Plasma Science and Technology
Room 310 - Session PS1-MoA

Emerging Plasma Applications

Moderator: V.A. Shamamian, Naval Research Laboratory

2:00pm **PS1-MoA1 A Surface-Micromachined Miniature Inductively Coupled Plasma Generator***, **J.A. Hopwood**, O. Minayeva, Y. Yin,* Northeastern University **INVITED**

The design, fabrication, and characterization of a surface micromachined plasma generator are described. Although there are many applications for miniature plasma sources, this device is intended for electronic excitation of gas samples such that the presence of impurities and toxins may be detected using a micromachined optical emission spectrometer. The plasma is sustained without electrodes by inductively coupling a 450 MHz current into a region of low-pressure gas. The inductively coupled plasma source is surface micromachined on a glass substrate by electroplating a planar spiral inductor (5 mm in diameter) and two interdigitated capacitors. A plasma can be sustained in argon and air between 0.1 and 10 torr (13.3 Pa - 1333 Pa) and rf powers between 0.3 and 3 W. The argon ion density increases from 10@super 10@ to 10@super 11@ cm@super -3@ over this range of powers. The electron temperature decreases from 4 eV to 2 eV as the pressure increases from 0.1 to 1 torr. Network analysis of the plasma generator circuit shows that over 99% of the applied RF power can be absorbed by the device. Of this, @<=@50% is absorbed by the plasma and the remainder of the power is dissipated as ohmic heating. Scaling laws associated with the miniaturization of inductively coupled plasma sources will be discussed including the dependence of electron temperature on scaled chamber dimensions, the preferred frequency of operation, and rf power coupling efficiency.

2:40pm **PS1-MoA3 Physics of Hollow Cathode Magnetron (HCM) Plasma Source***, **K.F. Lai**,* Novellus Systems, Inc.

The hollow cathode magnetron (HCM) is a new type of high-density plasma device developed for ionized physical vapor deposition (I-PVD). A novel magnetic geometry provides the confining magnetic field to sustain a magnetron discharge within a cup-shaped hollow cathode and the means of ion extraction from the source to the substrate. The use of a "cusp mirror" to reflect most of the escaping electrons back into the hollow cathode cavity has allowed the HCM to achieve extremely high plasma density (10@super 12@ - 10@super 13@ cm@super -3@). The HCM source is highly scaleable and has been successfully implemented in sources ranging from 19 to over 380 mm in diameter. Although the HCM has proven to be a very successful I-PVD source, there is a lack of understanding about its detail working mechanisms. Recent progress in three dimensional electrical probe measurements together with plasma modeling have revealed a different physics picture from our previous belief. Strong radial electric field on the order of 400 V/m was measured inside the hollow cathode. In conjunction with the confining magnetic field, a large ExB drift current is established because of the magnetron effect. As a result of this current and the incomplete shielding of the cathode voltage, the measured plasma density profile inside the cathode is hollow and funnel-shaped. The density profile becomes Gaussian as the plasma emerges through the magnetic null. Unlike other downstream plasma sources where the plasma density near the source is much higher than that downstream, no significant difference in plasma density is observed for the HCM. With the exception of the plasma edge where the presence of an energetic electron tail was evident, the electron energy distribution (EEDF) was approximately Maxwellian. Despite more than two orders of magnitude variation in plasma density, the electron temperature profile is relative flat throughout the entire plasma.

3:00pm **PS1-MoA4 Ion-Ion Plasma Formation and Negative Ion Extraction***, **S.K. Kanakasabapathy**[1], M.H. Khater, L.J. Overzet,* University of Texas, Dallas

Ion-ion plasmas are relatively electron-free, positive and negative ion only plasmas formed in the afterglow of Pulsed-power high electron affinity gas@footnote 1@ (Eg: Cl@sub 2@) discharges. They hold the potential to provide ambipolar fluxes of positive and negative ions that could reduce differential charging of high anisotropy structures which cause@footnote 2@ etch non-idealities. Time-resolved Langmuir probe and Microwave Interferometry measurements in a pulsed ICP discharge show that electrons are quickly lost (~ 10's of µmsecs) to dissociative attachment after turning power off. Time-resolved mass spectrometry has correlated the vanishing of electrons and consequently the confining plasma potential to the incipience of a negative ion (Cl@super -@) surface flux. Parametric characterization of Pulsed Cl@sub 2@ discharges has indicated that low pressures (1 mTorr), high powers (300 W peak), mid duty ratios (50%) and low pulse frequency (500 Hz) maximize this negative ion flux. Langmuir probe ion density decay rate measurements have shown ion-ion recombination to be the dominant loss process. We observe reproducible alternating irradiations of positive (Cl@sub 2@@super +@) and negative (Cl@super -@) ions corresponding to the negative and positive half-cycles respectively when a low frequency (20 kHz) bias applied to the mass spectrometer pinhole. This bias is applied as a phase-locked burst that is synchronized with the formation of ion-ion plasmas. Parametric characterization of this novel extraction technique reveals a bi-modal frequency response of the Cl@super -@ surface flux. This presentation is based upon work supported by the NSF under Grant No. CTS-9713262. @FootnoteText@ @footnote 1@D. Smith, A.G. Dean and N.G. Adams, J. Appl. Phys. 7, 1944-1962(1974) @footnote 2@G.S. Hwang and K.P. Giapis, J. Appl. Phys. 81(8) 3433-3439(1997).

