Manufacturing Science and Technology
Room 304 - Session MS-MoM

Metrology for IC Manufacturing

Moderator: G.W. Rubloff, University of Maryland

8:20am **MS-MoM1 Inline Quality Analysis in MBE Manufacturing of AlGaAs/InGaAs pHEMT Structure Using Photoreflectance and Contactless Electromodulation Spectroscopy**, ***G. Zhou***, *W. Liu, M. Lin,* Alpha Industries, Inc.

Molecular beam epitaxy (MBE) has become a predominate technology in the manufacturing of pseudomorphic high electron mobility transistors (pHEMTs) for microwave power amplifiers and switchers. In order to keep ahead of the performance and cost curves, nondestructive inline metrologies which leverage the yield learning curve of the fabricator are required. We report the study of implementation of photoreflectance (PR) and contactless electromodulation spectroscopy (CER) as inline quality monitoring tools for AlGaAs/InGaAs pHEMTs manufacturing. Using the reduced mass deduced from experiments, the built-in electric field, the band-gap and/or Al composition in the barrier region is obtained from the above band-gap Franz-Keldysh oscillations (FKO). Two dimensional electron gas (2DEG) density can also be determined by the line shape fitting of the transitions from InGaAs region, and the statistical data both from PR/CER and Hall measurements on a number of wafers are compared. The quality of the device structure and 2DEG density confined within the InGaAs quantum well are found to have a direct relationship both to the intensity of PR/CER transitions from AlGaAs/GaAs superlattice and the built-in electric field in the AlGaAs barrier layer. This observation reveals the possibility to use PR/CER as a screening technique.

8:40am **MS-MoM2 Three Dimensional Reconstruction Metrology by Combinatory Multiple Parameter Characterization and Scanning Probe Microscopy**, ***E.C. Houge***, Lucent Technologies and University of Central Florida; *J.M. McIntosh, J.E. Griffith,* Bell Laboratories; *L.A. Giannuzzi,* University of Central Florida; *J.B. Bindell,* Lucent Technologies

Critical dimension metrology of integrated circuits has historically constituted only single parameter characterization of SEM intensity line profiles, which was intended to be representative of the overall linewidth. Due to the surjective nature of the intensity line profile, different morphological patterns can be represented by a single parameter thus causing the inability to delineate deviant morphologies. As the linewidths continue to decrease smaller variations begin to have significant impact in the overall morphology of the linewidth and the pattern transfer function. Three dimensional reconstruction metrology leverages the advantageous of two next generation inline metrology techniques, multiple parameter characterization and scanning probe microscopy, to create a new methodology of metrology. Multiple parameter characterization of scanning electron microscope intensity line profiles initially has shown promise of being able to distinguish deviations from nominal profiles in the characterization and evaluation against preset process margin templates stored in memory. Inline scanning probe microscopy presents the ability to do morphological shape evaluation by nondestructive cross sectioning of critical dimension features obtaining topographic z(x,y) mapping as a function of planar positioning of the scan system. Through the use of these two techniques along with transform reconstruction, a three dimensional topography of the sample surface can be reconstructed utilizing only two dimensional intensity and topographic mapping of the sample surface. Single parameter characterization is then replaced by the determination of Scale (nm), Shape Quality (A weighted polynomial of process margin template deviation, 0-1), and Deviation Bin (A descriptor for type of deviation, A-Z). This segregation of shape and scale along with the full characterization of the feature morphology presents the possibility for the feedback and feedforward use of metrology.

