, Sweden

Due to its high dielectric constant, TiO_2 has been considered as a gate insulator material in Si-based MOSFETs, either in pure form or mixed with other compounds. In this contribution, I present a study of the initial stages of TiO_2 growth on Si(111)-(7x7) under ultra-high vacuum conditions using core level photoelectron spectroscopy (PES), x-ray absorption spectroscopy (XAS) and scanning tunneling microscopy (STM). The TiO_2 film was formed by means of chemical vapor deposition of titani um(IV) isopropoxide at a sample temperature of 500 C. The thickness and composition of the amorphous interface layer and its subsequent transition to crystalline anatase TiO_2 are discussed. Three different stages are identified: In the initial stag e (film thickness <1 nm), the oxygen atoms are coordinated mainly to Si atoms giving rise to Ti atoms with oxidation states lower than 4+. The next stage (<3 nm) is best described as an amorphous $TiSi_xO_y$ compound in which the oxidation state o f Ti is 4+ and the x and y values vary monotonically with the film thickness. Finally (>3 nm) a stoichiometric TiO_2 layer starts to form. The TiO_2 phase is anatase and the layer consists of largely equidimensional particles, approximately 10 nm wide. In addition, I will also broach the differences that occur upon lowering the growth temperature to 300 C and how the properties of the film can be altered by pre-oxidation of the Si(111)-(7x7) surface.

10:20am **AS-WeM7 Nitrided Silicon-Silicon Dioxide Interface: Electrical and Physico-Chemical Characterization by Complementary Surface Techniques**, ***L. Vanzetti***, *E. Iacob, M. Barozzi, D. Giubertoni, M. Bersani, M. Anderle*, ITC-irst, Italy, *P. Bacciaglia, B. Crivelli, M.L. Polignano, M.E. Vitali*, ST Microelectronics, Italy

The scaling down of MOS devices into the submicron regime needs high-quality ultrathin gate dielectrics. Silicon oxide nitridation is widely used to improve oxide reliability and to reduce interface degradation induced by electrical stress. Analytical issues in this field include electrical characterisation, nitrogen quantitative depth distribution and chemical characterisation. In this work NO and N_2O nitrided oxide layers with thicknesses in the range 70-120Å were studied. Different analytical techniques were used, namely the Elymat (Electrolytic Metal Tracer), SIMS and XPS. Surface recombination velocity was obtained from photocurrent measurements by a modification of the Elymat technique allowing the control of surface potential. The so-obtained surface recombination velocity was shown to be directly related to the interface state density of the as-grown oxide. Surface recombination velocity was correlated with nitrogen content in the silicon oxide layer, obtained by SIMS measurements. XPS analyses allow to explain the different electrical behaviour. In fact XPS measurements provide a complete chemical characterisation of these interfaces. In addition a comparison between quantified SIMS depth profiles and XPS etch-back depth profiles shows very good agreement in nitrogen profile shape and quantification. This approach results very effective for the full characterisation of this type of materials.

10:40am **AS-WeM8 Accurate SIMS analysis of SiON Films**, ***S. Miwa***, *H. Kobayashi*, SONY Corp., Japan, *K. Nakajima, K. Kimura*, Kyoto University, Japan

Oxynitride (SiON) films are generally used in advanced CMOS LSIs as gate dielectrics instead of SiO_2 films. The nitrogen distribution in the SiON films strongly affects the performance of the transistors, so it is important to analyze exact nitrogen profiles. Secondary Ion Mass spectrometry is the most frequently used method for the analysis of SiON films. In the analysis, low-energy Cs primary ions and the very high incidence angle (about 80 degrees from the normal incidence) are recommended to avoid knock-on, atomic mixing, and matrix effect over the SiON/Si structure. On the other hands, secondary ion yield is sensitive for the surface concentration of primary ion species. In this case, the surface coverage of Cs is dramatically varied depending on the slight change of the incidence angle because the incidence angle of primary ions is very high. We have carefully investigated that the angle dependence of relative sensitive factors (RSF) and the sputtering rate around this very high incidence angle. We have found that RSF is varied about 10% when the angle changed by 0.3 degrees and that sputtering rate is varied about 10% when the angle changed by 0.5 degrees. In conclusion, the incidence angle of primary ions must be controlled within only 0.1 degree in order to keep the quantification errors within 5%. We can control the angles well reproducibly by means of monitoring the ratio of the intensities of two secondary ions ($SiCs^+$ and Cs_2^+). We have also compared the N concentration obtained by SIMS with that obtained by High-resolution Rutherford Backscattering Spectrometry.

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