3:20pm **PS1-MoA5 Large Area Plasma Processing System Based on Electron Beam Ionization***, **D. Leonhardt**, S.G. Walton, D.D. Blackwell, W.E. Amatucci, D.P. Murphy, R.F. Fernsler, R.A. Meger,* Naval Research Laboratory

Electron beam ionization is both efficient at producing plasma and scalable to large area (square meters). The beam ionization process is also fairly independent gas composition, capable of producing low temperature plasma electrons in high densities. A 'Large Area Plasma Processing System' has been developed based on the beam ionization process, with the goal of modifying the surface properties of materials over large areas. The system consists of a planar plasma distribution generated by a magnetically collimated sheet of 2-5kV, ~ 10 mA/cm@super 2@ electrons injected into a neutral gas background (oxygen, nitrogen, argon, neon). Typical operating pressures range from 20-200 mtorr with beam-collimating magnetic fields strengths of 100-300 Gauss. Thus far, electron beams have been produced using pulsed (10-4000 ms pulse length, >50% duty cycle) and dc hollow cathode discharges in dielectric as well as conducting chambers. Temporally resolved plasma characteristics deduced from Langmuir probes, optical emission spectroscopy and microwave transmission measurements will be presented. Over large areas (2 cm x 60 cm x 60 cm), results show low electron temperature (T@sub e@ ~ 0.6 and 1.5 eV in molecular and noble gases, respectively) in a bulk diffusion-dominated plasma with densities ranging from 10@super 9@ to 10@super 12@ cm@super -3@. Temporally resolved plasma-to-surface fluxes (via mass spectrometry) and their energy distributions will be presented to give further insight into LAPPS for material processing applications. If time permits, additional photoresist ashing tests demonstrating anisotropic pattern transfer will be discussed, along with design improvements in the electron beam source. Additional details of in situ diagnostics in LAPPS will also be presented by co-authors.@footnote 1@ @FootnoteText@ S.G. Walton, D.D. Blackwell - NRL/NRC Postdoctoral Research Associates @footnote 1@ See other presentations by co-authors at this conference.

3:40pm **PS1-MoA6 New Development of Plasma Technology for Biomaterial Engineering***,* **INVITED**

1. Introduction There has recently been increasing interest in the applications of plasma processing in a variety of industrial fields. One of applications of organic plasma processing now in practical use is plasma treatment. One of the advantages of plasma treatment is the fact that it is surface limited (500-1000Å) so that only the surface properties can be changed without affecting the bulk properties. In view of the fact that surface reactions of plasma treatment are initiated by plasma-induced surface radicals, study of the resulting radicals is of utmost importance for understanding of the nature of plasma treatment. Thus, we have undertaken plasma-irradiation of a wide variety of polymers, synthetic and natural, and the radicals formed were studied by electron spin resonance(ESR) coupled with the aid of systematic computer simulations. On the basis of the findings from a series of such studies, we were able to develop several novel biomedical application works in the field of biomaterial engineering. In this contribution, our novel application works in drug engineering on plasma-irradiated organic polymers will be presented, which include (1) preparations of multilayered tablet applicable for drug delivery system(DDS)of sustained- and delayed-release, (2) fabrication of functionalized composite powders derived from plasma-irradiation onto powdered polymers followed by mechanical applications in the presence of

[1] **PSTD Coburn-Winters Student Award Finalist**

powdered drugs under anaerobic conditions,(3) preparation of biocompatible biomedical polymer surface useful for cathetal, as well as overviews of ESR studies on plasma-induced radicals of a variety of organic polymers.

4:20pm **PS1-MoA8 Detection of Perfluorinated Compounds by Microplasma Optical Emission Spectroscopy***, **D.D. Hsu**, D.B. Graves,* University of California, Berkeley

Because of impending restrictions on the emission of perfluorinated compounds (PFCs) by the semiconductor and other industries, methods for monitoring PFC concentrations in exhaust streams will be necessary. Current methods, including Fourier transform infrared (FTIR) spectrometry and mass spectrometry, are relatively expensive and complicated. One option to detect PFCs in exhaust streams at atmospheric pressure is the use of optical emission spectroscopy (OES) from a microhollow cathode discharge (MHCD). These intense glow discharges can be stabilized at elevated pressures and therefore offer the opportunity to exploit OES under a relatively wide range of conditions. This technique presents an inexpensive and simple way to monitor PFC concentrations. The circular geometry of a microhollow cathode produces intense excitation and hence, a strong source for OES. In the results we will present, various concentrations of PFC in a diluent gas were flowed through an MHCD with a hole diameter of 200 µm, and the optical emission was analyzed. A direct current of 8 mA and a voltage of 250 V were supplied to sustain the MHCD. Concentrations as low as 10 ppm C@sub 2@F@sub 6@ in argon at 700 Torr were detected by examining atomic carbon, atomic fluorine, and molecular C@sub 2@ spectra in the visible range. A linear relationship between PFC concentration and integrated emission intensity was found. The results suggest that fluorocarbon concentrations on the order of 1 ppm can be detected with this technique. Details of the experimental setup and the observed spectra of various PFC concentrations in different diluent gases will be discussed. In addition, the results obtained suggest that MHCD OES might be a powerful analytical tool for other species as well.

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