Manufacturing Science and Technology Group
Room Hall A - Session MS-ThP

Manufacturing Science and Technology Group Poster Session

MS-ThP1 Dynamic Simulation Based Learning Tools for Manufacturing Education and Training, ***G.W. Rubloff***, *A.R. Rose, Y. Sankholkar,* University of Maryland; *D.E. Eckard,* North Carolina State University

A critical issue for the semiconductor manufacturing industry is the skill of the workforce at all technical job levels. The challenge of education and training is especially difficult because it is highly labor intensive and because the reality of actual hardware is very expensive and difficult to access for training purposes. We have constructed software learning tools as an avenue to dealing with both problems. They exploit physically-based dynamic simulation, so that the learner may "operate" sophisticated equipment, even break it, without adverse consequence but with the opportunity to understand how the equipment and process work. The simulators are accompanied by integrated tutorial, guidance, and reference material to support the learner in exploring phenomena, principles, and physical behavior of the system. As self-contained learning tools, disseminated as software or across the Internet, these learning modules provide the opportunity to learn when and where the student chooses. The software platform is constructed to relate guidance materials directly to simulator objects, to support experimentation and record-keeping, to permit learner-directed exploration in depth, through examples, and through exercises and self-tests, and to facilitate authoring of tutorial material and construction of physically-motivated simulators and error handling with minimal need for manufacturing practicioners to write software. Learning modules are demonstrated which convey vacuum and gas flow, heat transfer, chemical reaction, and other concepts and realizations relevant to semiconductor manufacturing equipment and process.

MS-ThP2 Surface Cleaning on Aluminum for UHV using Supercritical Fluid CO@sub 2@ including NaCl and H@sub 2@O as Impurities, ***T. Momose***, *H. Yoshida,* Miyagi National College of Technology, Japan; *Z. Sherverni, T. Ebina, Y. Ikushima,* National Industrial Research Institute of Tohoku, Japan

Ozone treatment has been applied to several metals for UHV to improve outgassing rate. The surface of the ozone treated Al and superconducting Nb cavity @footnote 1@ showed the low adsorption characteristics and low density of hydroxide in the surface. These suggest that removal of the native oxide and the treatment without water can improve vacuum characteristics of the surface. Conventional surface treatments cause inhomogeneity and need water cleaning process. Therefore, we investigated the treatment with supercritical CO@sub 2@ because supercritical CO@sub 2@ can readily dissolve nonpolar compounds. Before the removal of surface oxide and ozone treatment, supercritical CO@sub 2@ was applied to the UHV material such as Al to clean the surface. A sample was a half piece of a swagelok cylinder (10.8 mm in diameter and 8.5 mm in length) cut along the axis with hard almite coating. CO@sub 2@ was supplied from a tank and charged into a syringe pump (HPB-350) via a cooler at about -10 °C. Liquefied CO@sub 2@ was transferred into a high pressure chamber made of stainless steel 316 cylinder with inner diameter of 50 mm, inner length of 50 mm and thickness of 20 mm. The surface analysis was carried out by XPS. The cleaned level was evaluated by the density (at%) of carbon (C) determined from the ratio of convoluted area of Al2p, O1s, and C1s peaks. The C density of untreated Al was 87 %. The C density of Al treated by supercritical CO@sub 2@ at 70 °C and 94 atm for 2 hours was 65 %. Furthermore, the C density of the surface treated by the addition of H@sub 2@O of 0.5 cc and NaCl of 0.05 g to supercritical CO@sub 2@ at 100 °C and 150 atm for 2 hours decreased to 13 %. The treatment with the same fluid showed no C density (13-25 %) dependence on pressure ranging from 100 to 250 atm. The treatment also showed the black surface which was locally oxidized with the aid of the contact potential with the chamber. Similar results were observed on the almite coating of the sample. @FootnoteText@ @Footnote 1@T. Momose. et. al., Vacuum, 47, No4, 319-324.

