Thursday Afternoon, November 1, 2001

Thin Films
Room 123 - Session TF-ThA

Emerging Thin Film Techniques
Moderator: T.M. Klein, University of Alabama

2:00pm **TF-ThA1 Ionized-PVD with Quasi-Stationary High Power Magnetron Sputtering**, ***U. Helmersson***, *J. Alami,* Linköping University, Sweden; *A.P. Ehiasarian,* Sheffield Hallam University, UK, United Kingdom; *K.M. Macák,* Sheffield Hallam University, UK; *J.T. Gudmundsson,* University of Iceland, Iceland **INVITED**

The development of ionized-PVD by sputtering over the last few years is based on the production of a high-density plasma (10@super 18@ - 10@super 19@ m@super -3@) in front of the source. As the atoms pass through this dense plasma, a large fraction becomes ionized. The high plasma densities can be achieved in several ways, by using an rf-coil, a hollow cathode arrangement, or as in the present case, simply by increasing the power supplied to the magnetron source. To avoid extensive heating of the cathode as well as the development of arcs, in the latter case, the power is pulsed with a duty factor of around 1 %, which maintains the average power at an acceptable level. In the present work, peak power densities of several kW cm@super -2@ with a repetition frequency of 50 Hz was used. This technique has been demonstrated for sputtering a range of different metals, yielding a degree of ionization of 30 to 70 % depending on cathode material and applied power as measured for Cu, Ta, and Cr cathodes. Optical emission studies demonstrate a temporal development of the plasma during the pulse. Initially the emission is dominated by Ar-lines, but later in the pulse lines from cathode-metal ions dominate the emission. This may indicate a transition from Ar-sputtering to self-sputtering during the pulse. That self-sputtering occurs is also supported by the observation that the relative deposition rate (pulsed rate as compared with normal dc rate) scales with self-sputtering yield giving low relative deposition rate for low-yield materials. Film growth by this sputtering technique is demonstrated in trench-filling applications, reactive sputtering of chromium nitrides, and for carbon films.

2:40pm **TF-ThA3 Ionization of Sputtered Titanium Atoms in Radio Frequency Magnetron Sputtering**, ***K. Okimura***, *T. Nakamura,* Tokai University, Japan

Recently, the ionization of the sputtered flux has received much attention for several aspects such as, assisting effect of low temperature crystallization, filling characteristics to high aspect ratio seed layer and damage in integrated circuits. We have investigated sputtered titanium(Ti) atom densities for both Ar discharge and Ar-O@sub 2@ reactive discharge by means of atomic absorption method.@footnote 1@ As for the ionization of sputtered atom, quantitative measurement is lacking for understanding ion flux incident to substrate. In this study, optical emission spectroscopy for Ti ions were performed using 250 mm monochromater in planar rf magnetron sputtering apparatus with 100 mm diameter titanium target and 35 mm electrodes spacing. Atomic absorption method using a hollow cathode lamp was also applied in order to evaluate concentration of Ti ions. A series of optical emission originated from Ti ion, 336.1 nm, 337.3 nm and 338.4 nm, were observed in a spectrum at argon pressure of 3.5 Pa and radio frequency power of 200 W. We discussed the ionization of sputtered atoms from relative intensities of ionic optical emission to atomic emission in measured spectra. Radial(r) and axial(z) profiles of optical emission intensity of Ti ions at 336.1 nm for different discharge conditions such as rf power, Ar pressure, were presented. At axial directions, z=15 mm, 21 mm, 27 mm, maximum emission of Ti ion located at radial position around r=35 mm where was slightly outward position compared to the position with maximum strength of transverse magnetic field. Absorption measurement of 336.1 nm line showed absorption intensity around 10@super -2@ indicating ionization degree less than several percent for sputtered Ti atom density. Plasma parameters and mass-resolved analyses of incident ions were served for discussion on mechanism of ionization and ion flux incident to substrate. @FootnoteText@ @super 1@T.Nakamura and K.Okimura : to be appeared in JVST-A.

3:00pm **TF-ThA4 High Rate Growth of Cu Thin Films Using New Magnetron Sputtering Source**, *H.K. Park,* Sungkyunkwan University, Korea, South Korea; *K.H. Nam, J.G. Han,* ***J.-H. Boo***, Sungkyunkwan University, Korea

We have deposited the copper (Cu) thin films on Si(100) and stainless steel substrates in the growth temperature between room temperature and 500 °C using pulsed D. C. magnetron sputtering method. An unbalanced magnetron sputtering source with high current (20 - 120 mA/cm @super 2@) and low voltage (100 - 1000 eV) was designed and constructed for high rate deposition. Based upon the results of magnetic field simulation, we built-up the highest power (120 W/cm @super 2@) Cu magnetron sputtering source to enhance the sputtering yield and film growth rate. The maximum deposition rate and sputtering yield of the newly developed sputtering source are 2.8 μm/min. and 70%, respectively. When an ion extraction grid was adapted between the Cu target and substrate, however, the growth rate was increased over 3 μm/min. This is 10 times higher than that of conventional sputtering method, and the sputtering yield was also reached to 80% due to low voltage and high current Cu-accelerated ions. XRD and XPS showed that highly oriented polycrystalline Cu(111) thin films with no impurity were obtained on the stainless steel substrates. During film deposition, plasma diagnostics was also carried out in situ by optical emission spectroscopy analysis. Electrical conductivity was also measured with four-point probe method.

