Manufacturing Science and Technology
Room 2018 - Session MS-ThA

Sensors, Metrology, and Control

Moderator: A.C. Diebold, SEMATECH

2:00pm **MS-ThA1 Three-dimensional Imaging of Nano-Voids in Copper Interconnects using Incoherent Bright Field Tomography***, P. Ercius, M. Weyland,* Cornell University*;* ***D.A. Muller,*** Cornell University, US*; L.M. Gignac,* Thomas J. Watson Research Center **INVITED**

As integrated circuits have shrunk, conventional electron microscopies have proven inadequate for imaging complicated interconnect structures due to the overlap of features in projection. These techniques produce transmission functions with a non-monotonic dependence of intensity on thickness for common microelectronic materials, making them unsuitable for tomography. We report the use of an incoherent bright field imaging technique in a scanning transmission electron microscope optimized for the three-dimensional reconstruction of thick copper microelectronic structures. Predictable behavior of the signal in samples up to ~1 micron thick allows us to reconstruct and quantify the shape and volume of stress voids within Ta-lined interconnects as well as analyze the liner roughness in 3 dimensions.

2:40pm **MS-ThA3 Critical Dimension Metrology: A Comprehensive Evaluation of Current Techniques in Spectroscopy-Based Scatterometry***,* ***C. Saravanan****, Z. Liu,* Nanometrics Inc

In recent years scatterometry has evolved into a reliable, non-invasive and fast technique to characterize critical dimensions (CD) in semiconductor device fabrication. Both polarized-light Normal Incidence Spectroscopy (NIS) and Spectroscopic Ellipsometry (SE) have been successfully used as competing techniques in CD metrology. While several studies have been performed to evaluate these techniques, a thorough evaluation of the 'optimal space' of applicability for these individual techniques does not exist. Furthermore, very little is known about the combined NIS and SE approach as an alternate method for CD metrology. In this paper we first explore 'regions' of optimal applicability of these three techniques (NIS, SE and NIS+SE) by performing simulations on multiple structures with varying heights, sidewall angles, optical properties and pitch (360nm, 180nm, 90nm, 45nm, 32nm and 16nm). We show that regions of optimal applicability exist for all three techniques. We also perform experimental studies for some typical applications and demonstrate the benefit of using combined analysis of NIS and SE to limit parameter correlation and to enhance sensitivity. This is particularly important for scatterometry applications in future technology nodes with much smaller device dimensions.

3:00pm **MS-ThA4 Low Coherence Optical Intereferometry and Raman Scattering Spectroscopy for Stress Tensor Measurements***,* ***W.J. Walecki****, T. Azfar, A. Pravdivtsev, A. Koo, J. Ryu,* Frontier Semiconductor

In this paper we discuss accuracy and reproducibility of two techniques for metrology of stress tensor in semiconductor wafers: novel combined IR low coherence optical interefermetry@footnote 1@ allowing simultaneous measurement of wafer topography and wafers and thin film thicknesses, enabling calculation of all in plane stress tensor components, and high precision tensor resolved Micro-Raman spectroscopy. Typical micro-Raman measurements are performed in backscattered geometry. Observed stress dependent Stokes shift is related to stress in the material using specific stress tensor model typically derived on a basis of symmetry considerations,@footnote 1,2@ the usual reported reproducibility of the stress measurement of the order of 10 MPa-30 MPa,@footnote 2,3@ which corresponds to reproducibility of the Stokes shift of the order of 0.05 cm-1). By applying very large focal length grating spectrometer (effective focal length 1.34 m), and proprietary thermal drift compensation we were able to achieve thermal stability of the better than 0.0002 cm-1 / min which allows us to further improve reproducibility. We also propose two methods for recovering three and six stress tensor components in cubic crystals (such as Si/SiGe) on microscopic scale. @FootnoteText@ @footnote 1@ W.J.Walecki, A. Pravdivtsev, K. Lai, M. Santos, G. Mikhaylov, A. Koo, in ''Characterization and Metrology for ULSI Technology 2005'', edited by D.G. Seiler, et al, American Institute of Physics, p. 338- 342, 2005@footnote 2@ V. T. Srikar, A. K. Swan, M. S. Unlu, B. B. Goldberg, and S. M. Spearing, IEEE Journal of Microelectromechanical systems, Vol. 12, No. 6, December 2003, pp. 779-787@footnote 3@ Ingrid De Wolf, Chen Jian, W.Merlijn van Spengen, Optics and Lasers in Engineering 36 (2) (2001) pp. 213-223.

