Wednesday Morning, November 4, 1998

Manufacturing Science and Technology Group
Room 317 - Session MS-WeM

Advanced Process Equipment and ES&H

Moderator: G.S. Oehrlein, State University of New York, Albany

8:20am **MS-WeM1 Complete Solvent Free Stripping of via Structures using NF@sub 3@,H@sub 2@O,O@sub 2@ Ashing Chemistry**, ***W. Au***, *R. Solis,* VLSI Technology, Inc.*; R. Bersin, H. Xu, M. Boumerzoug,* Ulvac Technologies, Inc.

The use of TiN as a base material in submicron vias employing tungsten plugs is becoming more and more accepted. One difficulty, however, is the etching of these vias and subsequent removal of polymeric residues residing at the via base and along the vertical sidewalls. Removal of these residues prior to deposition of a Ti/TiN glue layer is most critically important to achieve low contact resistance in the vias. Resist stripping and polymer-residue-removal from submicron vias is an area of intense interest at this time. Methods employing fluorine-based plasmas to render any residues DI water soluble, thereby avoiding costly and corrosive solvent processes, are under serious investigation. In this instance of TiN based vias, however, undercutting of the TiN and resulting high via resistance have been a major obstacle. A new process has been developed which address this problem. The residues are ashed utilizing a low bias RIE plasma comprising oxygen, NF@sub 3@, and H@sub 2@O vapor in correct proportions. The presence of the fluorine renders any ash residues soluble in DI water; and the H@sub 2@O vapor addition serves to inhibit the etching of the TiN base during the stripping process. The net result is a new manufacturing process which competes directly with conventional ashing and solvent processes in product performance; and which offers substantial cost savings through total elimination of solvent processing. Details of the parametric study of process conditions to achieve good TiN selectivity, excellent contact-resistance, and elimination of any TiN undercut will be discussed. A brief description of the manufacturing equipment involved will be included.

8:40am **MS-WeM2 Studies of a New High Dissociation Inductively-Coupled Plasma Downstream Strip Module**, ***W. Collison***, *T. Ni, B. Berney,* Lam Research Corp.

A new inductively-coupled high dissociation plasma downstream strip source (HD@super 2@ source) was developed to meet advanced market requirements for 200mm and 300mm photoresist stripping processes. Plasma simulations were used to study the dissociation percentage of O@sub 2@ gas for different chamber designs. It shows that this source can provide higher than 20% O@sub 2@ dissociation for 1500 watts power at 1 Torr. Fluid modeling was used to design the gas-redistribution plate to optimize ashing uniformity. Detailed process results will be presented and discussed. It is shown that adding 5-10% N@sub 2@ gas can increase photoresist etch rate 2-3 times. CHARM wafer tests have demonstrated no charging or UV damage. RF bias on the bottom electrode provides added capability to remove residues and enhance etch rate. A comparison of HD@super 2@ source and microwave source will also be discussed.

9:00am **MS-WeM3 Lithography for Smaller than 0.15 Micron Silicon Technology**, ***A. Ishitani***, Association of Super-Advanced Electronics Technologies (ASET), Japan **INVITED**

Lithography for smaller than 0.15 micron silicon technology Association of Super-advanced Electronics Technologies (ASET) Akihiko Ishitani KrF laser lithography (KrF) has reached its limits in terms of resolution capabilities, and hence it has become necessary to find practical application of such technologies as ArF laser lithography (ArF), electron beam direct writing (EBDW), and proximity X-ray lithography (X-ray) to realize further downscaling of silicon devices. As a result of research and development, these technologies have attained a resolution capability that is less than 100 nm. The remaining issues to be addressed are critical dimension and position accuracy, resist and optical materials, and mask fabrication. Defect inspection and repair technologies are important issues, too. Single layer resist technology for ArF will be employed down to 130 nm. Top-surface imaging technology for ArF, or mix and match of ArF with EBDW will be used between 150 to 70 nm, and VUV or EUV lithographies should deal with 100 to 50 nm. X-ray has enough potential for between 250 to 70 nm mass production. SCALPEL and Ion Projection Lithography (IPL) are also candidates for next generation lithography. ASET is focusing on optical lithography, X-ray, and mask writers. SCALPEL and IPL are mainly depending on the United States and Europe. In the future, lithography will be adopted to suit the type of LSI devices, depending on the required field size and the depth of focus. Mask size is another critical issue for mass production. Smaller mask size has higher capability for mask accuracy. Research and development of lithography now involve very large costs and risks, and hence international cooperation and exchange of information are essential for LSI industry. This work is being performed under the management of ASET in Ministry of International Trade and Industry (MITI) and Industrial Technology Development Organization (NEDO).

