Monday Morning, October 25, 1999

Manufacturing Science and Technology Group
Room 611 - Session MS-MoM

Advanced Design Methodologies and Factory Modeling

Moderator: S. Rauf, Motorola Inc.

8:40am **MS-MoM2 Aspect Ratio Dependent Etching**, ***T.S. Cale**, M. Bloomfield, S. Soukane,* Rensselaer Polytechnic Institute

This presentation reviews a study of 'aspect ratio dependent etching' (ARDE); i.e., the effect of aspect ratio on etch rate in reactive ion etching (RIE) systems. The goal is to provide guidelines for etch process developers, and involve simple but flexible models for the transport and kinetics. EVOLVE, a deposition, etch and thin film flow simulator, is used to characterize the ARDE via an RIE 'lag parameter'. Further simulation is then used relate ARDE to the neutral-to-ion flux flux ratio, in the simplified transport and kinetic models. This flux ration ratio can be related to RIE operating conditions.

9:00am **MS-MoM3 SEMATECH's Plasma Modeling Project**, ***G.L. Bell**, P.M. Ryan,* Oak Ridge National Laboratory **INVITED**

As wafer costs increase with size, the expenses associated with developing new tools and running process development experiments increase prohibitively. Robust plasma models and high-performance simulation tools are needed to reduce the significant cost of introducing new processing technologies. The goal of the SEMATECH Plasma Model Development project is to accelerate technology development through the advancement of predictive models for plasma etching. Three major barriers must be overcome to accomplish this goal: 1) the lack of detailed verified data on actual production tools to be used for testing the models and to support process development, 2) the need for gas phase and surface mechanisms for commercially relevant oxide and metal etch plasmas, and 3) the absence of a comprehensive database of detailed cross-sections of plasma etching gases for use by the modeling community. To address these hurdles, this SEMATECH project combines the efforts of universities and national labs into an integrated modeling effort. Supported research includes development of a relevant gas phase chemistry database through cross-section and reaction rate measurements and computations, development of surface reaction mechanisms from particle beam and in situ surface measurements during plasma processing, and experimental measurement of plasma parameters and ion/neutral species distributions on representative plasma reactors. The team produces "best known" database sets (gas phase, surface reactions, plasma diagnostics data and model inputs) to develop physical models for input into advanced codes which predict etch rate (selectivity) and uniformity. This presentation outlines the project structure, the role of the working groups and some representative data obtained to date. @FootnoteText@ G.L. Bell is currently on assignment to SEMATECH's Interconnect Division.

9:40am **MS-MoM5 A Comparison of Spectroscopic Measurements of an Inductive Plasma Source with the INDUCT Model**, ***M.L. Huebschman**, J.G. Ekerdt,* University of Texas, Austin*; P.A. Vitello,* Lawrence Livermore National Laboratory*; J.C. Wiley,* University of Texas, Austin

Noninvasive spectroscopic measurements of an inductively driven hydrogen plasma source with density and temperature characteristic of plasma processing tools have been done with an ultimate application of cleaning of silicon substrates These measurements allow full radial and axial profiles of electron density and temperature to be measured from absolutely calibrated multichannel spectroscopic measurements of upper state number densities and a collisional radiative model. Profiles were obtained over a range of powers from 50 to 200 W and pressures from 5 to 50 mtorr in hydrogen in a small cylindrical source. The hydrogen working gas and simple cylindrical geometry was chose to simplify detailed comparisons with a 2D computational model (INDUCT95) which uses a fluid approximation for the plasma and neutral gas. The code calculates the inductive coupling of the 13.56 MHz RF source, the collisional, radiative, and wall losses as well as a complete chemistry model for H@sub 2@, H, H@super +@, H@sub 2@@super +@ and H@sub 3@@super +@. We found good agreement between the model and experimental data over part of the operational range. Ranges of agreement and divergence will be discussed.

10:00am **MS-MoM6 Characterization of Showerhead Performance at Low Pressure**, ***D.B. Hash**,* ELORET*; T. Mihopoulos,* Motorola Inc.*; M. Meyyappan,* NASA Ames Research Center*; D.G. Coronell,* Motorola Inc.

The overall objective of this work is to characterize the flow through showerheads by deriving pressure drop versus velocity correlations that can be then used in reactor scale simulations where the showerhead is approximated as a porous medium. At relatively low Reynolds numbers (< 1-10 based on the hole length scale) and in the absence of slip flow, Darcy's Law, gradient P = µ U/ k, can be used to express the relation between the pressure drop and velocity where µ is the fluid viscosity and k is the permeability that can be theoretically predicted as k = e R@super 2@ /8, where e is the porosity. However, at sufficiently small hole diameters and decreased pressures (< 5 Torr), the Knudsen number based on showerhead tube radius increases, and the flow may be in a transition regime. Different expressions have been proposed to account for this effect in the permeability by expressing k as a function of either pressure or Knudsen number. But at even higher Knudsen numbers, the pressure drop - velocity dependence is non-linear, and Darcy's Law no longer holds such that a permeability cannot be defined. The direct simulation Monte Carlo method is used along side conventional CFD techniques to determine the extent to which the CFD technique is appropriate and helps to derive correlations for the more rarefied cases of interest in these showerhead flows.

