Monday, May 11

4:30 p.m.-8:00 p.m. Poster-1 Tribological Properties of CrAlSiN Coating with Post-Deposition Heat Treatment

W.Y. Ho and C.W. Chen, MingDao University, ChangHua, Taiwan; and W.Y. Ho, National Pingtung University, Pingtung, Taiwan

Researches of (Cr, Al, Si)N coatings have confirmed that these coatings possess the excellent properties of the superhardness (~40 GPa) and thermal stability. The property changes of these hard coatings by a post-deposition annealing treatment are discussed in detail. In bulk materials, annealing treatments are well known and powerful practices to adjust their microstructure. However, the significance of heat treatments to optimize properties of (Cr, Al, Si)N hard coating for specific applications is new so far. In this study, a CrAlSiN coating was synthesized by cathodic arc deposition with Cr and Al88Si12 dual rotating cathodes. The post-deposition heat treatment was then applied to the as-deposited coatings. The microstructural changes of the coating before and after heat treatment was compared by X-ray photoelectron spectroscope, X-ray diffractometer and scanning electron microscopy. The wear resistance of the coatings was studied by the ball-on-disc wear test without any lubricant. Field test of the forming dies with CrAlSiN coating with and without heat treatment was carried out. Results show that the post-deposition heat treatment in N_2 gas may play a protective role to modify the structure and increase the tribological resistance of the CrAlSiN coating.

Monday, May 11

4:30 p.m.-8:00 p.m. Poster-3 Particle-in-Cell Monte Carlo Analysis of Inhomogeneities in Large Area Magnetron Discharges

M. Siemers, A. Pflug, and B. Szyszka, Fraunhofer Institute for Surface Engineering and Thin Films IST, Braunschweig, Germany

Due to the increasing demand on productivity and quality of magnetron sputtering coaters, the design of sputter sources with optimized homogeneity has been subject of extensive R&D efforts during the past decade. Substantial progress has been possible within the last few years where the increasing availability of parallel hard- and software architectures has made plasma simulation more applicable in the model based development of industrial plasma technology. With the use of massive parallelization we realized a full featured 3D simulation environment for low temperature plasma discharges based on the Particle-in-Cell Monte-Carlo (PIC-MC) approach. Complex geometries can be defined by a finite-element mesh structure as can be obtained from CAD data with a mesh generator. We present calculations on the erosion homogeneity of planar magnetrons focusing on the so-called ”cross corner effect”, i.e. regions with locally enhanced erosion located close to the target ends. The simulated erosion profile is in good agreement with experimental data obtained from target profilometry. The PIC-MC simulations reveal two mechanisms, high-energy electrons and plasma squeezing, which are mainly responsible for these deviations and which can be understood in the context of the three-dimensional magnetic confinement of the electrons. Furthermore, the total pressure dependency of these effects and their impact on the erosion profile on a substrate is investigated.

Monday, May 11

4:30 p.m.-8:00 p.m. Poster-4 The Latest Soft Electron Technologies

G. Gotzmann, F.H. Roegner, and O. Roeder, Fraunhofer Institute of Electron Beam and Plasma Technology FEP, Dresden, Germany

The Fraunhofer FEP in Dresden is part of the Fraunhofer-Gesellschaft, one of the largest R&D organizations in Europe. Since 1991 the FEP has been developing low-energy electron accelerators for innovative industrial applications: 1. Agriculture: Disinfection of seed products and also foods and animal feeds 2. Packaging: Sterilization of packaging for pharmaceutical products and foods 3. Medical technology: Sterilization of implants and instruments 4. Waste treatment: Deactivation of microbiologically contaminated waste. Seed products such as wheat and corn have traditionally been treated with toxic pesticides to kill any pathogens. An environmentally-friendly and effective alternative is now e-ventus® technology. This technology is being increasingly used in Europe and is being marketed by the EVONTA® Group. The pharmaceutical industry requires technologies for sterilizing a broad spectrum of products. In collaboration with Bosch®, innovative Advance-Beam technology has been developed for in-line sterilization of pharmaceutical packaging. Soft electrons are excellent for sterilizing and functionalizing medical components and instruments. The latest results in this area are presented.

