Selected Energy Epitaxy Topical Conference
Room 327 - Session SE-WeA

Novel Sources for Selected Energy Growth

Moderator: R.B. Doak, Arizona State University

2:00pm **SE-WeA1 UHV Arcjet Atomic Nitrogen Source: Beam Characterization and GaN Epitaxial Growth***, **F.J. Grunthaner**,* Jet Propulsion Laboratory*; R. Bicknell-Tassiuis,* Jet Propulsion Laboratory, US*; P. Deelman, P.J. Grunthaner,* Jet Propulsion Laboratory*; J. Guilani,* Naval Research Laboratory*; C.E. Bryson,* Surface/Interface, Inc. **INVITED**

2:40pm **SE-WeA3 Flow Characteristics of a UHV Nitrogen Arcjet***, **C.H. Chang**,* Thermosciences Institute, US*; F.J. Grunthaner,* Jet Propulsion Laboratory*; R. Bicknell-Tassiuis,* Jet Propulsion Laboratory, US*; P. Deelman, P.J. Grunthaner,* Jet Propulsion Laboratory*; J.L. Giuliani, J.P. Apruzese, P. Kepple,* Naval Research Laboratory, US

Flow characteristics in the nozzle of a nitrogen arcjet have been simulated by a model. Electrons, ions, and neutral atoms and molecules are represented as separate species. Dissociation, ionization, and recombination are treated as separate reactions. Thermal non-equilibrium is represented by a two-temperature model. Energy input to plasma from the arc is modeled as a source determined by local current and electrical conductivity. Momentum and energy losses and recombinations at the nozzle wall are included as source/sink determined by fluxes to the wall. The results show essentially frozen gas-phase reactions and thermal nonequilibrium due to Joule heating of electrons and in the expansion part of the nozzle. Wall interactions have strong effects on the results, indicating that they play important roles in the flow due to very high surface area relative to the volume of the plasma. For example, plasma velocity decreases from 6000 m/s without wall interactions to 3000 m/s with modest amount of wall interactions. These results also show reasonable agreement with optical emission measurements, which confirms that the arcjet plasma is far from LTE. The spectra suggest nitrogen dissociation levels of 0.3% - 9%, depending on nitrogen flow rate and arc plasma current, which also determine the relative amounts of excited atomic and molecular nitrogen. Langmuir probe studies of the source show that electron and ion fluxes increase with increasing power, and that the ion energy distribution shifts to lower energies. Typical ion fluxes were on the order of 4E-9 A/cm@super 2@ with a maximum ion kinetic energy of 3.5eV. The median electron energy was 1eV, with a maximum of less than 4eV.

3:00pm **SE-WeA4 Gas-Phase Diagnostics for Wide Bandgap Semiconductor Development***, **D.G. Fletcher**, G.A. Raiche,* NASA Ames Research Center

Efforts to develop commercially viable wide bandgap semiconductors can be aided considerably by a characterization of the atomic beam. For arcjet devices used for nitride epitaxy, this involves determining the thermochemical state of a partially dissociated nitrogen flow. Since arcjet flows of nitrogen are also used in the development of thermal protection systems for aerospace applications, laser-spectroscopic techniques have been developed for flow characterization, and this has been driven by the need to relate test results to the flight environment. Recently, two-photon laser-induced fluorescence of ground-state atomic nitrogen has been used to determine the degree of dissociation and the enthalpy distribution in a large scale arcjet facility.@footnote 1@ Based on observations from these experiments and the similarities between the arcjet devices used in nitride epitaxy and aerospace materials testing, diagnostic strategies are proposed to establish the link between electronic state populations and nitride material growth. The paper will include a discussion of recent, relevant experimental results for ground state atomic nitrogen, and will report on progress made in developing laser-diagnostic strategies for determining the populations of the two low-lying, metastable doublet states of atomic nitrogen. @FootnoteText@ @footnote 1@D.G. Fletcher "Arcjet Flow Properties Determined from Laser-Induced Fluorescence of Atomic Nitrogen", AIAA Paper No. 98-0205, Reno, NV, January, 1998.