10:20am **MS-MoM7 IMP-PVD Equipment Level Process Analysis Using Simulation**, ***P.L.G. Ventzek**, S. Rauf, D.G. Coronell, V. Arunachalam, X.-Y. Liu, J. Arnold, D. Denning, S. Garcia, A. Korkin,* Motorola Inc.*; Y.-K. Kim,* National Institute of Standards and Technology

Ionized metal plasma physical vapor deposition continues to be viewed as a promising means of depositing seed and barrier layers in tight critical dimension high aspect ratio features. Issues that require attention at the equipment level deal with obtaining sufficient film continuity and conformality in a uniform way across a wafer. Critical to these metrics are the delivery of the appropriate net ion current (both metal and inert) and ionization fraction of the metal flux (energy distribution and angular spread). Also important may be the energy content brought to the surface by excited state species. We have characterized these parameters using HPEM (University of Illinois) and will present a comparison between the model predictions for DOE's performed on a Cu IMP-PVD chamber. Of note from this study is the sensitivity of predicted behavior on the capacitive-inductive power distribution from the inductive coils. Very high percentages of the power delivered to the coil are lost capacitively and the fraction in very sensitive to the power capacitively coupled to the wafer. The role of metastable species generated in the plasma is also investigated. Metastable species are usually thought only to play the role of facilitating relatively low energy pathways for ionization . It turns out that heavier metals have a wealth of metastable states even at very low energy allowing them to alter the plasma behavior and to facilitate different processes at the surface when compared to lighter atomic number metals.

10:40am **MS-MoM8 Holistic Yield Learning Methodology**, ***A.J. Strojwas**,* PDF Solutions Inc. **INVITED**

Each year, IC manufacturers invest billions of dollars in new equipment in an attempt to increase their competitiveness by delivering enhanced performance and more functionality at a lower cost. Success in today's marketplace requires successful technology integration under increasing market pressure to deliver products as quickly as possible. Unfortunately, standard yield improvement practices focus too narrowly on defect elimination and use techniques that solve yesterday's not today's problems a comprehensive view of yield learning. To ensure profitability, a new approach to yield learning must be developed. Inevitably, these changes require a re-defining of the interfaces between design, test and manufacturing. In this paper, we present a comprehensive view of the yield problem and a "holistic" yield ramping methodology specifically designed to significantly reduce the yield ramp time by eliminating not only defects, but also by resolving parametric and systematic problems. Manufacturing defect data, process recipe, and design information are analyzed simultaneously, to derive a much deeper understanding and subsequent solution to the process and design architecture issues that affect yield and performance. In combination with the use of simulation and a hypothesis-driven work style, this approach delivers increased yield and performance in a fraction of the time required by traditional methods.

11:20am **MS-MoM10 Particle Simulations of Chemically Reacting Plasmas**, ***M.A. Gallis**, T.J. Bartel,* Sandia National Laboratories

This work focuses on the development of a particle simulation code that can be used for the modeling of low pressure inductively coupled high density plasma reactors. The code is based on the Direct Simulation Monte Carlo methodology where a relatively small number of particle simulators mimic the behavior of a large number of real particles. Only heavy particles (ions and molecules) are directly modelled. The electron number density is deduced from this of the ions assuming local charge neutrality. Since the plasma sheathes are very small the assumption of charge neutrality is used through out the computational domain. The electron temperature is calculated using two different methods. The first one uses an electron energy equation using ICP power electron conduction and inelastic electron impact reactions. The second one uses a kinetic treatment of the electrons creating an equilibrium distribution of electrons every time an estimation of the electron temperature is needed. The motion of the electron gas is then followed in a fully kinetic fashion and for a time period short enough to assume that the heavy particles remain in their positions. The ICP power deposition for both methods is determined by an external code from Oakridge National Laboratories, ORMAX. The neutral-neutral and neutral ion interactions are directly modeled. The two methods will be compared for two electro-negative systems; pure CL2 and C2F6 in the GEC test cell geometry.

11:40am **MS-MoM11 Simulations of Low Field Helicon Discharges@footnote 1@***, **R.L. Kinder**, M.J. Kushner,* University of Illinois, Urbana

Due to their high ionization efficiency, ability to deposit power within the volume of the plasma and ability to operate at low pressures, helicon reactors are attractive for downstream etching and deposition. The power coupling of the antenna radiation to the plasma is a concern due to issues related to process uniformity when using high magnetic fields (100s G to kG). Operating at low magnetic fields (< 100 G) is therefore preferred to provide more uniform ion fluxes and to reduce the cost of the tool. To investigate helicon operation over large ranges of magnetic fields a full tensor conductivity has been incorporated into the electromagnetics module of the Hybrid Plasma Equipment model (HPEM) augmented by an effective collison frequency to account for Landau damping. Plasma properties for helicon excitation of Ar, Ar/N@sub 2@ and process relevant gases (CF@sub 4@, C@sub 2@F@sub 6@) as a function of magnetic field strength, field configuration and power will be discussed. Results of an argon plasma excited by a m = 0 mode field operating at 13.65 MHz shows a resonant peak in the plasma density occuring in the low magnetic field range and is attributed to off-resonant cyclotron heating. The transition from inductive coupling to helicon mode appears to occur when the fraction of power deposited through radial and axial fields dominates. Results from HPEM-3D will be used to resolve helicon wave structure in the m = 1 and -1 modes. @FootnoteText@ @footnote 1@This work was supported by SRC, AFOSR/DARPA, Applied Materials and LAM Research.

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