Microbiologically contaminated waste (e.g. waste containing salmonellae, HIV (AIDS) and H5N1 (bird flu)) must be deactivated before disposal. In conjunction with Glatt®, the FEP has developed a process for treating liquid waste containing solid matter. The waste can also be granulated and refined into reusable materials.

Monday, May 11

4:30 p.m.-8:00 p.m. Poster-5 Cr-Si-N Coating for Aerospace Applications

E. Bousser, M. Benkahoul, M. Azzi, L. Martinu, and J.E. Klemberg-Sapieha, École Polytechnique de Montréal, Montréal, Canada

Erosion by solid particle impact is known to cause severe damage to critical components in aircraft engines. In order to find coating system solutions to this problem, we have undertaken a collaborative project with industrial partners to evaluate different functional coatings that could offer enhanced erosion resistance. While CrN coatings have not proved to be excellent erosion resistant coatings, they do offer excellent protection against corrosion. Therefore, in this work we have studied the Cr-Si-N coating system deposited on AISI SS410 substrates. We first present the material development phase, during which we deposited Cr-Si-N coatings with increasing silicon content on c-Si substrates. Then, following interface engineering, these materials were deposited on stainless steel at greater thicknesses. It was found that the addition of Si during deposition affects coating preferred orientation which in turn significantly influences mechanical properties at the microscopic level. Also, nitriding conditions were found to have a very strong impact on the corrosion resistance and adhesion. The pin-on-disk wear resistance was then evaluated and the best performance was obtained for the coating containing 2.3 at.% of Si with a wear rate 500 times smaller than that of the substrate. Finally, Solid particle erosion (SPE) testing was conducted according to the ASTM G76 standard with Al_2O_3 particles with an average diameter of 50 μm, a mean velocity of 70 m/s and an incident angle of 90°. The minimum erosion rate was found for Cr-Si-N with CrSi = 11.6 at.%. It is one order of magnitude lower than that of pure CrN and 20 times lower than that of the substrate. This high SPE resistance of the coating is attributed to an enhanced micro-hardness and an increased resistance to plastic deformation due to a dense (200) preferred orientation.

Monday, May 11

4:30 p.m.-8:00 p.m. Poster-6 Laser-Based Sensor for Real Time Sputter Monitoring and End Point Detection in Ion Beam Etch Systems

A. Yalin and L. Tao, Colorado State University, Fort Collins, CO; and N. Yamamoto, Kyushu University, Fukuoka, Japan

Real time *in situ* monitoring of the concentration of sputtered particles would provide a powerful tool for process control in ion beam etch systems, including end point monitoring. In this contribution we present a laser based sputter sensor that uses the continuous-wave cavity ring-down spectroscopy (cw-CRDS) technique. Cw-CRDS is a laser-based absorption diagnostic that provides ultra-high sensitivity by housing the measurement volume within a high-finesse optical cavity (placed within the vacuum chamber). The demonstrated system is based on detection of sputtered manganese atoms using a compact diode laser in the vicinity of 403.07 nm. The laser sensor is fully fiber coupled allowing integration to a variety of vacuum chambers and sputtering configurations. Measurements from a manganese-iron target are presented. End-point detection is demonstrated by monitoring the time dependence of manganese concentration for a multilayer target comprised of alternating manganese layers. Detection limits are shown to be adequate for today's commercial ion beam sputter systems.

Monday, May 11

4:30 p.m.-8:00 p.m. Poster-7 Study on Surface Modification of Polycarbonate Polymer Plastics by Low Energy Ion Beam

Y. Yan, J. Wu, G. Zhang, Y. Wang, and P. Wen, Beijing Institute of Aeronautical Materials, Beijing, China

Ar/Oxygen ion beam generated in Kaufman ion beam source with low energy was employed for surface modification of Polycarbonate (PC) aimed at improvement of its surface statement. The water contact angle of modified surfaces was measured and surface composition as well as surface roughness were analyzed by X-photoelectron spectroscopy and atomic force microscopy. The results showed that the hydrophilicity of PC was significantly improved after modification because ion beam bombardment resulted in a large variety of reactive groups and then increased the oxygen content at the surface of PC rapidly. Surface roughness was also changed after modification due to ion beam etching effect. The rigidity, chemistry stability properties of the plastics were improved. And the optical property was changed slightly. The modification mechanism is discussed.