3:20pm **SE-WeA5 Fast Deposition of Amorphous Hydrogenated Silicon and Carbon***, **D.C. Schram**, M.C.M. van de Sanden,* Eindhoven University of Technology, The Netherlands **INVITED**

For solar cell and other developments faster and more efficient deposition of thin layers amorphous hydrogenated materials are necessary. With plasma beam expanding from very efficient thermal plasma sources rates of 10-100 nm/s over a large area has been studied. For a-C:H it proves that the faster the deposition the more dense the material and 100 nm/s has been reached. For a-Si:H good electronic material can be grown with rate of 10 nm/s and elevated substrate temperature (T~350 oC). A picture based on plasma fragmentation processes and surface kinetics will be discussed and illustrated with measurements on mass spectrometry, FTIR and other diagnostics.

4:00pm **SE-WeA7 Inexpensive Corona Discharge Source for the Growth of III-N Semiconductors***, **D.C. Jordan**, C.T. Burns, R.B. Doak,* Arizona State University

The III-N nitrides AlN, GaN and InN are under intense study due to their wide bandgap properties. It is thought that the ideal nitrogen species for GaN growth may be the metastable A@super 3@@SIGMA@@super +@@sub u@ state of molecular nitrogen@footnote 1@. We have developed a low cost supersonic free-jet corona discharge source that produces exclusively this nitrogen species. The source consists of a quartz tube drawn to an orifice diameter in the range of 100-250 µm enclosing a tungsten or rhenium wire. A high voltage ranging between 2-2.5 kV at 5-9 mA is applied to that wire, resulting in a readily discernible bright plume at the tip of the nozzle. A custom-made refractory graphite skimmer then extracts a beam of activated species as the free-jet expands into vacuum. The beam transits a differentially pumped section then enters the deposition chamber where controlled growth can take place under molecular beam epitaxy (MBE) conditions. We have performed optical spectroscopy at several different locations downstream of the nozzle for different tip polarity and different argon/nitrogen gas mixtures, characterizing the expansion as it unfolds. Overall nitrogen intensities range from the 5x10@super 17@-2x10@super 18@ molecules/sr/s. Our calculations indicate that an appreciable percentage (ca.10%) of the nitrogen molecules is in the desired metastable A@super 3@@SIGMA@@super +@@sub u@ state. Growth studies of AlN on Si(100) are currently under way. The low cost, the ease of operation and the ability to produce only a single excited species are in stark contrast to the broad spectrum of different species of any other commercially available plasma source, making the corona discharge source attractive for a broad range of future applications. Supported by ONR grant # N00014-95-1-0122 & N00014-96-1-0962 @FootnoteText@ @footnote 1@ R.P.Muller, B.L.Tsai and W.A.Goddard III, SEE-3 Workshop, Tempe 1998

4:20pm **SE-WeA8 Development of Atomic Nitrogen Sources and Atomic Nitridation Processes***, **O. Gluschenkov**, K. Kim,* University of Illinois, Urbana-Champaign

With the goal of developing an efficient source of atomic nitrogen suitable for electronic materials processing, we have fabricated novel atomic nitrogen sources and with them conducted an investigation of nitrogen dissociation in a low-pressure nitrogen plasma. Plasma electric field, electron density, and vibrational temperature of nitrogen molecules have been estimated from experimental data obtained with the prototype sources. A simple model has been developed to predict the efficiency of atomic nitrogen production as a function of the source parameters: pressure, geometry, deposited power, and nitrogen throughput. An atomic nitrogen source with 60% of nitrogen atoms at the output has been constructed to study the atomic nitridation processes, the processes where nitridation is effected by atomic nitrogen only. The extremely high chemical potential of atomic nitrogen, small size of nitrogen atoms, and absence of other energetic particles and chemical contaminants lead to a dramatically different chemical kinetics and allow for high-rate, low-temperature, low-pressure, and low-damage processing. The processes investigated include the nitridation of thin SiO@sub 2@ gate dielectric and the growth of Group-III-Nitride crystals.