MS-ThP3 Design of Dynamic Simulation Experiments for Assessing Manufacturing Metrics, ***R.Z. Shi***, *Z. Han, K. Moores, E. Li, Z. Chen, G.W. Rubloff,* University of Maryland

Evaluation of equipment and processes commonly focuses on raw process time, with equipment overhead contributions to cycle time playing a secondary and/or separate role in decision-making. This work is directed at equipment and process design while treating on an equal footing the contributions to cycle time which arise from raw process time and the cycle time elements associated with establishing process conditions and recovering from them after process completion. Design of experiments (DOE) methodology (using commercial ECHIP@super TM@ software) and dynamic simulation (using a previously designed simulator based on VisSim@super TM@ software) are employed to optimize a rapid thermal CVD polySi process. The RTCVD simulator captures the essential physics and chemistry of mass transport, heat transfer, and chemical kinetics of the RTCVD process as embodied in a specific equipment design. Various parameters for process recipe as well as for equipment design were first selected as possible factors for the response deposition rate and cycle time. A screening design was first carried out to choose those most significant factors, followed by more extensive experiments leading to the generation of response surface models, i.e., for deposition rate and cycle time. The results reveal different regimes of process and equipment design in which cycle time is primarily determined by raw process time, as well as regimes where equipment design is critical in its influence on overhead contributions to the total cycle time, e.g., for establishing reactor pressure initially, or for wafer cooldown. This work demonstrates that the combination of DOE methodology and dynamic simulation provides a powerful tool for examination and optimization of multiple figures of merit; these include more complex but critical metrics like the full cycle time, as well as more specific process measures such as steady-state deposition rates.

MS-ThP4 Fluid Simulation of Distributed Gas Injection for Aluminum and Photoresist Etch, ***D.F. Beale***, *N. Williams,* Lam Research Corporation

The differences between two gas injection designs were studied via 3D fluid simulations. The two cases considered were a typical showerhead injected reactor with side pumping and a novel distributed injection reactor. In the novel design, gas entered the reaction chamber subsonically through a hexagonal array of cells. Each cell consisted of a circular gas inlet port with a concentric annular outlet port. Simulations of both designs were performed for a typical low pressure Aluminum etch and a high pressure photoresist (PR) strip. Plasma effects were not considered because the commercial fluid simulation used predicts Al etch trends well@footnote 1@ and because the stripper plasma was distant from the wafer. Peclet number values calculated from simulation output showed more diffusive transport in the novel geometry than in the standard one. This difference was important for the transport-limited etching of Al by Cl@sub 2@, but not for the interface-limited etching of PR by O@sub 2@. Differences between the two etch chemistries were further characterized via Reynolds numbers, Knudsen numbers and sticking coefficients calculated from simulation output. Axisymmetric 2D simulations of a showerhead-injected reactor and 3D simulations of a novel injection reactor with 19 inlet/outlet cells were performed. @FootnoteText@ @footnote 1@"Trends in aluminum etch rate uniformity in a commercial inductively coupled plasma etch system", JVST B 16(3), May/Jun 1998.

MS-ThP6 Reaction Products in a-C:H Film Growth by DC Glow Discharges in the Novillo Tokamak, ***R. Valencia***, Instituto Nacional de Investigaciones Nucleares (ININ), México; *J. de la Rosa,* Instituto Politécnico Nacional, México; *E. Camps, R. López,* ININ, México

In this work we report the reaction products generated during the growth of a-C:H films by DC glow discharges in a toroidal chamber using a calibrated mixture of 5 % methane and 95 % hydrogen and at a total pressure of 5x10@super-2@ Torr. The products were analyzed using a differentially pumped mass spectrometer. The time evolution of the partial pressure recorded after initiation of the glow discharges indicates that the reaction products are generated by the plasma-wall interaction. During the initial phase of the experiment, a continuous increase of the peak m/e=28 and a decrease of those at m/e=18, 32, and 44 was seen to occur. We suppose that the 28peak is principally due to CO because in the case of a carbonized surface, part of the initially deposited C atoms can form CO with surface oxides and the residual water vapor. The decrease of the peaks 18, 32 and 44 are due to a molecular dissociation of H@sub 2@O, O@sub 2, CO@sub 2. The films were characterized by X-ray diffraction and scanning electron microscopy. The thickness and refractive index of the films were determined from the interference fringes of the transmission spectrum.

