New Horizons in Coatings and Thin Films
Room San Diego - Session F2-3

HiPIMS, Pulsed Plasmas and Energetic Deposition

Moderators: Tiberiu Minea, Université Paris-Sud, Jon Tomas Gudmundsson, University of Iceland

8:00am **F2-3-1 Ultra-thick CrN/AlN Superlattice Coatings Deposited by a Combination of Plasma Enhanced Magnetron Sputtering and High Power Impulse Magnetron Sputtering**, ***Jianliang Lin***, *R Wei,* Southwest Research Institute, USA

Plasma enhanced magnetron sputtering (PEMS) is an advanced version of conventional magnetron sputtering by generating a global plasma, in addition to the magnetron plasma, in the entire deposition system using hot filament thermionic emission to enhance the ionization and bombardment. As one version of high power impulse magnetron sputtering (HiPIMS) technique, deep oscillation magnetron sputtering (DOMS) generates large oscillation high power pulses to achieve a high ionization fraction of target species for reactive HiPIMS sputtering. Both DOMS and PEMS aim at utilizing a highly ionized plasma to improve the structure and properties of the coatings. In this paper, ultra-thick CrN/AlN superlattice coatings (20 µm) were deposited on steel substrates by reactive sputtering using a combination of PEMS and DOMS techniques. These coatings were deposited at different PEMS plasma discharge currents (0 to 4 A) which represent different levels of low energy ion bombardment. The bilayer thickness of the nanolayers was controlled in the range of 4 to 7 nm. The microstructure of the coatings gradually changes from long columnar grains to extremely dense structure with an increase in the PEMS discharge current. These thick CrN/AlN coatings show very high hardness and excellent adhesion . The high temperature wear resistance of selected coatings was measured using a high temperature pin-on-disc tribometer in the ambient air from 600 °C to 900 °C. The solid particle erosion resistance of these ultra-thick CrN/AlN coating was evaluated and compared with other thick hard coatings, e.g. CrN, TiN, TiSiCN, etc., using an air jet sand erosion tester.

8:20am **F2-3-2 Deposition of DLC Coatings by HIPIMS to Arc Mixed Mode**, ***Holger Gerdes***, *R Bandorf, J Rösler, M Vergöhl, G Braeuer,* Fraunhofer Institute for Surface Engineering and Thin Films IST, Germany

The deposition of hard carbon or diamond-like carbon (DLC) films is still of high interest, especially in combination with high power impulse magnetron sputtering (HIPMS). In automotive applications, the use of hydrogen-free, so-called ta-C coatings is well established. The ta-C are mainly deposited by arc processes, suffering increased roughness due to high energetic macro-particles. Introducing a HIPIMS to Arc mixed mode by M. Lattemann et al. opened the scene for combining the high density sputtering of smooth coatings with the high energy processing by arc. In 2015 Ganesan et al. reported on the deposition of ta-C films with high sp3-content from a 3 inch target.

This presentation will show an approach for upscaling a HIPIMS-Arc mixed mode to an industrial sized cathode (0.5 m). The process parameters and basic aspects on how to design a pulse for transitioning into an arc will be discussed. The investigations by optical emission spectroscopy (OES) showed clearly an indication on generating carbon-ions. The Vickers hardness of prepared films were measured and showed first results with a hardness of up to 3500 HV.

8:40am **F2-3-3 Performance Improvements of Tungsten and Zinc Doped Indium Oxide Thin Film Transistor by Fluorine Based Mixing Plasma Treatment with a High-K Gate Dielectric**, ***Yu-Chuan Chiu***, *P Liu, D Ruan, M Yu, K Gan, T Chien, Y Chen, P Kuo, S Sze,* National Chiao Tung University, Taiwan