4:40pm **SE-WeA9 Energetic Oxygen Atom Surface Passivation of Cd@sub 1-x@Zn@sub x@Te Radiation Detectors***, **M.A. Hoffbauer**, S. Cook, T. Prettyman, J. Rennie,* Los Alamos National Laboratory*; J.C. Gregory, M.A. George,* University of Alabama, Huntsville

Recent investigations show considerable progress in developing large-volume Cd@sub 1-x@Zn@sub x@Te radiation detectors for room-temperature x-ray and gamma-ray spectroscopy and imaging where bulk material with high resistivity and uniform electrical properties is required.@footnote 1@ Surface effects can also play an important role in the performance of CdZnTe spectrometers, since dark current may be dominated by surface leakage in gridded or pixellated devices.@footnote 2@ A novel surface oxidation process has been developed for the treatment of CdZnTe using a source of energetic oxygen atoms to treat the surface held near ambient temperatures.@footnote 3@ Following the oxidation process the chemical composition and morphology of the surface were investigated using X-ray photoelectron spectroscopy and atomic force microscopy. No detectable unreacted Te substrate XPS feature is observed. The Te-oxide peak indicates that the oxidation process is complete, and that the suspected Te precipitates left on the surface following polishing and etching have been totally reacted to form a uniform Te-oxide layer >10 nm thick. AFM studies show a relatively uniform and smooth surface oxide layer. A significant reduction in surface leakage current and detector noise results in a 25% improvement in detector resolution measured at a gamma-ray energy of 662 keV. This new surface passivation method for high-quality, spectrometer-grade material increases the accuracy and sensitivity of measurements of radionuclides with complex gamma-ray spectra, including special nuclear material. When CdZnTe detectors with small spacing between electrodes become available, surface passivation will be even more critical in determining performance and energy resolution. @FootnoteText@ @footnote 1@K. B. Parnham, "Recent Progress in Cd@sub 1-x@Zn@sub x@Te Radiation Detectors," Nucl. Instr. Meth. Phys. Res., A377, 487(1996). @footnote 2@K.T.Chen, D.T. Shi, B. Granderson, M.A. George, W.E. Collins, A. Burger, and R.B. James, "Study of Oxidized Cadmium Zinc Telluride Surfaces," J. Vac. Sci. & Technol. A15, 850(1997). @footnote 3@M.A. Hoffbauer, J.C. Cross, and V.M. Bermudez, "Growth of Oxide Layers on Gallium Arsenide with a High Kinetic Energy Atomic Oxygen Beam", Appl. Phys. Lett., 2193(1990).

5:00pm **SE-WeA10 The Atmospheric-Pressure Plasma Jet: Properties and Materials Applications***, **A. Schütze**,* University of California, Los Angeles*; J. Park,* Los Alamos National Laboratory*; S.E. Babayan, J.Y. Jeong, V.J. Tu,* University of California, Los Angeles*; G.S. Selwyn,* Los Alamos National Laboratory*; R.F. Hicks,* University of California, Los Angeles

Atmospheric-pressure plasma jets can be used in a wide range of materials applications, including surface cleaning, selective etching and thin-film deposition. The plasma source consists of two closely spaced electrodes through which helium and other gases flow (O@sub 2@, CF@sub 4@, etc.). A variety of electrode configurations can be used, and the source is suitable for large-area processing of materials. Measurements with an impedance probe have shown that this source exhibits a low breakdown voltage at atmospheric pressure, between 50 and 300 V, depending on the gap spacing and gas mixture. The current-voltage characteristics are analogous to a low-pressure DC discharge, in which normal and abnormal glow regions occur. Normal glow is observed between 0.01 and 1.0 A with a corresponding voltage of about 150 V. As an example application, we will discuss the plasma-assisted chemical vapor deposition of silicon dioxide. Film growth rates of 0.3 to 1.0 µm/min are achieved using tetraethoxysilane or silane sources. The growth rate increases linearly with RF power and Si source pressure, but decrease with increasing pressure. The properties of the SiO@sub 2@ films deposited at 350 °C, as determined by infrared spectroscopy, photoemission spectroscopy and capacitance measurements, are comparable to those of thermally grown SiO@sub 2@ films at 900 °C.

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