9:00am **MS-MoM3 Application of Scanning Capacitance Microscopy to the Characterization of Semiconductor Device Operation**, ***C.Y. Nakakura***, *D.L. Hetherington, M.R. Shaneyfelt, P.E. Dodd,* Sandia National Laboratories

Scanning capacitance microscopy (SCM) has become increasingly used for the study of semiconductor doping due to its ability to measure two-dimensional free carrier profiles with nanometer-scale resolution. The bulk of recent SCM work has focussed on carrier profile measurements in cross-sectioned, metal-oxide-semiconductor field-effect transistors (MOSFETs); however, limitations in the hardware and sample structures have restricted most studies to non-functioning devices. To address this, we have modified a commercial SCM and fabricated specially designed test structures that provide independent electrical access to the device regions, enabling the use of SCM to study actively biased devices. By recording images while incrementally increasing the gate bias voltage, we were able to visualize devices switching between the off and on states. The evolution of the SCM images as a function of operating bias provides insight into changes in the channel region during MOS device operation and will be presented in movie form. Complications in image formation, which arise from biasing the device, will be discussed. @FootnoteText@ This work was performed at and supported by Sandia National Laboratories under DOE contract DE-AC04-94AL85000. Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation for the United States Department of Energy.

9:20am **MS-MoM4 Metrology with Electron Beams - The Current State and Future Directions**, ***D.C. Joy***, University of Tennessee and Oak Ridge National Laboratory **INVITED**

Electron beam tools have become the instruments of choice for CD metrology, as well as for defect detection and analysis, because of the many benefits that they offer. As a result of intensive development work the performance of CD-SEMs and related tools has kept pace with the rapid decrease in feature size and the demands for increased throughput. However with the imminent advent of 100nm design rules in 2003 and the requirement for measurement precisions as low as 1nm and the need to detect defects as small as 10nm, it is clear that this situation is changing because the scope for further enhancements in microscope performance is now small. For example, at low beam energies the SEM is now operating at close to the minimum probe diameter set by diffraction, and the physics of electron-solid interactions and of secondary electron generation set a limit to resolution which may be as poor as 3 to 5nm in materials such as resists. Although some incremental improvements can be anticipated, through new technologies such as aberration corrected lenses, and new ultra-bright electron emitters, these advances will not be sufficient to bring the instruments to the levels required for sub-100nm devices and they will certainly not be sufficient to ensure a continued development path to even smaller structure, and the new molecular devices envisioned beyond the end of the road map. Some radical new solutions must therefore be examined. This talk will therefore examine several possible solutions including the use of high beam energies. the replacement of imaging by holographic techniques, the use of energy filtered imaging methods, and the use of point projection microscopes.

10:00am **MS-MoM6 Limitations of SIMS Depth Profiling for Shallow Implant and Thin Gate Dielectric Metrology**, ***M.G. Dowsett***, University of Warwick, UK **INVITED**

SIMS depth profiling is now expected to extract accurate quantitative data from the top 10 nm of a wafer under circumstances where a significant part of the measurement may be in the top 3 nm, and where the total impurity level in the material may be above 1%. The reality is that, however reproducible the data, accurate profiles can only in general be obtained for impurity levels below 1% and in the depth range 3-10 nm by very careful selection of the analytical conditions. For high dose, ultra-shallow, implants using molecular ions such as BF@sub 2@ (where the total impurity level may be as high as 30%) or for thin (1-5 nm thick) dielectric layers the inherent nonlinearity of both sputtering and ion emission, combined with the fact that the region of interest overlaps with the transient region leads to very strong matrix effects for which no correction procedure has yet been devised (indeed, depending on the level of non-linearity, no correction procedure may be possible). Given that there is an insatiable demand for profiles from the problem region outlined above, how can one obtain accurate profiles, or at least establish the level of error in, say, the dose, junction depth, or internal profile from a 2 nm thick oxynitride layer? The general answer is to examine profiles obtained under different analytical conditions and from different analytical techniques to see if the data converge on a dose or even a shape, to measure changes in erosion rate in the transient region using techniques other than SIMS (e.g. MEIS), and to compare directly profiled data with data where the transient has been removed from the problem by capping the wafer. In addition, measurements should be made under the most linear conditions possible so that reasonable correction procedures can be devised. Of course, suitable reference materials are required, in order to establish such conditions. Techniques for accurate profiling of the top few nm of a wafer still require research and further development of the tools before claims to a reproducible dose and junction depth can be translated into a known accuracy in profile shape, dose and junction depth.

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