Vacuum Metallurgy Division
Room 620 - Session VM+TF-TuM
Ionized Plasma and Chemical Vapor Deposition
Moderator: B. Sartwell, Naval Research Laboratory

9:00am **VM+TF-TuM3 New Plasma Sources for Ionized PVD**, ***D.N. Ruzic***, University of Illinois, Urbana; *D.B. Hayden,* Novellus Systems Inc.; *D.R. Juliano, M.M.C. Allain,* University of Illinois, Urbana **INVITED**

Three plasma sources have been investigated on a commercial magnetron sputtering system: an inductively coupled plasma (ICP) coil, a helical resonator, and an external helicon antenna.@footnote 1@ The main variables presented are the ionization fraction to the substrate, the deposition rates, the electron density and temperature. The ICP coil with an Al target achieved ionization fractions to the substrate in excess of 80%. The deposition rates are around 1500 Å/min. Electron densities are found as high as 2.6±0.3 X 10@super 11@ cm@super -3@. The main drawback to the ICP approach is that the coil is too intrusive, leaving visible shadowing effects which destroy uniformity. The coil sputters some, and also flakes off built-up deposited metal, which can contaminate the system. The helical resonator coil has a much larger diameter and avoids the shadowing effects. Ionization fractions are found with a Cu target at 73±15% under conditions with deposition rates of 1000 Å/min. The electron densities approach 2. X 10@super 12@ cm@super -3@. A ground at the center of the coil eliminates the sputtering problem by maintaining a DC bias of 0~V. There is still metal flaking off the coil as metal builds up on it. The helicon antenna sits remotely outside the vacuum system, so all shadowing and contamination problems are eliminated. Cu ionization fractions to the substrate of 51±10 % with a deposition rate of 850 Å/min. are found using one remote source. The plasma density was only 2. X 10@super 11@ cm@super -3@, but the temperature of that plasma was significantly higher than without the remote helicon present. Six or more remote sources are envisioned to sit around a sputtering chamber, which can help control uniformity while increasing the ionization further. Since there is no threat of contamination inside the vacuum chamber and the substrate to target distance can remain small, the helicon source may have the highest potential of these three secondary sources in industrial IPVD applications. @FootnoteText@ @footnote 1@ D.B. Hayden, D.R. Juliano, M.N. Neumann, M.M.C. Allain, D.N. Ruzic, "Helicon Plasma Source for Ionized PVD," Surf. Coating Tech., to be published (1999).

9:40am **VM+TF-TuM5 Simulations and Experimental Measurements of a Hollow Cathode Magnetron Ionized Metal Plasma Deposition System**, ***G.I. Font***, *K.F. Lai, Q. Lu,* Novellus Systems, Inc.; *M.J. Kushner,* University of Illinois, Urbana

The hollow cathode magnetron (HCM) is a novel new plasma source used for ionized metal deposition. The HCM employs geometric, electrostatic, and magnetic confinement to produce a high density plasma (>1e+12 #/cm3). This plasma serves as a source of ions for sputtering the target and metal ions for deposition on a wafer. In the results reported here, numerical simulations of the HCM using a copper target were performed using the Hybrid Plasma Equipment Model (HPEM) developed at the University of Illinois. The HPEM iteratively combines particle and fluid transport models for ions, electrons, and neutrals to simulate HCM performance. The model includes sputtering of the target by metal and argon ions, secondary electron emission, magnetic confinement of electrons, and thermalization and ionization of sputtered neutrals. The numerical results are compared with experimental Langmuir probe and wafer deposition profile measurements. The numerical results are found to systematically track the experimental measurements. In both experiments and modeling of an HCM, the magnetic field configuration resulted in a confined 'beam' of plasma emanating from the HCM. The physics of the operation of the HCM is described as supported by numerical and experimental results.

10:00am **VM+TF-TuM6 Low Temperature Polysilicon Deposition by Ionized Magnetron Sputtering**, ***J. Joo***, Kunsan National University, Korea

Ionized PVD has deep potential for wide range of applications in thin film deposition. Poly Si deposition on glass should be one of them. A-Si based TFT technology has a limit of electron mobility less than 1 cm@super 2@ V/sec. Excimer laser annealing would be one solution for recrystallization but too expensive and slow process in economic point of view. As Si has very high melting temperature, the required substrate temperature for crystallization is well over the softening temperature of conventional glass in flat panel industry. RF ICP based ionized magnetron sputtering was applied to deposit polysilicon on glass substrate while keeping substrate temperature less than 400C. From X-ray diffraction analysis, small evidence for microcrystalline Si was confirmed at 250C of substrate temperature and floating substrate potential. The effects of pulsed dc sputtering power, substrate biasing frequency and ICP driving frequency will be addressed in detail.

