Wednesday Afternoon, November 2, 2005

Manufacturing Science and Technology
Room 207 - Session MS-WeA

Metrology & Process Control for Advanced Manufacturing

Moderator: S. Shankar, Intel Corporation

2:00pm **MS-WeA1 Optical Interferometric Microscope for Real-Time Monitoring and Control of Focused Ion Beam Processes**, *D.P. Adams, M.B. Sinclair, T.M. Mayer,* ***M.J. Vasile****, W.C. Sweatt,* Sandia National Laboratories

Focused ion beam (FIB) techniques have a wide range of applications including lithographic mask repair, specimen preparation, semiconductor analysis and nanodevice prototyping. Although FIB systems offer excellent in-plane spatial resolution, these do not include instrumentation that actively monitors milled feature depth. In order to enhance the control of FIB systems, we have designed, fabricated and tested a custom optical interferometer microscope suitable for operation during processing. This Michelson interferometer is intended for real-time monitoring and feedback control of focused ion beam processes including sputtering. The apparatus is designed for minimal outgassing / UHV operation, and the optics are retractable (within the vacuum system) providing ample space when removed for other commonly-used diagnostic tools and gasjet assemblies. The optical path and ion beam vector are co-incident at the sample. This is made possible through use of a pinhole mirror that is positioned between the exit aperture of the ion gun and the specimen. Long working distance (39 mm), high numerical aperture (NA = 0.39) objectives have been custom designed and fabricated for the interferometer. Tests with FIB-milled Si samples demonstrate 1.0 micron optical in-plane resolution. Out-of-plane resolution is approximately 1-2 nm.

2:20pm **MS-WeA2 Method for Creating Cross-Sectional TEM Single Crystal Diamond Samples using Focused Ion Beam and In-Situ Lift Out**, ***D.P. Hickey****, E. Kuryliw, K.S. Jones,* University of Florida

A method is described for creating a transmission electron microscope (TEM) cross section of single crystal diamond using a focused ion beam (FIB) and in-situ lift-out. The method results in samples less than 50 nm thick at the tip and approximately 100-300 nm thick across the length, and does not require a large amount of starting material. Few TEM studies of single crystal diamond have been reported, most likely due to the time and difficulty involved in sample preparation. This technique can create a cross-sectional TEM sample in less than five hours. Creating cross-sectional TEM samples for single crystal diamond are slightly different than silicon due to the exceptional hardness and insulating properties of the diamond. The method also allows for additional thinning for use with high-resolution TEM imaging. The method is applied to oddly shaped diamond samples, and does not require a wafer-flat sample to create a TEM sample. This sample preparation technique has been applied to the study of ion implantation damage in single crystal diamond and its evolution upon annealing.

2:40pm **MS-WeA3 Temperature and Film Thickness Sensor for Substrates with Multi-layered Thin Films using Optical Fiber type Low-coherence Interferometry**, ***T. Ohta****,* Wakayama University, Japan*; K. Takeda,* Nagoya University, Japan*; M. Ito,* Wakayama University, Japan*; C. Koshimizu,* Tokyo Electron AT LTD., Japan

The temperature control of substrates is very significant to fabricate much finer and deeper patterns in ultra-fine processing technologies such as plasma processes. So we have developed a temperature sensor for measuring the temperature of each layer of multi-layered substrates, such as Silicon On Insulator (SOI), using a low-coherence interferometer and a Michelson interferometer. This system consisted of Super Luminescent Diodes (SLD:1550nm and 1310nm), a Laser Diode (LD:850nm), a scanning mirror, optical fibers, etc. We measured the temperature of multi-layered substrates of Si/SiO@sub 2@/Si=300µm/500µm/300µm, and as a result, we have found that this system has the resolution of 1 °C. However, this system had difficulty in measuring the temperatures of substrates with thin film layers, which have the optical pass length less than the coherent length of a low-coherent light source. To solve this problem, we have proposed a novel measurement for measuring the thickness of the thin film layer as well as the temperature of substrates. The thickness of the thin film was measured from the ratio of interference intensity of SLDs and the measured value corresponded with theoretical value within 2 micron of thickness. By estimating the film thickness the effect of interference overlapping was reduced, thus improving the error rate of temperature measurement.

