Advanced Surface Engineering
Room: Cimmaron - Session SE+PS-MoA

Pulsed Plasmas in Surface Engineering
Moderator: J. Patscheider, EMPA, Switzerland

2:00pm **SE+PS-MoA1 2010 AVS Peter Mark Award Lecture - High Power Impulse Magnetron Sputtering (HIPIMS) - Fundamentals and Applications**, ***A.P. Ehiasarian****, Sheffield Hallam University, UK **INVITED**

High power impulse magnetron sputtering (HIPIMS) is one of the youngest magnetron sputtering technologies. It provides new parameter space and new level of control of deposition parameters which are unattainable by conventional sputtering or cathodic arc evaporation technologies.

HIPIMS utilises a short (impulse) gas discharge with duration of ~100 µs and duty cycles of <1% allowing it to access high peak power densities of 3000 Wcm^{-2} at voltages of several hundred volts and current density of 1-4 Acm^{-2}. Within each HIPIMS pulse the discharge is ignited through a hot electron ionisation wave and then develops into a cold metal plasma. The properties of the target material such as sputter yield, secondary electron emission coefficient, atomic mass and ionisation potential determine the power dissipated in the discharge, the density of plasma and the transport from the target to the substrate. The lifetime of both gas and metal ions spans over several milliseconds after the pulse often extending to the next pulse, thus creating a constant bombardment of ions at the substrate.

The degree of metal ionisation is controlled by the peak power density dissipated at the target and reaches 50% for Ti and 70% for Ta. The high metal ionization fraction of the HIPIMS technology has been utilised in applications for metalizing high-aspect vias with depth-to-width ratio of 30:1 achieving 10% bottom coverage for Ti, Ta and Cu films. The technology has been upscaled to a production cycle for through-silicon via (TSV) interconnects on 200 mm wafers.

HIPIMS pretreatment can implant metals and rare earths in substrates whilst maintaining the crystalline character, promoting local epitaxial growth over large lateral areas and excellent adhesion. This enables the introduction of oxidation- and corrosion- barriers at the coating-substrate interface.

Reactive sputtering in Ar and N_2 atmosphere in HIPIMS are characterised with a strong dissociation of the nitrogen molecule. In conditions of high power density, the N^{1+} : N_2^+ ratio and Ti^{1+}:Ti^0 ratio can exceed 1 thus promoting a fully dense intercolumnar boundaries in TiN films and increase their hardness. A preferred growth orientation of (200) is observed even without substrate biasing.

Nanoscale multilayer (superlattice) structured coatings based on CrAlYN/CrN have been grown with very low waviness and strongly improved density. These coatings provide excellent oxidation resistance and reduced fatigue deficit of aerospace turbine blades.

Nanocomposite coatings based on CrAlSiN were also deposited by HIPIMS for applications in high-temperature oxidation protection. Closer packing and reduced misorientation of nanocrystals as well as increased size of nanoclusters in which they are grouped are crucial mechanisms crucial in enhancing the film hardness.

The technology is finding new applications in the deposition of $Cu(InGa)Se_2$ in industrial photovoltaic cell coaters where a 3% improvement in efficiency over conventional sputtering has been achieved.

2:40pm **SE+PS-MoA3 Influence of Plasma Conditions on the Properties of Hafnium and Titanium Films Deposited using HIPIMS**, ***A.N. Reed***, Air Force Research Laboratory, *M.A. Lange*, Air Force Research Laboratory/Universal Technology Corp., *J.G. Jones, C. Muratore, J.J. Gengler, A.A. Voevodin*, Air Force Research Laboratory

The orientation of a film can have a significant effect on its physical properties, for example the thermal conductivity of hexagonal materials. There has been a significant amount of work in the area of controlling the microstructure of films using deposition parameters. High power impulse magnetron sputtering, HIPIMS, is a PVD technique that produces a sputtered flux with a higher ion content than conventional DC magnetron sputtering. The ionization fraction of material upon the substrate permits some control of the film characteristics. In this study films were grown at pressures ranging from 5-30 mTorr, and pulse duration from 20-200µs. The resulting films exhibited pressure dependent deposition rates as well as changing crystalline structure based on pulse duration. Energy resolved mass spectrometry and optical emission spectroscopy allowed correlation of ion energy distributions to deposition rates. Material characterization techniques, such as XRD, XPS, and SEM, have been used to correlate film structure to processing conditions for hafnium, titanium, and their nitrides. Time-domain thermal reflectance was used to measure the films' thermal conductivities. Differences in these values were related to the film microstructure.