10:20am **VM+TF-TuM7 A Study of the Mechanical Behaviour of Plasma Deposited Silica Films on Polycarbonate and Steel**, *A. Hofrichter, A. Constantinescu,* CNRS, Ecole Polytechnique, France; *S. Benayoun,* E.N.S.A.M, France; *P. Bulkin,* ***B. Drévillon***, CNRS, Ecole Polytechnique, France

The deposition of silica for protective coatings on polymers is of increasing interest for various applications. Key issues in the mechanical behaviour of the film are the properties of the film-substrate interface that can be modified by different pretreatments. The objective of this work is to estimate the constitutive behaviour of the film and the interface by a serie of mechanical experiments and computer simulations. In order to gain a better understanding of the involved phenomena a comparison between depositions on polycarbonate and stainless steel have been performed. The films are deposited in a low pressure (1 mTorr), scaleable integrated distributed microwave 2.45 GHz electron cyclotron resonance (IDECR) reactor, which allows fast deposition at room temperature of dense, stoechiometric silica. The internal stress of the films was evaluated with profilometry and their Young modulus measured by the vibrating slab technique. Microscratch as well as nano-, micro- and Vickers indentation tests were performed on polycarbonate and steel samples for different thickness and processing powers. As indentation measurements can not be interpreted directly, the tests have been simulated by finite elements using the Castem2000 code (CEA-France). The simulated indentation curves and the final shape of the indent were compared to the measurements. The obtained stress and strain distribution in the film conducts to a reasonable explanation of the crack system observed on the indented surfaces. Finally a parametric study of the influence of the material parameters of the interlayer on the global mechanical behaviour will also be presented.

10:40am **VM+TF-TuM8 Carburizing of Tantalum by Radio-Frequency Plasma Assisted CVD**, *A. Rubinshtein,* Ben-Gurion University; ***A. Raveh***, NRC-Negev, Israel; *J.E. Klemberg-Sapieha, L. Martinu,* Ecole Polytechnique, Canada

Tantalum carbide has a great potential as an alternative to tantalum and tantalum oxide for applications requiring thermal stability and corrosion resistance. In the present work we are studying hard TaC layers prepared by inductive rf plasma-assisted CVD (IPACVD) in different gas mixtures containing argon, methane, and hydrogen. The IPACVD approach combines plasma-induced diffusion with chemical vapor deposition. Maximum temperature of the tantalum substrate measured during 6 hours of processing time was 900 degC. Microstructure of the TaC layers was characterized by XRD, AFM, AES, and XPS, and the mechanical properties were studied by micro- and nanoindentation techniques. Close correlation between carburizing parameters, microstructure and mechanical properties of the layers has been established. The best mechanical performance in terms of elasto-plastic properties (microhardness of about 25 GPa) were obtained for several micrometers thick TaC films prepared at rf power levels between 1.6-2.0 kW and pressures between 40 and 60 mTorr. The effect of gas composition, rf power and substrate temperature on the layer composition (TaC/Ta@sub 2@C phase ratio), and the mechanical behavior will be presented and discussed.

11:00am **VM+TF-TuM9 Electrical and Pressure Probe Measurements of a Hollow Cathode Magnetron Plasma**, ***K.F. Lai***, *Q. Lu, J. Chau, G.I. Font,* Novellus Systems

The hollow cathode magnetron (HCM) is a new type of high-density plasma device developed for ionized physical vapor deposition (I-PVD). While I-PVD using RF inductively coupled plasma has a plasma density of 10@super 11@ to 10@super 12@ cm@super -3@ and operates best above tens of mTorr, the HCM achieves high levels of ionization at only a few mTorr, primarily due to its extremely high plasma density (~10 @super 13@ cm@super -3@). The plasma profiles of a HCM were measured using Langmuir probes and a novel pressure probe under various operating conditions for two different target materials (Cu and Ti). With the exception of the plasma edge where the presence of an energetic electron tail was clearly evident, the electron energy distribution function (EEDF) was approximately Maxwellian. The measured plasma density was found to increase linearly with the magnetron power whereas the electron temperature only has a weak dependence. Under similar operating conditions, the Ti HCM has a plasma density ~30% higher than that of Cu. A novel pressure probe was used to measure both the argon neutral and ion density profiles. Argon neutrals were measured when the probe was biased slightly above the plasma potential whereas both the argon neutrals and ions were collected when the probe was negatively biased. The percentage of gas rarefaction was found to increase with sputtering power but was only weakly dependent on argon density. The argon ion density profile (deduced by alternating the pressure probe bias) has similar shape as the electron density (measured by the Langmuir probe) indicating that argon is the dominant ion species. The experimental results are in good agreement with simulation using the hybrid plasma equipment model (HPEM) code.

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