Monday Morning, October 31, 2005

Plasma Science and Technology
Room 302 - Session PS-MoM

Plasma Diagnostics

Moderator: S.G. Walton, US Naval Research Laboratory

9:00am **PS-MoM3 Emissive Probes in Processing Plasmas - A Good Way to Measure the Plasma Potential*, N. Hershkowitz*[1]***, *D. Lee,* University of Wisconsin **INVITED**

Electron emissive probes can provide measurements of the plasma potential with potential resolution of 0.1 V and spatial resolution of 0.1 cm in low pressure DC Argon plasma. The plasma potential is an important parameter in processing plasmas. However, such plasmas present many challenges to the use of emissive probes including rf, reactive gases, plasma deposition, impurity generation and relatively high neutral pressure so probes are rarely used. This talk provides experimental evidence that many of the challenges can be overcome and argues for increased use of emissive probes.

9:40am **PS-MoM5 A New Diagnostic Method of Radio-Frequency Plasmas Produced in Insulated Vessels*, H. Shindo,*** Tokai Univeristy, Japan

A new method to measure electron energy by an emissive probe has been proposed. The method is based on measurement of the functional relationship of the floating potential and the heating voltage of emissive probe. From the measured data of the floating potential change as a function of the heating voltage, the curve of the probe collection current-voltage can be analytically obtained. The present method has several important advantages of the following: (1) it is even applicable to radio-frequency plasma in which the potentials are usually fluctuating, (2) also applicable to plasmas which are produced in non-conductive containers. In the experiment, the emissive probe 30 micrometer diameter tungsten was heated by 40 kHz pulse voltage, and the floating potential at the heating voltage off period and the floating potentail difference between the heating off and on period were measured by digital oscilloscope in argon plasma. The measurements were made in both the capacitively coupled and inductively coupled plasmas. It was shown that the plasma electron energy probability function could be obtained without any RF compensating circuit even in capacitively coupled plasmas. In particular, since the method is very sensitive near the plasma potential, the clear indication for the depletion of the low energy electron could be obtained. This low energy electron depletion is due to high plasma potential. Therefore, in the inductively coupled plasma this low energy electron depletion was obtained near the induction antenna, but at the further positions from the antenna the energy distribution became Maxwellian. This feature has also been reported recently. This change in the electron energy distribution found in ICP was very systematic with the gas pressures and the distnaces from the antenna. Thus the present method is quite innovative in that it is applicable to the potential fluctuating RF plasma and measurements are all done in a floating condition of probe.

10:00am **PS-MoM6 Energy Dissipation in Capacitively Coupled Discharges of Molecular Gases*, G.F. Franz,*** Munich University of Applied Sciences, Germany

The heating of heavy plasma components by elastic collisions with electrons is one of the main mechanisms of energy transfer to ions and neutrals at low and medium power input, but often regarded inevitable. It is measured by optical emission spectroscopy, employing rovibrational bands of nitrogen, which is doped to capacitively coupled discharges of hydrogen and chlorine, and for comparison, also argon.@footnote 1,2@ The temperatures in chlorine are comparable to the inert gas argon, whereas hydrogen is significantly cooler, but all three will saturate at higher power inputs (more than 1/4 W/cm@super 2@ absorbed power density or at dc bias values higher than about 600 V). It is this region where parasitic processes (the most prominent is power absorption by ions in the sheath) will begin reducing the phase angle of power input from nearly perfect -90° to values of less than -20°. These data is discussed in terms of the functional dependence of electron density and electron temperature on discharge pressure and power input which have been recorded earlier.@footnote 3,4@ @FootnoteText@ @footnote 1@ M. J. Schabel, V.M. Donnelly, A. Kornblit, and W.W. Tai. Determination of Electron Temperature, Atomic Fluorine Concentration, and Gas Temperature in Inductively Fluorocarbon/Rare Gas Plasmas Using Optical Emission Spectroscopy, JVST A 20, 555 (2002)@footnote 2@ B. Bai and H.H. Sawin: Neutral Gas Temperature Measurements within Transformer Coupled Toroidal Argon Plasmas; JVST A 22, 2014 (2004)@footnote 3@ G. Franz: Comprehensive Analysis of Capacitively Coupled Chlorine-Containing Discharges, to be published in JVST A, May/June 2005@footnote 4@ G. Franz, M. Klick: Electron Heating in Capacitively Coupled Discharges and Reactive Gases, to be published in JVST A, 2005.

10:20am **PS-MoM7 Spatial and Temporal Measurement of Electric Fields in a Plasma*, E.V. Barnat,*** Sandia National Laboratories

We employ laser-induced dip-fluorescence to detect Stark shifts of atomic argon Rydberg states induced by electric fields present in the plasma sheath. The choice of the probed Rydberg state determines the electric field range and resolution we can achieve. Using the experimentally calibrated behavior of the Rydberg levels, both spatially and temporally resolved maps of the electric fields are obtained above powered electrodes generating a plasma. Electric fields around a technologiclly relevant electrode are mesured and compared to fields measured around simplified electrode structures. Both maps of the electric fields as well as excition and ionization profiels around the electrode demonstrates how the surfaces couple to the plasma. @FootnoteText@ This work was supported by the Division of Material Sciences, BES, Office of Science, U. S. Department of Energy and Sandia National Laboratories, a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

10:40am **PS-MoM8 Modified Actinometry for Monitoring Atomic Radicals in Molecular Gas Discharge*, T. Ishijima***, *T. Okada, Y. Tanabe, H. Sugai,* Nagoya University, Japan