This study investigates the physical analysis and electrical characteristics for amorphous tungsten and zinc doped indium oxide thin film transistor (a-InWZnO TFT) with a high-k gate insulator, which is applied by fluorine based mixing plasma treatment. Compared with the traditional InGaZnO TFT, the tungsten dopant was proposed as excellent carrier suppressor, which may improve the reliability significantly. However, the carrier mobility was also slightly inhibited by the dopant. In order to achieve good stability and high carrier concentration simultaneously, the fluorine based mixing plasma treatment was introduced in the device process. The fluorine plasma is used as a method to passivate carrier traps within the channel or at the channel/dielectric interface, which can effectively improve the channel conductivity. In addition to that, the oxygen vacancies are also increased in the back channel region by only fluorine plasma treatment. This may result that a extreme high carrier mobility at the back channel surface which can't be control by a reasonable gate bias. With a mixing plasma process, this phenomenon can be suppressed. Furthermore, a high-k gate insulator is applied for improving the ability of gate control. In this report, the devices with $CF_4 + N_2O$ plasma treatment show a high field-effect mobility of $\sim$ 25 cm^2/V.s, a high On/Off current ratio of $\sim 6\times10^6$ and a small subthreshold swing of 0.1 V/decade for a best interface quality for all samples. This research proposes that the fluorine based mixing plasma treatment may be an effective approach to improve the interface quality for novel metal oxide TFT fabrication.

9:00am **F2-3-4 Effect Of Craters Formation On Deep Hardening Under Pulsed Electron Beam Treatment**, ***Thierry Grosdidier***, LABoratoied'ExcellenceDesign des Alliages Métalliques pour Allègement de Structures (Labex DAMAS), France; *Y Samih,* Laboratoire d'Etude des Microstructures et de Mécanique des Matériaux (LEM3), France; *C Dong,* Key Laboratory of Materials Modification, Dalian University of Technology, China

Techniques like the intense pulsed electron beams (IPEB) or intense pulsed ion beams (IPIB) generally induce surface melting, evaporation followed by rapid solidification and quenching which are accompanied by the formation of stress waves. As a result, surface/near surface properties such as corrosion and wear resistances can be improved while the generation of structural defects such as vacancies and dislocation loops also affect the depth of the samples and can lead to sub-surface hardening. While the improved wear resistance and corrosion resistance have been attributed to several complementary factors (surface hardening, nanostructure formation) the mechanisms responsible for the deep hardening are much less understood.

In the case of IPEB, the large pulse duration (about 800 ns under High Current Pulsed Electron Beam) and, accordingly, the low rate of energy input, does not provide with the formation of the dynamic stress wave and the increase in dislocation density was entirely provided by the action of the quasi-static thermal stresses. In their modelling approach, Quin et al. [1] suggested that the subsurface initial melting that is associated with the specific energy distribution of the electron beam could create an additional source of plastic deformation via the recoil impulses that are generated as a consequence of crater eruptions.

To the authors knowledge however, there is no experimental work that has been carried so far to undoubtedly verify the electiveness of the formation of craters on hardening the surface and subsurface of HCPEB treated samples. The aim of the present paper is to investigate experimentally the contribution of the potential crater bursts on modifying the deep hardening phenomena. To this end, the HCPEB technique has been applied under similar processing conditions on two stainless steels of very close chemistry but having different potential for crater formation.

[1] Qin, Y ; Dong, C ; Song, ZF; Hao, SZ; Me XX; Li, JA; Wang, XG; Zou, JX; Grosdidier, T, JOURNAL OF VACUUM SCIENCE & TECHNOLOGY A, 27, Pages: 430-435, MAY 2009

9:20am **F2-3-5 Mechanical Property Evaluation of ZrCN Films Deposited by a Hybrid Superimposed High Power Impulse- Middle Frequency Sputtering System**, *Q Tang, Y Wu,* National Taipei University of Technology, Taiwan; ***Jyh-Wei Lee***, Ming Chi University of Technology, Taiwan

High power impulse magnetron sputtering (HiPIMS) is a relatively new physical vapor deposition technology, which is characterized by its ultra-high peak current, peak power density and high-density plasma to achieve unique thin film mechanical properties, such as high hardness, good adhesion and good wear resistance. Recently, a superimposed HiPIMS-middle frequency (MF) power system has been proved to increase the deposition rate of HiPIMS technique effectively. In this study, a superimposed HiPIMS-MF power system was used to deposit the ZrCN films with different carbon content on hardened tool steel disks and silicon wafer substrates. The phase of each coating was studied by means of the X-ray diffractometer. The microstructures of thin films were examined by a field-emission scanning electron microscopy. Atomic force microscopy was used to characterize the surface morphology and roughness. The nanoindentation and scratch tests were used to evaluate the hardness and adhesion properties of thin films, respectively. The pin-on-disk wear test was employed to study the tribological property of coating. Effects of carbon content on the microstructure, mechanical and tribological properties of ZrCN coatings were further discussed in this work.

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