9:40am **MS-WeM5 Evaluation of Chamber Liners, in TCP Metal Etchers, to Reduce the Equipment Clean Time and to Increase the Mean Time between Cleans**, ***J. Sappidi***, *A. Liu, D. Parks, W. Au, S. Smith,* VLSI Technology, Inc.

Implementation of in-situ clean in TCP metal etchers has decreased the defect density and increased the sort yield. However, the polymer treated with in-situ clean plasma is very difficult to remove. Soaking the chamber wall with DI water or scrubbing the chamber wall to remove polymer have disadvantages. Water absorbed by chamber walls during soaking take a long time to out gas, this increases the equipment downtime. Scrubbing the chamber is very labor intensive and extends the clean time. Scrubbing combined with reactive ion bombardment during plasma processing accelerates the erosion of the chamber walls anodization. In order to reduce the clean time and increase the life of anodization on chamber walls, a set of chamber liners were evaluated. When the machine goes down for clean, rather than cleaning the entire inside chamber wall, the dirty liners can be replaced with the clean ones. This helps in reducing the cleaning time and protects the chamber anodization from eroding. . These liners were evaluated for 0.5 µm and 0.35 µm technologies. Installation of chamber liners demonstrated less than five percent process shift in terms of etchrates and selectivities. Experiments also demonstrated the metal etch process repeatability of the liner kits installation after chamber wet clean. The metal etch related defects were monitored with and without liners. The sort yield data was also collected and analyzed. The reactor with chamber liners proved superior in terms of both cleanliness and sort yield.

10:00am **MS-WeM6 Evolution Effects of Reactor Inner Wall Surface on Fluorocarbon Plasma Parameters**, *H. Oshio, M. Ogata,* ***T. Ichiki***, *Y. Horiike,* Toyo University, Japan

SiO@sub 2@ contact hole etching using fluorocarbon plasmas cause various issues such as etch stop, relating closely to the change of plasma state due to the deposition on the reactor wall. To clarify wall effects, variations of CFx(x=1-3) radical densities, pressure and wall temperatures with the C@sub 4@F@sub 8@ discharge time were investigated. Inductively coupled plasma was generated by 13.56 MHz power supplied to an antenna wound around a 130 mm @phi@ quartz bell jar connected to a 150 mm @phi@ SUS reactor. A 130 mm @phi@ Cu barrel, whose temperature was controlled by water was inserted into the reactor. An orifice head of the appearance mass spectroscope(AMS) was set at 15 cm apart from the antenna. Etching experiments were carried out on a stage equipped with a load-locked system. At first the reactor was cleaned by ashing, then pressure evolution with discharge time was measured for different residence times,@tau@. At @tau@=100 msec the pressure once dropped, and then gradually increased after 3 min. AMS revealed the pressure increase was mainly attributed to increase in CF@sub 3@ radical. The initial decrease resulted from singnificant adsorption of radicals on the cleaned wall. The run-to-run variations were measured by repeating a cycle of 3 min discharge on and 3 min off for 20 times. The wall temperature rise reached its steady state at 50 - 80 ° after the 5th run, while the pressure kept on increasing even over the 20th run. SiO@sub 2@ and Si etch rates as well as plasma potentials decreased corresponding to these increases. In contrast, at @tau@=30 msec run-to-run variation slightly occured after the 3rd run and detailed measurements of pressure evolution with time revealed no initial drop but the rapid increase after plasma ignition, caused by the high deposition rate due to the high radical density. Furthermore, water cooling of the bell jar suppressed the increase in pressures. Consequently to adopt short residence time and control the wall temperature is important for keeping CF@sub 3@ radical density constant to achieve good reproducibility.

10:40am **MS-WeM8 Studies of 300MM Poly-Silicon Etch Processes Using A Inductively Coupled Plasma Source**, ***T. Ni***, *W. Collison,* Lam Research Corp.*; K. Takeshita,* Lam Research Corp., Japan, Japan.

