Tuesday Afternoon, November 5, 2002

Plasma Science
Room: C-103 - Session PS1-TuA

Microdischarges
Moderator: M.L. Steen, IBM T. J. Watson Research Center

2:00pm **PS1-TuA1 Microhollow Cathode Discharges**[1], ***K.H. Schoenbach***, *M. Moselhy, W. Shi, R. Bentley*, Old Dominion University **INVITED**

By reducing the dimensions of hollow cathodes into the hundred micrometer range, stable, direct current, high (atmospheric) pressure glow discharges in rare gases, rare gas-halogen mixtures and in air could be generated. The electron energy distribution in these microdischarges is non-maxwellian, with a pronounced high-energy tail. The high electron energy together with the high gas density, which favors three-body collisions, is the reason for an efficient excimer generation in rare gas and rare gas-halogen microplasmas. Excimer efficiencies of up to 8% have been measured for Ar, Xe, ArF, and XeCl with a radiant excimer emittance on the order of 1 W/cm^2. Pulsing Xe discharges with 20 ns electrical pulses has led to an increase in radiant excimer emittance to 15 W/cm^2, and a simultaneous increase in efficiency to more than 20%. Operating the discharges in an abnormal glow mode has allowed us to generate microdischarge arrays without individual ballast. Stable atmospheric pressure plasmas are not only obtained with microhollow cathodes but also in electrode geometries with planar cathode, and large diameter, ring-shaped anodes, separated by approximately 100 µm. Discharges in such geometries show for pressures on the order of 100 Torr self-organized regular plasma patterns. With increasing pressure the individual plasma structures merge into a homogeneous surface plasma with similar excimer emission characteristics as that obtained with microhollow cathode discharges. Applications of these plasmas are excimer lamps, potentially micro-excimer lasers, and electron emitters.

[1]This work is supported by the NSF under Grant # CTS-0078618 and INT-0001438.

2:40pm **PS1-TuA3 Hollow Cathode Sustained Atmospheric Plasma Microjets**, ***R.M. Sankaran***, *K.P. Giapis*, California Institute of Technology

Microhollow cathode discharges (MHCDs) or microdischarges have gained recent attention for their high-pressure operation and intense UV radiation. They are normally formed between two metal foils, a cathode with a pin-hole (diameter~100 µm) and an anode of arbitrary shape. To more easily incorporate these discharges in materials processing, we have recently extended their operation to a tube geometry where gas flow can be directly coupled to the electrodes. Discharges are formed in the tube hole similar to a static case, but the flow carries the plasma outside the tube to form a microjet. In this talk, we will present features of this novel source and discuss possible applications in thin film growth and effluent gas treatment. Plasma microjets are ignited in direct current mode using a stainless steel capillary tube with a 178 µm diameter hole as the cathode and a metal grid or plate as the anode. Optical characterization has confirmed that it is necessary to shrink the hole size to below 200 µm in diameter to operate inert gases at atmospheric pressure in the hollow cathode mode. Argon microjets can be operated in ambient air at 760 Torr with voltages as low as 260 V for cathode-anode gaps of 0.5 mm. Increasing the gap and extending the plasma microjet results in an increase in the plasma voltage. The current-voltage characteristics of the plasma microjet are also influenced by the gas flow rate. For a given interelectrode distance and plasma current, increasing the flow rate reduces the plasma voltage by as much as 200 V. These effects suggest that the diffusion of air into the argon plasma stream is important. Plasma microjets offer a simple tool to perform rapid materials optimization by operating arrays of discharges. As a proof-of-concept, we have demonstrated that CH_4/H_2 plasma microjets can be used to grow diamond with fine control of the film properties by changing the gas composition.

3:00pm **PS1-TuA4 Microhollow Cathode Discharge Microreactor Chemistry**, ***D.D. Hsu***, *D.B. Graves*, University of California, Berkeley

The peak neutral temperature of a microhollow cathode discharge (MHCD) has been found from optical emission spectroscopy to be on the order of 2000 K, although adjacent temperatures rapidly drop off to near room temperature. These thermal properties suggest that MHCDs are suited to promote endothermic chemical reactions. Thin-film resistive heaters often are employed to heat reactants in microreactors. Unlike resistive heaters, the electrical power of the microdischarge heats the gas directly, offering the possibility of higher peak temperatures and greater energy efficiency. Ammonia decomposition is a highly endothermic reaction, and such a reaction could be used as a source of hydrogen for a microfuel cell. Pure ammonia was flowed through a 200 µm diameter microhollow cathode at flowrates up to 64 sccm and pressures up to atmospheric pressure. Ammonia conversion was measured by FTIR, and production of hydrogen and nitrogen was monitored by a mass spectrometer. A discharge at 490 V and 9 mA converted 16 percent of ammonia flowing at a rate of 2.5 sccm at 100 Torr. Conversion was largely dependent on the residence time of the gas in the plasma. Based on published kinetic data, the conversion and residence time data are consistent with thermal decomposition at temperatures near 3000 K. We discuss the behavior of these microplasmas as reactors for ammonia and other chemistries, and we explore methods for increasing reaction conversion.