Monday, May 11

4:30 p.m.- 8:00 p.m. Poster-8 A Comparison of Deposition Techniques for High-End Optical Coatings

P. Biedermann, S. Wuethrich, and A. Jaunzens, Evatec Ltd., Flums, Switzerland

With its inherent flexibility, conventional vacuum evaporation is still the mainstay for commercial production of optical thin films. However, at relatively low coating flux energies of 1eV or less, there are limitations to the refractive index, optical and mechanical stability of the films produced. A number of enhanced evaporation techniques with higher flux energies, coating densities and improved optical indices have also now found widespread where enhanced film properties are specified. Most recently, sputtering techniques have now shown themselves to be viable alternatives for mass production with the development of new sophisticated optical and plasma emission monitoring techniques. Reactive magnetron sputtering is now able to produce some of the highest performance optical films available with no spectral shift at increased temperature or humidity. However, the optical engineer needs to consider a number of factors in choosing a viable deposition technique for any particular application. New data from a number of evaporation and sputter techniques will be presented including a discussion on the relationship between film properties and microstructure.

Monday, May 11

4:30 p.m.- 8:00 p.m. Poster-9 Study of Structure Densification in TiO2 Coatings Prepared by Magnetron Sputtering Under Low Pressure of Oxygen Plasma Discharge

J. Domaradzki, D. Kaczmarek, and E.L. Prociow, Wroclaw University of Technology, Wroclaw, Poland; and Z.J. Radzimski, Silicon Quest International, Reno, NV

It is well known that the structure evolution of thin films prepared by reactive magnetron sputtering is strictly dependent on the particle energy at the film nucleation site. The energy could be changed typically by: (1) additional heating of the substrates, (2) decrease in plasma pressure, (3) increase in the temperature of the sputtered target surface (hot target) and (4) increase the sputtering power. Present work presents results of studies on structural and optical properties of the TiO_2 thin films prepared by two methods: Low Pressure Hot Target Magnetron Sputtering (LPHTRS) and High Energy Reactive Magnetron Sputtering (HERMS). Both these methods allow adjusting the process energy using all four options mentioned above. In both processes oxide thin films are deposited from metallic targets using oxygen gas only instead of the usually used mixture of Ar-O_2. Additionally, in HERMS, an increased amplitude of unipolar pulses powering the magnetron has been applied. It is shown that all prepared coatings were stoichiometric and by changing only the discharge voltage it is possible to influence the resulting structural phase and optical properties of prepared thin films. TiO_2 thin films prepared using LPHTRS had anatase structure with refraction index n=2.1 (at 500 nm) whereas HERMS allows obtaining high temperature stable rutile structure with n=2.52 (at 500 nm), i.e. equal to the n value reported for the monolithic rutile. It is also shown that enhanced kinetic energy in HERMS caused higher degree of densification of the coatings and a change in the type of stress from compressive to tensile.

Monday, May 11

4:30 p.m.- 8:00 p.m. Poster-10 The Design and Development of an LPCVD Reactor for the Growth of 3C-SiC on Si

M. Orthner, L. Rieth, and F. Solzbacher, University of Utah, Salt Lake City, UT

A low-pressure chemical vapor deposition (LPCVD) reactor has been developed for the growth of beta-phase silicon carbide (3C-SiC) thin films on silicon. To our knowledge, this is the first LPCVD system that couples, by radiation, a resistive graphite heater with silicon substrates that are rotated from below. The heaters electrical, thermal, and mechanical properties were modeled and optimized using finite element analysis. The final design used a 6.5 inch (diameter) circular graphite serpentine heater with two individual current paths. Empirical measurements of substrate temperature agree well with FEA results and were made by melting a group of pure metals in vacuum. Thermal experiments when compared to numerical simulations are in good agreement, and demonstrate the system is capable of temperatures in excess of 1500˚C with a uniformity of < ±10˚C across the silicon substrates. Initial growth runs were performed with precursors: silane, propane, and hydrogen. X-Ray Diffraction (XRD) analysis found the microstructure of film was 3C-SiC with the observation of a reflection at 41.4° (θ/2θ).