Inductively-coupled plasma sources have been successfully applied to 200mm poly-silicon wafer etch processes. As semiconductor wafer size increases from 200mm to 300mm, scaling up sources to meet the same or even more stringent requirements is very challenging. In this study, a

transformer coupled plasma (TCP) chamber is designed and studied for 300mm poly-silicon etch processes. Plasma simulation and Langmuir probe were used to investigate the effects of TCP power, chamber pressure, aspect ratio , and coil configuration on plasma uniformity. As a result, plasma uniformity is optimized from 5mTorr to 80mTorr. Effects of different gas injection schemes are carefully examined. It is found that gas injection has strong impact on etch uniformity and profile. A unique gas injector is designed to deliver gas efficiently and minimize profile microloading. A TCP coil is constructed to provide uniform plasma and uniform etch rate. Large conductance of the chamber allows high flow processes. Advanced control systems are implemented to improve process repeatability, minimize chamber-to-chamber variation, and increase throughput. Excellent etch results and wide process window were achieved. Detailed etch process results will be presented and discussed.

11:00am **MS-WeM9 Integrating Process Models and Operational Methods**, ***J.W. Herrmann***, *N. Chandrasekaran, R.Z. Shi, B.F. Conaghan, G.W. Rubloff,* University of Maryland

Though substantial attention is currently paid to unit process modeling/optimization and to operations/scheduling at the sector and fab levels, the relation between them has seen little exploration. This work attempts to bridge the gap between manufacturing process models and operational methods in order to systematically examine the consequences of these interactions: e.g., how the evolution of process technology will affect production, alter equipment design preferences, or suggest changes in scheduling strategies; or, what benefit to sector or factory metrics might be achieved if process or equipment improvements could be realized. The sensitivity analysis and optimization techniques in this work incorporate response surface models, which describe the manufacturing processes, and simulation and scheduling techniques, which evaluate the manufacturing system. Current work, described here, focuses on the fabrication of the tungsten plug, involving contact clean, Ti/TiN liner, and W CVD process steps carried out in a cluster tool. Response surface models for these steps are integrated in operations simulations for different cluster tool architectures (e.g., Novellus Concept II and Applied Centura) to evaluate the consequences of process-operations interactions. For each cluster tool, we describe how throughput and cycle time change as the process parameters and equipment design parameters vary. Thus, each tool's operational sensitivity is measured, which enables prediction of the impact of process changes.

11:20am **MS-WeM10 Application of an Inductively-Coupled Plasma Source to Destruction and Abatement of Fluorine-based Gases**, ***L.J. Mahoney***, *D.C. Carter, M.S. Amann, G.A. Roche,* Advanced Energy Industries

Recently high density plasma sources have been used to assist in the abatement of residual hydro-fluorocarbon and per-fluorocarbon gases which are used in many manufacturing processes. In this application, oxygen-containing gas mixtures are added with the exhaust gases from a vacuum process chamber within the foreline of a processing system. The mixture is then activated by a high-density plasma means in order to converted the hydro-fluorocarbon and per-fluorocarbon process gases into constituents that are more easily removed from the exhaust within an air scrubber. An economical and modular inductively-coupled plasma source has been devised to investigate the power coupling and process requirements necessary to effectively abate post-process gases by this method. The relatively high power density source is configurable to operate near 400 kHz , 2 MHz or at 13.56 MHz with more than 2 kW of delivered power. Abatement destruction efficiencies are shown for several gases including CF@sub 4@, C@sub 2@F@sub 6@, CHF@sub 3@, and SF@sub 6@ as determined by mass spectroscopy over a wide range of power, pressure, and total flow conditions and range of added oxygen/argon/nitrogen gas mixtures.

11:40am **MS-WeM11 Low Dielectric Polymer Etching with a Downstream Microwave Plasma**, ***R.R.A. Callahan***, *G.B. Raupp, S.P. Beaudoin,* Arizona State University

The semiconductor industry has signed a memorandum of understanding with the EPA to reduce the amount of fluorocarbon gases used. In particular, this impacts the way that silicon dioxide etching is performed. At the same time, new dielectric materials that offer lower dielectric constants than silicon dioxide are required to help reduce chip speeds. Polymer dielectrics offer reduced dielectric constants compared to silicon dioxide, and they also can be etched using oxygen, not fluorocarbon gases. We have studied the etching of parylene films using a downstream microwave oxygen plasma, and we will report on the effects of temperature on the etch rate and will provide a tentative etching mechanism.

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