MS-ThP7 Physically-based Dynamic Simulation of a Tungsten CVD Cluster Tool, *J.N. Kidder, Jr.,* ***N. Gupta****, G.W. Rubloff,* University of Maryland

Dynamic, physically-based simulation has proven effective in representing the time-dependent behavior of equipment, process, sensor and control systems. Here we extend previous work to address multichamber cluster tools and to include more complex pumping systems and models. Using a Windows-based simulation program, VisSim(tm) (Visual Solutions, Inc.), we have constructed and validated a system-level dynamic simulator for the Ulvac ERA-1000 tungsten CVD cluster tool at the Laboratory for Advanced Materials Processing, U. Maryland, in order to support research on chemical sensing, control, optimization, and fault management. The simulator reflects the time-dependent behavior of: the vacuum and gas handling components of the load lock, the buffer chamber, the process reactors, multi-stage gas pumping systems (e.g., mechanical and turbo pumps), and the gas delivery and exhaust systems; the process behavior in the reactor chambers; and the dynamics associated with process recipes. This enables the evaluation of dynamic process parameters (e.g., deposition rate, film thickness) as well as manufacturing parameters (e.g., cycle time), so that manufacturing figures of merit can be evaluated as a function of process and equipment design. Synchronous measurements of process variables and equipment state parameters provide experimental validation of the dynamic simulator.

MS-ThP8 Computer Simulation of Three-Dimensional Asymmetries in Inductively Coupled Plasma Reactors, ***T. Panagopoulos****, V. Midha, D.J. Economou,* University of Houston

MPRES-3D, a three-dimensional version of the Modular Plasma Reactor Simulator, has been developed to study azimuthal asymmetries of the etch rate introduced by gas injection and pumping ports, and by non-uniform power deposition profiles. The finite element method using higher order elements allows accurate representation of complicated reactor geometries. A 3-D Maxwell solver was also implemented to self-consistently account for azimuthal variations of the power deposition in the plasma. The chlorine plasma etching polysilicon was taken as a system for study. Gas inlets were found to introduce some local azimuthal asymmetries. In general, however, they did not contribute substantially to non-uniformities at the wafer level. The effect of pumping port(s) and non-uniform power absorption were more important since significant disturbances of all essential plasma species can be introduced. The implementation of a focus ring was found to yield practically azimuthally symmetric etching profiles. Overall, 3-D simulation tools are viewed as critically important for the design and optimization of upcoming 300 mm wafer plasma processing tools.

MS-ThP9 Ion Beam Deposition Systems for Highly Uniform Defect-free Coatings for Electronic Manufacturing Applications, ***A.V. Hayes****, H. Hegde, V. Kanarov, C.C. Fang, J. Wang, D. Kania,* Veeco Instruments, Inc.

Ion beam deposition (IBD) techniques are of increasing interest for use in the manufacturing of electronic devices. The most developed application is the production of high quality Extreme Ultraviolet (EUV) reticle masks.@footnote 1@ The IBD multilayer coatings generated by this work were very uniform, precisely deposited, and were lower in defects by several orders of magnitude compared to the best sputter deposited coatings. This has directly stimulated interest in extending the technique to the coating of advanced generation optical photomasks. On another front, recent advances have been made in the production of high quality Giant Magnetoresistive sensors using IBD methods. Such sensors are used in MRAM (Magnetic RAM) devices. In this work the ion beam deposition of low defect, uniform multilayer coatings with precisely controlled thickness, and of high quality magnetic films, is reviewed. This will be followed by a discussion of modeling and preliminary experimental data regarding extension of the technique for uniform coating of 300 mm substrates. @FootnoteText@ @footnote 1@S.P. Vernon, et al, Optical Society of America Trends in Optical Photronics, 4 (1996).

MS-ThP10 Estimation of the Ion Energy Distribution Function at Sputter Coils in PVD-IMP Systems, ***R. Veerasingam****, P. Gopalraja, E Kim, J.C. Forster,* Applied Materials, Inc.

Computer simulations were used to evaluate the ion energy distribution function (iedf) at the sputter coil of PVD-IMP systems. In the simulations, Ti/Ar and Ti/N2/Ar plasmas at 20 mTorr fill pressure were used to model the systems. The simulations revealed that in TiN systems, the plasma temperature and densities are lower compared to Ti systems. The existence of the excited states of nitrogen such as N* and N2*, provide an additional channel for electron energy dissipation rather than ionization and also lead to nitridization of surfaces. A TiN surface such as a nitridized sputter coil may have lower sputter yield compared to a pure Ti coil. By modifying the ion energy distribution function it is possible to enhance sputter yields from the coils. Control of the iedf at the coil surface provides a means to improve coil sputter and hence deposition uniformity. Experimental densities will be used to calculate the iedf. Results of the calculated plasma properties and iedfs will be presented.

Author Index

Bold page numbers indicate presenter