3:40pm **TF-ThA6 Low Temperature Hollow Cathode Sputter Deposition of Al@sub 2@O@sub 3@ Thin Films**, ***A. Pradhan***, *S.I. Shah, K.M. Unruh,* University of Delaware

Hollow cathode sputtering offers a novel way of conformally coating three-dimensional objects. It offers the added advantages of uniform sputtered flux and high plasma density. We have characterized a Hollow Cathode Source (HCS) for depositing alumina thin films by reactive sputtering. The target potential decreased sharply in the poison mode. This is contrary to what is observed in most reactive sputtering systems. This was attributed to the large secondary electron emission coefficient for Al@sub 2@O@sub 3@. The hysteresis behavior of planar sputtering was not observed. High growth rates at low power densities were obtained even in the poison mode. This was probably due to the enclosed geometry of the hollow cathode and very high cathode to anode area ratio. The oxidation state of the film was determined using X-ray Photoelectron Spectroscopy (XPS). The alumina content of the films increased sharply with the addition of oxygen to the system. Above a certain oxygen concentration pure Al@sub 2@O@sub 3@ films were obtained. A low cost high deposition rate method for depositing crystalline alumina films will be presented.

4:00pm **TF-ThA7 Influence of the Growth Conditions of AlN Films by Laser Ablation**, ***A. Basillais***, *C. Boulmer-Leborgne,* GREMI, France; *J. Perriere,* GPS, France

The pulsed laser ablation of targets in vacuum or in a reactive ambient gas (especially for oxide layer) is a very popular method for growing thin films with complex compositions and various properties. But the reliability of the pulsed laser deposition technique needs a wider understanding of thin film growth for nitride films. In this study we report AlN thin film growth by pulsed laser ablation of Al target in N2 reactive ambient gas compared to laser ablation of AlN target in vacuum or N2 gas. An approach of AlN film grown on Si(100) and Al2O3 substrates is studied. The best experimental conditions are defined in relation with film quality deduced from surface analysis (RBS, NRA, XPS, XRD, MEB). The influence of process parameters such as nature of the target, laser energy density and nitrogen partial pressure on the composition, chemical nature and structure of the films has been investigated. The main problem in AlN film growth was the oxygen incorporation. The origin of this contamination and the mechanisms of incorporation were studied, and the crucial parameter was found to be the residual pressure during ablation. Due to the difference in chemical reactivity between O and N, it is necessary to increase the density of atomic nitrogen to obtain pure AlN films. Thus, a RF discharge device was added allowing a better nitrogen molecule dissociation. Finally the hexagonal AlN phase can be formed in the laser deposited films. Highly textured films presenting epitaxial relationships with (001) Al2O3 substrates can be grown with only 5% oxygen contamination. The plasma plume investigation by emission spectroscopy allows the reactive species kinetics study for AlN growth. A secondary discharge device is mounted on the substrate to study the dark zone where there is no more plasma plume emission.

4:20pm **TF-ThA8 Low Temperature and Plasma Damage Free Deposition of Silicon Dioxide on Novel Film Deposition Method Called a Radical Shower-CVD (RS-CVD)**, ***A. Kumagai***, *K. Ishibashi, X. Ge, M. Tanaka, H. Nogami, O. Okada,* Anelva Corporation, Japan

A novel film deposition method called a Radical Shower-CVD (RS-CVD) has been developed for high quality gate-oxide film formation on low temperature Poly-Si TFT-LCD fabrication. RS-CVD has the advantages of both conventional plasma enhanced-CVD and remote plasma-CVD without

having their disadvantages and is characterized by plasma damage free deposition on a large area substrate at a low temperature of about 300°C. As a silicon dioxide film is deposited on the substrate through the diffusion of SiO@sub2@ formed by the reaction of oxygen radical with SiH@sub4@ in the gas phase, oxygen radical quantity, distance from gas injection to substrate, and deposition pressure are very important as a control factor of gas phase reaction. Dependencies of film quality on those factors are investigated to confirm the optimization methods in RS-CVD film deposition process. The calculation of the gas phase elementally reaction have been performed to discussion the formation mechanisms of SiO@sub2@. As a result of this study, it was confirmed to be important in suppressing the contamination of the elements including the OH bonding groups in the films during the deposition itself. The oxygen radical quantity, the distance from gas injection to substrate, and the deposition pressure were useful to control the speed of overall reaction and the elements arriving at the substrate. It was important in the film properties to control the residence time of gases until they reach the substrate by adjusting those factors mutually.

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