3:40pm **SE+PS-MoA6 High Power Impulse Magnetron Sputtering for the Growth of Functional Amorphous and Nanocrystalline Films**, ***K. Sarakinos***, *A. Aijaz, M. Samuelsson, U. Issaksson, U. Helmersson*, Linköping University, Sweden **INVITED**

Growth of films by condensation from the vapor phase frequently proceeds far from thermodynamic equilibrium giving rise to metastable configurations with unique attributes which are largely determined by the energy of the film forming species. One way of transferring energy to the growing film is via bombardment by ionized species which are present in plasma assisted physical vapor deposition (PVD) techniques. High power impulse magnetron sputtering (HiPIMS) is a novel plasma assisted PVD technique in which large fluxes of energetic ions are made available at the growing film. This is achieved by applying the power to the target in short unipolar pulses of low duty cycle (<10%) and frequency (<10 kHz). This mode of operation results in the generation of ultra dense plasmas (electron densities 10^{18}-10^{19} m^{-3}) and a subsequent high degree of ionization for both gas atoms and sputtered material. HiPIMS has been extensively used for the deposition of polycrystalline elemental and compounds films facilitating control over their microstructure, phase composition, optical, mechanical and electrical properties. In the present talk the use of HiPIMS for the deposition of amorphous and nanocrystalline carbon and metal nitride based films is demonstrated. Discharges are generated using a variety of experimental parameters with respect to the pulse width, pulsing frequency, composition and pressure of the gas atmosphere. Time-averaged and time-resolved plasma diagnostics reveal that the variation of the above mentioned process parameters allows for control over the flux, the energy and the nature of the bombarding ionized species. Growth of films at those conditions enables to tune their bonding properties, their microstructure and their crystallinity and through this tailor important functional attributes such as their mechanical performance and high temperature stability.

4:20pm **SE+PS-MoA8 New Development in Modulated Pulse Power Sputtering of Aluminum Oxide, Aluminum Nitride and Carbon Films**, ***R. Chistyakov***, Zond Inc, *B. Abraham*, Zpulser LLC

Modulated pulse power (MPP) sputtering is a versatile high power pulse magnetron sputtering technique in which there can be multiple voltage steps within a pulse. In this study, multiple voltage steps have high amplitude voltage oscillations. It was found that at certain level of voltage oscillations amplitude and frequency it is possible to sustain near arc free discharge in reactive gas environment. A special plasma generator with adjustable voltage oscillations amplitude and frequency was developed. The maximum output voltage is 1400 V. Aluminum oxide and aluminum nitride films have been reactively deposited with new approach in near arc free mode. The deposition rate, film structure, orientation, and mechanical properties were analyzed and measured, and the results of the film property measurements will be presented. Carbon films were sputtered with high average and peak power. It was found that with particular voltage pulse shapes there is no cones formation on the target surface during the deposition

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* Peter Mark Memorial Award Winner

Authors Index

Bold page numbers indicate the presenter

— A —

Abraham, B.: SE+PS-MoA8, 1
Aijaz, A.: SE+PS-MoA6, 1

— C —

Chistyakov, R.: SE+PS-MoA8, **1**

— E —

Ehiasarian, A.P.: SE+PS-MoA1, **1**

— G —

Gengler, J.J.: SE+PS-MoA3, 1

— H —

Helmersson, U.: SE+PS-MoA6, 1

— I —

Issaksson, U.: SE+PS-MoA6, 1

— J —

Jones, J.G.: SE+PS-MoA3, 1

— L —

Lange, M.A.: SE+PS-MoA3, 1

— M —

Muratore, C.: SE+PS-MoA3, 1

— R —

Reed, A.N.: SE+PS-MoA3, **1**

— S —

Samuelsson, M.: SE+PS-MoA6, 1
Sarakinos, K.: SE+PS-MoA6, **1**

— V —

Voevodin, A.A.: SE+PS-MoA3, 1