3:20pm **MS-ThA5 Micro-Probe CV and IV Analysis of Thin Dielectric Films in Product Wafer Scribe-Line Structures***,* ***V.V. Souchkov****, T.M.H. Wong, V.N. Faifer, M.I. Current,* Frontier Semiconductor

A 50 µm metal probe has been coupled with pattern recognition optics and a precision stage for automated CV and IV testing of dielectric layers in scribe-line test structures on IC product wafers. Highly repeatable contact conditions are obtained though the use of a MEMS-based torsion balance spring mounting which provides capacitance measurements within 0.1% for repeated landings of the probe. High repeatability capacitance measurements provide for correspondingly high quality determination of dielectric characteristics, EOT, Vfb, Dit, Na and Qeff, from CV analysis. Dielectric leakage and breakdown characteristics, including Vbd, Qbd and TTBD, can be obtained for positive and negative ramped bias conditions. Examples of dielectrics include thin (1 nm) SiO@sub 2@, oxy-nitrides and Hf-based oxides as bare films and incorporated in capacitor structures.

3:40pm **MS-ThA6 Characterizing Copper Lines for Advanced Interconnect Using Normal Incidence Scatterometry***,* ***Z. Liu****, Y. Hao,* Nanometrics Inc.

With the continuous evolution of smaller device dimensions and denser circuit integration, copper interconnect with low-k dielectrics have been the most popular solution for future technology generations. In copper interconnect, one of the major challenges is the dimensional control of the interconnect features, which is critical to achieve necessary circuit performance of the device. To achieve best device performance, there is limited tolerance of the profile variation in interconnect structures. This dimensional control requirement demands metrology solutions to characterize the interconnect structures in all metal levels. In this paper we propose to use normal incidence scatterometry to characterize the copper lines (line width and height) at various metal levels. Normal incidence scatterometry uses a polarized broadband light source to measure the reflectance spectrum of the grating line structure. Using the modeling technique, profile information including line width and height can be determined. In this work we measure copper grating line structures at different metal levels (M1, M3 and M7) after each chemical mechanical polishing. These structures correspond to different copper line-widths ranging from 0.09 to 0.8 um. Structures with copper lines either parallel or perpendicular to each other between adjacent metal levels are studied. Advanced modeling techniques are used to decouple spectral contributions between the top metal level and the metal levels below. The measurement results are compared with results from other reference techniques, e.g. X-SEM and a very good agreement is demonstrated.

4:00pm **MS-ThA7 Leakage Current and Dopant Activation in Ultra-Shallow Junctions Following Ms-Anneals Measured by Non-Contact Junction Photo-Voltage Methods***,* ***V.N. Faifer****, T.M.H. Wong, M.I. Current,* Frontier Semiconductor

Leakage current and dopant activation characteristics of ultra-shallow junctions formed with ms-timescale anneals, which provide the beneficial result of minimal dopant diffusion, are highly sensitive to damage accumulation effects during the implantation of dopants, pre-amorphizing and various cocktail (C, F, S, etc.) ions. Damage accumulation levels are a result of the choice of ion, energy, dose and target material as well as process conditions such as beam current density, wafer temperature and beam scanning details for each implant cycle. The residual damage levels after annealing depend on the depth and character of the accumulated damage and the time-at-temperature ramp and ambient atmosphere conditions during each annealing step. For ms-timescale anneals which involve the use of scanned and pulsed energy deposition, the uniformity of the dopant activation and damage annealing process is strongly dependent on the spatial extent and overlap strategies used for the energy deposition beam used for heating. Measurement of junction characteristics through analysis of surface photo-voltage levels provides non-contact, high precision and independent measures of sheet resistance and leakage current density over 4 orders of magnitude. Discussion of leakage current effects will include the impact of background doping and defect density on carrier recombination and trap-assisted tunneling mechanisms. High-resolution (1,000 points per wafer) mapping of sheet resistance and leakage current variations provides rapid feedback for process evaluation of implant and annealing process equipment and correlation of conditions which result in favorable dopant activation and damage annealing.

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