Monday, May 11

4:30 p.m.- 8:00 p.m. Poster-13 Optical Emission Spectroscopy of Ni, Cr, and NiCr 80/20 for DC and High Power Impulse Magnetron Sputtering (HiPIMS)

H. Gerdes, J. Wellhausen, R. Bandorf, and G. Braeuer, Fraunhofer Institute for Surface Engineering and Thin Films IST, Braunschweig, Germany

In technical applications, applied forces are often measured by polymer strain gauges. Unfortunately, those strain gauges are also highly sensitive to humidity and temperature resulting in creep and swelling. By direct application of the strain gauges onto the surface of the workpiece by physical vapour deposition process (PVD) this negative influence is avoided. As typical material for a stress sensing thin film layer, NiCr is well established. Since the sensing properties of these layers are influenced by the plasma properties, e.g. the induced power or the PVD process itself (DC or HiPIMS), using High Power Impulse Magnetron Sputtering HiPIMS, the induced peak power and current is significantly increased and therefore the material properties are also modified. For a better understanding of the influence of the process used on the plasma properties, optical emission spectroscopy was used for investigation. In this paper the influence of pulse length and charge voltage of the pulse unit on the resulting plasma was investigated. As reference also OES spectra from DC processes obtaining a comparable average power are used.

Monday, May 11

4:30 p.m.- 8:00 p.m. Poster-14 Decorative Coating Deposition by PVD

J. Esparza, R. Rodriguez, J.A. Garcia, and M. Rico, Asociacion de la Industria Navarra, Pamplona, Spain

The development of the Physical Vapor Deposition (PVD) technique has traditionally been linked to machine tool applications. In the last decades, researchers have been working in several new applications for PVD coatings such as photovoltaic technology, medical applications or decorative coatings. The versatility of the PVD technique provides a wide range of colors and optical effects that could be very interesting in order to increase the added value of some specific products. The objective of this study is to deposit different PVD decorative coatings on several substrates such as tiles, metals, glass or even polymers. In addition, the characterization of the mechanical properties of this new coatings has been performed. The results of three research lines are presented: The first study covers the simulation of a specific color (nickel) on brass substrate, the control of the shade of the coating depends on several parameters such as temperature, pressure, targets, bias and intensity. In the second research line, several colors have been obtained by the deposition of titanium oxides, the color depends on the thickness of the oxide layer. In the last research line, the result of the deposition of metallic and ceramic PVD coatings on different substrates is presented.

Monday, May 11

4:30 p.m.- 8:00 p.m. Poster-15 Research of Electrical, Optical and Structural Characteristics of Ga-Doped ZnO Coatings Deposited by Magnetron Sputtering on a Polymeric Substrate

M. Misels-Piesins, E. Machevski, I. Ashmanis, and V. Kozlov, Sidrabe, Inc., Riga, Latvia (Presented by E. Yadin, Sidrabe, Inc., Riga, Latvia)

While Al-doped ZnO films on glass have been recently brought into production as a low-cost TCO for silicon solar cells, they are not applicable to plastic substrates due to elevated deposition temperatures. A promising low-cost TCO for flexible substrates is Ga-doped ZnO (GZO). The electrical properties of this material are highly dependent on the process parameters, therefore, it needs thorough investigation and optimization of the deposition technology. In this work, smooth GZO films were deposited from ceramic targets on PET substrates by DC and MF sputtering in a roll-to-roll coater. Influence of working pressure, oxygen, hydrogen, sputtering power, substrate temperature, magnet system configuration, silicon dioxide buffer layer, substrate angle and electrical shielding of charged particles were investigated. Depositions at different parameters were performed without interrupting magnetron operation to ensure repeatability. PET substrate was substituted with glass to evaluate characteristics before and after thermal annealing in oxygen-free ambient. Statically deposited samples indicated a strong tendency to form poorly conducting regions directly above the erosion zones. Within the optimal process window, a typical resistivity of 2mOhm−cm and optical transmittance of up to 85% in the visible spectra was repeatedly achieved.