Actinometry technique has widely been used for detecting radicals in processing plasmas owing to its simplicity. There are many arguments on its reliability, especially from a viewpoint of electron-impact excitation processes. For example, one often encounters a serious difficulty in detecting atomic radical X in a discharge in diatomic molecule gas X@sub 2@: the dissociative excitation of X@sub 2@ induces the same optical emission line with the direct excitation of X, so that a standard actinometry taking the optical intensity ratio between actinometer (say, Ar) and the radical does not give the direct information of the radical density. Here we propose a method to discriminate a direct excitation component in the actinometry. This method is successfully applied to monitoring the N atom and the O atoms in high-density plasma nitridation and oxidation of silicon surface at low temperatures, respectively. The relative atomic densities obtained in the modified actinometry are compared with the absolute densities measured by appearance mass spectrometry. Preliminary measurements were applied in the the microwave excited plasmas of 2.45 GHz at 0.3 - 1.0 kW. The relative N atom densities are evaluated with N@super 4@P intensity (821 nm) normalized by Ar@super 2@P intensity (750 nm). When the pressure increases from 50 mTorr to 300 mTorr, both the absoulte N atom density and relative atomic densities increase monotonously in the same condition for input power and mixing ratio of Ar/N@sub 2@=9/1. Correlation with the measured atomic densities with the surface analysis data is discussed.

11:00am **PS-MoM9 Rare Gas and O Metastable Density in Rare Gas Diluted Oxygen RF Plasmas*, T. Kitajima,*** National Defense Academy of Japan, Japan*; K. Takahashi, T. Nakano,* National Defense Academy of Japan*; T. Makabe,* Keio University, Japan

Rare gas diluted O2 plasmas are interested for application to high quality SiO2 film formation. Especially, metastable O(1D) atoms produced in rare gas diluted O2 plasma is believed to promote higher production rate of the oxide films. The density of rare gas metastable atoms and O metastable atom in rare gas diluted O2 radio frequency (RF) capacitively coupled plasma (CCP) was measured by optical absorption spectroscopy (OAS). By decreasing O2 fraction in plasma, O(1D) metastable density icreases to twice of pure O2 plasma at 100 mTorr. Decreases of rare gas metastable densities due to addition of O2 indicate efficient O atom production by rare gas metastables via collisional quenching. Krypton metastable had highest density among four rare gas species for fixed RF power. The decrease of Ar metastable density due to O2 addition showed quantitative agreement with reported quenching rate coefficient. Detailed discussion on different gas pressures illustrates reduced O2 fraction is the key for selective production of O atoms through rare gas metastables.

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[1] **2004 Plasma Prize Winner**

11:20am **PS-MoM10 Prediction of Plasma UV Radiation Damages Using On-wafer Monitoring Sensors*, Y. Kato*,** *Y. Ishikawa, M. Okigawa, S. Samukawa,* Tohoku University, Japan

We have proposed a simple on-wafer monitoring sensor for prediction of UV and VUV photon radiation damages. In this sensor, the electrical currents were induced in the dielectric film and they could be measured by the plasma radiation. We first found that the current was completely corresponding to the generation density of hole-electron pairs in dielectric films and to the increase in interface state at the interface between the dielectric film and silicon under plasma irradiation. In this paper, the relationship between the induced electrical current in the sensor and plasma discharge conditions was investigated to predict the UV radiation damages. The dependence of the induced currents in the sensor on the plasma generation power, discharge pressure and gas flow rate was evaluated. Based on these results, we found that the UV radiation damages could be predicted and the low damage processes could be proposed for plasma etching processes.

11:40am **PS-MoM11 Sheaths and Pre-sheaths in Collisionless and Collisional Active Plasmas: Planar and Cylindrical Probes*, F. Iza*,** *J.K. Lee,* Pohang University of Science and Technology (Postech), S. Korea

Ion kinetics in the sheath and pre-sheath of planar and cylindrical probes have been studied by means of particle-in-cell computer simulations. Low temperature argon discharges with Maxwellian electrons have been simulated in collisionless and collisional regimes. As pressure increases, the sheath, i.e. the region of positive space charge surrounding the probe, becomes collisional and the velocity of the ions entering the sheath falls below the Bohm velocity (u@sub B@). For planar probes, ions enter the sheath with a velocity given approximately by u@sub B@(1+4@lambda@@sub D@/@lambda@@sub i@) where @lambda@@sub i@ is the ion mean free path and @lambda@@sub D@ the Debye length at the sheath edge. This relation differs from that given in@footnote 1@ because the electric field boundary condition at the sheath edge used in@footnote 1@ corresponds to a field reached well inside the sheath. For a floating planar probe, the voltage drop across the sheath increases with pressure to balance the electron and ion fluxes and the ion flux is almost independent of pressure despite the variations in ion velocity. As observed experimentally,@footnote 2@ simulation results show that the voltage across the presheath can be significantly larger than half electron temperature. For planar probes, this voltage depends non-linearly on the electron temperature and increases rapidly for electron temperatures below 2eV. For cylindrical probes, however, the voltage across the presheath can be drastically reduced by the geometrical increase of current density as ions approach the probe. The floating potential and the ion velocity at the sheath edge decrease with decreasing probe radius and for thin probes (r@sub p@<@lambda@@sub D,i@), the voltage drop across the presheath is negligible (<<0.5T@sub e@). @FootnoteText@ @footnote 1@ V A Godyak and N Sternberg, IEEE Trans. Plasma Sci. 18 (1990) 159-168.@footnote 2@ L Oksuz and N Hershkowitz, Plasma Sources Sci. Technol. 14 (2005) 201-208.

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