Wednesday Morning, November 6, 2002

Plasma Science
Room: C-105 - Session PS-WeM

Conductor Etch II
Moderator: S.J. Ullal, Lam Research Corporation

8:20am **PS-WeM1 Plasma Etch Chemistries for III-V Lasers and Light-Emitting Diodes**, ***S.J. Pearton***, University of Florida **INVITED**

A review will be given of plasma chemistries for etching AlGaN/InGaN, InP/InGaAsP and AlGaAs/GaAs diode lasers and light-emitting diodes. With Cl_2-based chemistires, it is generally necessary to heat the sample when etching In-containing compounds, because of the low volatility of $InCl_x$. By contrast, the use of Br_2 or I_2 based chemistries produces practical etch rates at room temperature. Plasma-induced damage can play a significant role in determining device performance through effects on ohmic contact resistances or optical output power. Special attention must be paid to the quality of the initial lithography for patterning resist, since sidewall roughness is transferred into the semiconductor during subsequent etching. Gratings for DBR or DFB layers are also readily created using holographic lithography and plasma etching.

9:00am **PS-WeM3 Surface Chemical Changes of Aluminum During NF3-Based In-Situ Chamber Cleaning: Critical Discharge Parameters**, ***X. Li***, *G.S. Oehrlein, X. Hua, L. Ling*, University of Maryland, *E. Karwacki, B. Ji*, Air Products

During plasma-based in-situ chamber cleaning of deposited dielectric films using NF3, a significant transformation of aluminum into AlF3 can occur. We studied the roles of fluorine atoms and ion bombardment in this process by employing NF3 discharges mixed with He, Ne or Ar. Polished Al 6061 alloy coupons and sputter-deposited Al films were used. Typical process conditions were a pressure of 1 Torr, a total flow rate of 300 sccm, and power levels up to 300 W RF bias power for a 125 mm diam wafer. Aluminum erosion rates and surface chemistry changes, and information on the species that evolve from the surfaces during the process were obtained by real-time ellipsometry and mass spectrometry, respectively. X-ray photoemission spectroscopy characterization of processed Al surfaces was also performed. We find that a complex Al-fluoride layer is produced by the plasma processes. For RF-based discharges employing NF3 a threshold RF power exists below which a thicker reacted Al-fluoride layer is not produced (about 2 W/cm2 for our reactor). When Al is exposed to an NF3 RF discharge above this power level, a thick reacted Al fluoride layer is produced. If instead a He/NF3 discharge is used, the Al surface modifications are minimized at high RF power as long as the NF3 concentration is less than 40%, and an increasingly thicker Al fluoride layer is produced with a greater proportion of NF3 in He/NF3. In addition, we will report RF electrical characterization of NF3/He discharges under these processing conditions, and results of comparative studies using Ne/NF3 and Ar/NF3 discharges, and microwave remote plasma production.

9:20am **PS-WeM4 Metal Etching in High-Density Plasmas**, ***R. Blumenthal***, *A.S. Orland*, Auburn University

Metals are found at the heart of many important current and developing device technologies, such as GMR read heads, MRAM and FeRAM. As the scale of these devices continues to be reduced, high performance etch technologies will become a necessary component of the fabrication of these devices. The chemical mechanisms of high-density plasma etching of Fe, Ni, Co and their alloys will be presented for a range of etch chemistries ranging from the more traditional etching of the metals with Cl_2 to the more novel example of $CO-NH_3$ etching and finally to a new etch chemistry based on H_2-CO gas mixtures. The chemical mechanisms of etching have been determined from measurements of the variation of chemical composition as a function of plasma conditions, using supersonic pulse, plasma sampling mass spectrometry.

9:40am **PS-WeM5 Effects of Dry Etch Process for Platinum Upper Electrodes on Electrical Properties of High-k (Ba,Sr)TiO_3 Thin-Film Capacitors**, ***D.-S. Wuu***, *R.-H. Horng, C.-Y. Kung*, National Chung Hsing University, Taiwan ROC

Inductively-coupled-plasma (ICP) etching behavior of the platinum (Pt) thin films has been characterized with Ar gas by varying the etching parameters such as chamber pressure, ICP power, and bottom rf power. After the dry etch process, the restoring method of plasma-induced damage was investigated in terms of rapid-thermal and furnace annealing. Quantitative analysis of the etch damage was attempted to discuss the mechanism of leakage current density and dielectric constant with various bottom rf power and ICP power in Pt/(Bs,Sr)TiO_3(BST)/Pt capacitor. It was found that the parameters of etching process for the top electrodes of BST capacitors would influence the methods of recovering technique. In this study, a better condition with lower leakage current density was observed under a coil power of 1000 W, bottom rf power of 100 W, and chamber pressure of 0.67 Pa. The plasma-induced damage samples can be effectively recovered with furnace annealed at around 600°C in oxygen ambience. It can not only improve the leakage current density less than $5x10^{-8}$ A/cm^2 under an applied voltage of 1 V, but also enhances the dielectric constants to 350 for the damaged samples.