Monday, May 11

4:30 p.m.- 8:00 p.m. Poster-16 The Tribological Characteristic of TiN, TiC, TiN/TiC Films Prepared by Reactive Pulse Arc Evaporation Technique

D.M. Devia Narvaez, Universidad Nacional de Columbia, Manizales, Columbia; and J. Restrepo, A. Ruden Muñoz, J.M. Gonzalez Carmona, F. Sequeda Osorio, Universidad del Valle, Cali, Columbia

Titanium nitride (TiN), titanium carbide (TiC) thin films and TiN/TiC multilayers have been deposited on AISI 304 steel substrates by PAPVD - Reactive Pulsed Arc method and characterized from the structural, mechanical and tribological point of view . The structural characterization of the coatings was performed by XRD showing a preferential orientation in the (111) difraction peak, which is characteristic of the FCC phase in this kind of coatings. Tribological behavior was investigated using Ball on Disc technique (Nanovea) with an Al_2O_3 ball, 10 cm/s speed, distance 100 m and 1N load. The average COF was measured, showing mean values of 0.64 for TiN and 0.53 TiN/TiC. A dynamic wear curve was performed for each coating, observing the evolution and wear mechanism as a function of the distance, using optical stereoscopic techniques.

Monday, May 11

4:30 p.m.- 8:00 p.m. Poster-17 The Effect of Deposition Temperature on Tribological Behaviour of Ti-Al-N Coatings Deposited by Magnetron Co-Sputtering Technique

M. Cano, J. Restrepo, A. Ruden, and F. Sequeda Osorio, Universidad del Valle, Cali, Columbia; and J.M. Meza, Universidad Pontifica Bolivariana, Medellin, Columbia

The Ti-Al-N coatings have been deposited on H-13 tool steel substrates and silicon wafers by DC Magnetron co-sputtering at different temperatures (50°C, 150 °C and 200 °C), in order to study the influence of this parameter on the tribological behavior. For all coatings a crystalline NaCl structure was obtained which is typical for titanium based nitrides. For all coatings a strong (200) texture relative to the (111) orientation was found. Profilometry measurements showed a decrease of average surface roughness (50 to 28 Amstrongs) as deposition temperature was varied from 50 °C to 200 °C and nanoindentation measurements (Nanovea Instrument) indicated a maximum hardness of 23Gpa. Tribological measurements were made using a room temperature tribometer (pin/ball on disk, CSEM Instrument) allowing measurement of the dependency COF on cycles (sliding distance). The evolution of COF with the cycles was measured under different conditions: sliding speed (10 and 20 cm/s), load (1N and 3N) and wear rate of the ball (WC, $100Cr_6$ and Al_2O_3) and coating. The wear tracks were examined by optical methods and SEM, in order to identify wear evolution and corresponding mechanisms (mild wear, fracture or delamination). The results showed that the load and sliding speed produces changes in the COF and wear mechanism. In coatings deposited at 150 °C and using testing WC balls and low speed (10cm/s), the COF was 0.85 and the debris is present in all wear track. When increased speed (20cm/s), the COF decreases (0.49) and debris was produced just at the last 1000 cycles and the wear rate decreased 50%. Similar behavior was observed when using other counterparts, balls materials.

Monday, May 11

4:30 p.m.- 8:00 p.m. Poster-18 Tribological Properties of Duplex TiN Coatings Applied on Chrome Based Steels

A. Murcia, Universidad del Valle, Cali, Columbia; S.P. Bruhl, Universidad Tecnologica Nacional, Concepcion de Uruguay, Argentina; A. Neira, North Carolina State University, Raleigh, NC; and F. Sequeda Osorio and A. Ruden, Universidad del Valle, Cali, Columbia

Duplex process consisting on plasma nitriding [N_2 + 3H] and Titanium Nitride- TiN PVD coating deposited by Magnetron Sputtering, was conducted on AISI 420 substrates, showing to be effective in reducing friction coefficient (COF) and wear rate and increasing surface hardness. Chrome based steels are widely used due to its corrosion resistance, high tensile strength, moderate corrosion resistance and the high load-carrying capability. Tribological properties were determined by ball-on-disc test, while the wear mechanism against an alumina ball was assessed by analyzing the wear debris using SEM. Results showed a 20-25% decrease in COF and wear rate as compared with steel substrates with no duplex treatment. Micro hardness analysis showed an increase in surface hardness of 50%. Low hardness decrease due to indentation depth was also observed through nano-indentation measurements. Using SEM and XRD, the effect of nitrogen inclusion on the crystal structure of the steel was further analyzed as well as the interface between the nitride layer and the hard coating.