3:20pm **PS1-TuA5 One-dimensional Simulation of Glow-like Plasma Phenomena in Parallel-plate Microdischarge Geometries**, *X. Yuan*, ***P. Kothnur***, *L. Raja*, University of Texas at Austin

Recently, microdischarges have gained much attention in the plasma process community for a variety of applications. Proposed applications range from generation of intense UV radiation to maskless etching of thin films. While some estimates of properties of microdischarge plasmas are available, a detailed understanding of the plasma dynamics and chemistry is completely lacking. This talk presents results from a self-consistent, one-dimensional computational study of the glow-like phenomena in microdischarges. A dc microdischarge in a parallel-plate geometry with gap distances of the order of 10's-100's of microns is modeled. Results for a noble gas (helium) microdischarge indicates the formation of a relatively large cathode sheath that occupies a significant fraction (~ 50 %) of the micron-sized geometry with the remaining region being the bulk plasma. The electron temperatures attain significantly high peak values (~ 50 eV) in the cathode sheath with relatively low (~ 1 eV) temperatures in the bulk plasma. Gas temperatures of ~ 1000 K and electron densities in excess of 1e14 /cm^3 are predicted. The results indicate that microdischarge plasmas are quite unique with properties that are somewhat intermediate between classical glow-discharges and thermal arc discharges.

3:40pm **PS1-TuA6 Characteristics of Miniature Microwave Excited Plasma Discharges**, ***T.A. Grotjohn***, *D. Story, S. Zuo, J.J. Narendra, A. Wijaya, J. Asmussen*, Michigan State University

Small microwave generated plasma discharges are characterized to determine their properties for discharges with sizes ranging from 0.3 mm to 10 mm and for a wide range of discharge aspect ratios. The discharge characteristics investigated included microwave power density, plasma density, electron temperature and gas temperature. The outcome of this investigation to be presented is an understanding and quantification of the microwave power density needed to operate small discharges of specific sizes, shapes, densities and gas compositions. Three microwave plasma sources are used to accomplish this investigation including (1) a highly flexible and adjustable coaxial waveguide source with the plasma generated in an adjustable gap located in the center conductor, (2) a microstrip-line based plasma source with the discharge created in a long quartz tube of 0.3 mm to a few mm in inside diameter, and (3) a microwave powered electrode system where the plasma is formed at the end of the electrode and the plasma is either unbounded or confined in a small spherical, long cylindrical or flat disk shaped chamber. The plasma compositions investigated include argon, nitrogen and hydrogen discharges. The diagnostic measurements are performed using Langmuir probes and optical emission spectroscopy. The plasma characteristics measured and modeled indicate that as the characteristic dimension of the discharge decreases to less than 1 mm, the power densities approach and exceed 1000 W/cm^3 and the plasma densities are above 10^{13} cm^{-3}.

4:00pm **PS1-TuA7 Materials with a High Secondary-electron Yield Studied in a Macroscopic Discharge Cell**, ***T.J. Vink***, *R.G.F.A. Verbeek, A.R. Balkenende, H.A.M. van Hal, S.T. de Zwart*, Philips Research, The Netherlands

Reduction of the firing voltage in plasma display panels (PDPs) calls for electrode coatings with a high secondary-electron yield. To this end we have selected a range of materials that have a low electron affinity and thus potentially a high electron emission yield. Among these materials are MgO, used as a default in PDPs, MgF_2, Al_2O_3, CsI, Rb-halogenides etc. The materials, in thin film form, were tested in a so-called macroscopic discharge cell, with dimensions that are 50 times larger than those of a discharge cell in a real PDP. Compared to the real PDP the product of pressure times electrode gap width is kept constant, and the capacitance of the dielectric layer above the electrodes is scaled accordingly. Furthermore, because of its relatively large size the macroscopic discharge cell enabled us

to prepare some of the more chemically reactive materials in situ, which is crucial for measuring surface sensitive electron emission properties properly. It is shown that the firing voltages measured in the macroscopic discharge cell compare quantitatively with respect to values obtained from a PDP test panel. A 50% reduction in the firing voltage relative to the best quality MgO can be achieved. The measured firing voltages correlate well with a relatively simple model based on ionization energy of the gas atom, and band gap and electron affinity of the solid. Finally, the occurrence of secondary-electron emission yields above the Auger limit of 0.5 are discussed in terms of ion- and photon-induced processes.

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