10:00am **PS-WeM6 Residual-Free Reactive Ion Etching of the Bell Contact Ti/Pt/Au**, ***G.F. Franz***, *R. Kachel, S. Sotier*, University of Applied Sciences, Germany

The etching of the complete Bell contact consisting of a layer of Ti/Pt/Au was performed in highly reactive plasmas containing Cl_2 for Ti, PF_3/NF_3 for Pt, and Cl_2 and/or BCl_3 for Au. All the constituents of the Bell contact form volatile compounds in either capacitively-coupled low-density plasmas or high-density plasmas generated by electron cyclotron resonance. This is a conditio sine qua non for surfaces and sidewalls which have to remain free of any residues. Its functionality was demonstrated as self-adjusting mask for a surface-emitting laser.

10:20am **PS-WeM7 Advanced Metal Gate Etch with 193nm Lithography in a Silicon Decoupled Plasma Source Etcher (DPSII)**, ***D. Yan***, *M. Shen, D. Shashank*, Applied Materials, *T. Chowdhury, C. Yang*, Cypress Semiconductor

193nm lithography is becoming increasingly important as the critical dimensions of semiconductor devices continue to scale down towards sub-0.10um. From dry etching perspective, however, 193nm resist brings new challenges due to its poorer plasma etch resistance, line edge roughness and lower thickness compared to 248nm DUV resist. Consequently, issues such as line edge roughness and poor profile control were observed after dry etch processing using etch processes developed for 248nm resist. This paper presents a successful development of advanced 0.1mm metal gate application using 193nm lithography on Applied Materialsâ€™ decoupled plasma etcher (DPSII). The integrated process involves a hard mask open with ex-situ resist strip followed by metal/poly dual gate etching. Process chemistry and process parameters for nitride mask step were thoroughly investigated. With CF4/CHF3 based chemistry, the process achieved high nitride to resist selectivity with straight nitride profile and smooth sidewall. Less than 7nm 3-sigma of CD bias uniformity was obtained across the wafer with edge exclusion up to 4mm on a 200mm substrate. Process parameters such as pressure, gas ratio and the total fluorine-containing flow were shown to be the most influential on resist selectivity, profile and CD control. A careful balance of these parameters needs to be maintained in order to deliver an overall process. The subsequent W/WN/poly gate etch features a three-step approach that has produced straight profiles, excellent CD control and excellent gate oxide integrity. Post-etch measurement of line edge roughness shows comparable performance to that obtained on 248nm resist. Bright field ultra sensitive defect monitoring on product wafers showed comparable performance to previous 248nm resist poly gate process. Process trends and proposed mechanisms are addressed in detail in the paper.

10:40am **PS-WeM8 Effect of Carbon Based Polymer Formation on Process Stability in Polysilicon Etching**, *S. Xu, S. Deshmukh*, ***Th. Lill***, Applied Materials, *O. Joubert*, CNRS/LTM, France

High density plasma at low pressure has been used extensively in etching ultra-small feature devices to achieve precise critical-dimension control. In such a processing environment, plasma properties become significantly dependent on the wall condition of the reactor through plasma wall interactions. Commonly, halogen containing silicon oxides are deposited on the chamber walls during polysilicon etching. Recently, in-situ dielectric mask open or dielectric anti-reflective coating open steps are being used more frequently. These steps generate carbon based deposits on the chamber walls. Another source of carbon polymers are CF4 and other CxHyFz additives used in silicon etching to achieves good n/p etch behavior and dense/iso microloading. This paper extends previously published studies on the influence of polymer formation on the chamber walls to carbon based polymers. The effect of surface polymerization has been characterized by studying the variation of the plasma properties and process performance. Clean, oxide covered and carbon covered chamber wall are being compared in terms radical densities, plasma emission properties, etch rates, and critical gate dimensions. Effective approaches to

reduce the impact of chamber wall on the plasma and process stability will be discussed.

Authors Index

Bold page numbers indicate the presenter