Monday, May 11

4:30 p.m.- 8:00 p.m. Poster-19 Study of Synergistic Effect of Erosion-Corrosion of CrN and TiN Hard Coatings on AISI 1045 Mild Steel

H. Payan, W. Aperador, F. Sequeda Osorio, and A. Ruden, Universidad del Valle, Cali, Columbia

Results of the study of synergistic effect of corrosion-erosion of CrN and TiN hard coatings deposited by PVD - Magnetron Sputtering on AISI 1045 mild steel and a comparison with a stainless steel AISI 316 and a mild steel AISI 1045 with no coating are shown. These behaviors have been investigated by potentiodynamics measurements (Tafel curve) in a solution of 0.5M H_2SO_4 + 3.5% in weight of NaCl and mass loss techniques respectively. Results of electrochemical testing indicate the behavior of CrN and TiN are quite different. For different angles of incidence of corrosion-erosion fluid, it was observed that part of the layer of CrN was stripped from the substrate due to the action distributed by the continuous shocks of the abrasive particles; however the electrochemical behavior shows that CrN was the noblest material in respect to the solution and presents a smaller current density than TiN, indicating better corrosion resistance. This is possibly due to CrO formed on the coating surface of CrN being more protective and corrosion resistant than those of the TiN. This can also explain why CrN has a similar behavior to the stainless steel. Synergistic effect in all the studied materials are presented and discussed.

Monday, May 11

4:30 p.m.-8:00 p.m. Poster-20 Plasma Analysis of a Novel PECVD Process for Corrosion Resistant Interior Coating of Pipelines

S. Lapp and F. Placido, University of the West of Scotland, Paisley, United Kingdom

The main problems of industrial piping are corrosion and erosion/wear of the interior surface. A low-priced and effective coating technology to produce a hard and smooth film without any pinholes would reduce cost of plant construction and maintenance in a wide area of industry. We report on work on characterizing a novel DLC coating technology to reduce corrosion inside of pipelines and improve flow rates of fluids. The pipe itself acts as the vacuum chamber where the molecules of the process gases are decomposed by the ignited pulsed dc plasma inside the pipe. This novel concept allows the interior coating of parts with different dimensions and geometries. Optical emission spectroscopy (OES) is used to analyze the emitted light of the plasma to characterize the plasma condition inside the pipe at different positions along the pipe. The neutral density and ion density of the different process gases can be determined to understand the respective transition for different process conditions. The electrical properties of the plasma such as electron density, ion density and electron energy distribution function (EEDF) were analyzed by a Langmuir Probe plasma diagnostic system. The set up used allowed a spatial and time resolved investigation of the plasma condition along and across the pipe. The presentation contains the analysis of the plasma conditions in pipes of variable size and for different process parameters like power, pressure and gas flow.

Monday, May 11

4:30 p.m.- 8:00 p.m. Poster-21 The Effect of Superfinishing and Plasma-Assisted PVD and CVD Coatings on Rolling Element Bearings Under Lubricant Starvation Conditions

J. Eichler, University of Sheffield, Sheffield, United Kingdom; G. Doll, Timken Research, Canton, OH; A. Leyland and A. Matthews, University of Sheffield, Sheffield, United Kingdom

This is a report on tests carried out using a bespoke high-cycle rolling-contact test facility based on a thrust ball bearing configuration. The test machine is instrumented for temperature, torque, vibration and speed measurement. Following on from previous publications, this report concentrates on rolling contact fatigue behaviour of coated and uncoated counterfaces under boundary lubrication conditions created by inadequate lubrication. The main coatings tested were Cr_2N and WC/aC:H which were deposited by plasma-assisted PVD and hybrid PVD-CVD processes respectively. In addition, the effect of vibratory superfinishing, both in isolation and as a surface pre-treatment, is investigated. Data is presented illustrating the benefits provided by surface modifications under these extreme operating conditions and their ability to delay the onset of catastrophic bearing failure.