3:00pm **MS-WeA4 Endpointing Chamber Clean by Calorimetric Probing of Plasma Effluent**, ***I.S. Chen****, J.W. Neuner, J.J. Welch, P.S.H. Chen, F. DiMeo,* ATMI

The semiconductor industry employs gas-phase cleaning widely to remove materials deposited on the chamber walls during thin film deposition processes. Chamber clean endpointing - i.e., terminating the process when the chamber is clean - is desirable to manage cost-of-ownership and environmental impact. Existing endpointing methods tend to rely on changes of plasma characteristics as the in situ plasma removes the deposit in time. Chamber clean technology is moving towards remote generation of plasma species for cleaning. In this arrangement, the chamber is located downstream from the plasma source. Because the etching reaction occurs ex situ, there are no relevant changes occurring in the plasma characteristics, and the effectiveness of many existing methods decreases. We report the development of a calorimetric probe for chamber clean endpointing. The probe has an all solid-state construction and is engineered to immerse in the plasma effluent during endpointing operation. The probe measures the heat flux carried by the effluent, and the signal has been shown to correlate with chamber condition. By virtue of its downstream location, the probe operation does not depend on the plasma sourcing scheme (in situ vs. remote). We demonstrate successful endpointing for in situ chamber clean of TEOS deposition process on a PECVD tool. The probe results compare favorably with other co-installed endpointing solutions.

3:20pm **MS-WeA5 Sensing and Control Strategies for Spatially Programmable CVD**, ***Y. Cai****, R. Sreenivasan, R. Adomaitis, G.W. Rubloff,* University of Maryland

A multiplexed mass spectrometric gas sampling system was designed and implemented for real-time, in situ measurement of gas species concentrations in a spatially programmable chemical vapor deposition (SP-CVD) reactor, a new paradigm for equipment design based on a segmented gas injection showerhead with exhaust gas recirculation up through the showerhead (U.S. Patent No. 6,821,910). To extend chemical sensing and metrology techniques developed for conventional CVD reactors to this new reactor configuration, we have developed a multiplexed gas sampling system based on a dynamic simulation of the sampling system, and demonstrated it in the SP-CVD reactor. Built on a three-segment SP-CVD prototype reactor, the gas sampling system was used to assess experimentally reactant gas transport mechanisms, focusing on: (1) inter-segment gas diffusion through the gap between showerhead and wafer surface; and (2) gas back diffusion through the common exhaust volume above the showerhead. We quantified the contribution of each transport mechanism to gas phase composition measured in each segment by fixing the sampling tube position and varying the gap dimension between the wafer and the movable showerhead. W CVD experiments using H2 reduction of WF6 were used to establish a model describing the relationship between the time integrated HF reaction product signal from the mass spectrometer and post-process thickness measurements obtained from four-point-probe maps of sheet resistance. Thickness metrology with precision of 3-4% has been obtained, approaching the desired range of thickness control precision. We expect that this sensing methodology not only will enable real-time spatially-distributed end point control, but also will make it possible to guide rapid reprogramming of process recipes intended to achieve simultaneously high material quality and uniformity, or to serve as a valuable asset to potential combinatorial experimental capabilities of the SP-CVD reactor.

3:40pm **MS-WeA6 High Resolution 2D dopant profiling of FinFET Structures and Silicon-based Devices using Scanning Probe Microscopies**, ***A.A. Khajetoorians****,* University of Texas at Austin*; X.-D. Wang,* Freescale Semiconductor Inc.*; J. Li,* University of Texas at Austin*; D. Pham,* International Sematech*; A.C. Diebold,* International Sematech, US*; C.K. Shih,* University of Texas at Austin

The ability to perform dopant/junction profiling with high spatial resolution is critical for development of future generation devices such as FinFET structures. Among various forms of scanning probe microscopy, scanning tunneling microscopy (STM) has demonstrated direct atomic imaging of dopant atoms on GaAs (110) surfaces. More recently, scanning thermoelectric microscopy (SThEM) (H.K. Lyeo et al Science v.303 p816 (2004)) has been applied to profile GaAs p-n junction with unprecedented spatial resolution. The key challenge to successfully apply these techniques to silicon-based devices is to prepare a surface that is both chemically and electronically passivated. Here we present our progress toward this goal. We present STM and SThEM studies on Si p-n junction devices including

FinFET structures. We also present in-depth profiling of fin structures using scanning capacitance (SCM) and conductive atomic force microscopy (C-AFM).

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