**Wednesday, May 13**

**8:30 a.m. T-6 Present Status of Carbon Based Cutting Tool Coatings for Soft Alloy Workpiece Materials**

G.J. van der Kolk, Ionbond Netherlands, Venlo, The Netherlands; and E. Damond, Ionbond France, Chassieu, France

Cutting tool coatings are increasingly optimized for the dominant wear phenomena. For soft metals and alloys like Al-alloys and Ti-alloys adhesive wear is one of the dominant wear mechanisms. Coatings provided for these applications are focusing partly on abrasive wear reduction by having a high hardness, partly on avoiding adhesive wear by working on the surface energies, and avoiding matching with the workpiece materials. The applied coatings range from pure diamond, diamond like carbon (DLC) in many variations, to nitrides and carbo-nitrides. An overview will be presented of the present state-of-the-art coatings. Further, a model will be discussed trying to link the coating engineering to the expected wear mechanisms due to the cutting conditions and work piece material. Special emphasis will be on multilayer coatings produced by unbalanced magnetron technology, mainly based on a load carrying layer of CrN with a top coating of hydrogenated DLC (CrN/a-C:H) and on non-hydrogenated DLC coatings produced by ARC technology (ta-C).

**Wednesday, May 13**

**9:10 a.m. T-13 DLC Base Coating on Plastics as Support for Scratch Resistant Decorative Finishes**

P. Peeters, I. Kolev, J. Landsbergen, R. Tietema, and T. Krug, Hauzer Techno Coating BV, Venlo, The Netherlands

PVD colour coatings are widely spread since the early 1990s due to their high hardness in comparison with galvanic coatings, thus protecting the colour for much longer periods of time then ever achievable with galvanic coatings or lacquers. Because decorative PVD coatings are relatively thin (0.5 micron), their high hardness is only advantageous when deposited on a adequate support layer. For plastics this support is often provided for by a galvanic coating, while for stainless steels it is provided for by a thicker PVD base layer. DLCs can be used as an alternative, since they also exhibit high hardness, and generally have smooth surfaces. If the technology is mastered in the proper manner, these coatings can be produced with relatively low costs and high growth rates. These properties make DLC coatings suitable candidates to serve as a base layer for decorative coatings on relatively soft substrates. The problem related to adhesion between the DLC base coating and the decorative top coating has been mastered, as shown in a SVC presentation of 2008. The process parameters for depositing adequate DLC support layers on plastic substrates will be addressed in the current presentation.

**Wednesday, May 13**

**9:30 a.m. T-14 Adavnced Magnetron Sputter Technique for Deposition of Superhard a-C:H Coatings**

K. Bewilogua, M. Keunecke, H. Thomsen, and R. Wittorf, Fraunhofer Institute for Surface Engineering and Thin Films IST, Braunschweig, Germany; Y. Ivanov, SVS Vacuum Coating Technologies GmbH & Co. KG, Karlstadt, Germany; and T. Zufrass, Systec GmbH & Co. KG, Karlstadt, Germany

Superhard amorphous hydrogenated carbon (a-C:H) coatings were prepared in a large scale batch coater equipped with 4 targets and electromagnetic coils. Coils around each target and an additional coil generating a magnetic field over the chamber volume caused high substrate ion currents. The sputter gas was a mixture of argon and acetylene. To improve the adhesion different interlayer systems, e.g. from chromium or tungsten carbide were used. The a-C:H coating deposition was carried out working with varying parameters of substrate bias (d.c. and pulsed d.c.), acetylene flows and coil currents. The highest hardness values were reproducibly measured with up to 50 GPa. The coatings characterization was done by SIMS and Raman spectroscopy as well as by hardness and wear tests. The hardness clearly depended on the hydrogen contents and the hardest coatings could be prepared at about 10 atom % hydrogen. Reasons for this behavior will be discussed considering the effects of the most essential process parameters. For a fully loaded machine processes suitable to deposit well adhering coatings were developed. To achieve optimum adhesion for components or tools, respectively, different types of interlayers were applied. The addition of HIPIMS steps allowed additional process modifications influencing coating properties, especially the adhesion.

**Wednesday, May 13**

**9:50 a.m. T-15 Influence of Surface Roughness on the Tribological Performance of Superhard Amorphous Carbon Films**

H.-J. Scheibe, A. Leson, and V. Weihnacht, Fraunhofer Institute for Material and Beam Technology IWS, Dresden, Germany

Diamond-like carbon films (DLC) have proven to be excellent low friction and wear protection coatings for components and tools under different tribological conditions. The new generation of hydrogen-free ta-C films (ta-C = tetrahedral bounded amorphous carbon) have extraordinary high wear resistance under extreme abrasive conditions due to their hardness close to crystalline diamond. They possess excellent dry-running and emergency-operating properties at lubrication break down if their surface roughness adapt to the running conditions. Too rough ta-C films are very abrasive and the friction partner can be severely damaged in a short time. Conventional ta-C films deposited by unfiltered arc-deposition mostly are not directly applicable due to their typical high roughness. By using plasma-filtered deposition methods or polishing after deposition ta-C films with sufficiently smooth surface can be obtained. In this investigation, ta-C films are deposited with a pulsed arc deposition process (Laser-Arc) on different substrate materials. The ta-C surface roughness has been modified by three different methods. Firstly a mechanical polishing of the as deposited films, secondly the deposition of a soft running in top layer on the ta-C film and thirdly a new filtering process for ta-C film deposition were applied. The influence of these three methods has been studied by means of tribological testing under the same dry and lubricated friction condition. The results will be discussed and examples of successfully introduced applications of such modified ta-C films will be presented.

**Wednesday, May 13**

### 10:30 a.m. T-16 How Substrate Constraints Affect the Performance of Thin Film Coatings Under Dynamic Impact Loading

L.V. Davies, Caterpillar, Inc., Peoria, IL

*Invited 40 min. Talk*

The study of dynamic impact performance of thin film coatings has largely been focused on the coating alone, using high hardness, highly polished steel to eliminate substrate effects. But in practice, it is vital to study the combined effect of the coating and the substrate (known as the coating system). When selecting engineering steels for coated components a large amount of the decision is based on functionality, manufacturability and cost requirements, and less so on the tribological needs of the system. In sliding motion, this is less of a problem, provided the substrate has sufficient load bearing capability for the coating and operating conditions. However, under dynamic impact, substrate selection becomes much more critical. The cyclic impact loading applied to the coated surface generates energy waves that must be accommodated by the coating system. The substrate must possess a high toughness to absorb the severe macromechanical stress fields from the impacts whilst have sufficient elasticity to accommodate any substrate deformation that may occur under impact. This paper will define impact resistance and provide an example of how engineering functional requirements plus manufacture constraints directly affected the performance of a coated control valve.

**Wednesday, May 13**

### 11:10 a.m. T-17 Erosion, Corrosion and Wear Resistance and Microstructure of Diamond-Like Carbon (DLC) Coatings Prepared Using a Mesh Method

R. Wei, M. Jakab, V. Poenitzsch, and K. Coulter, Southwest Research Institute, San Antonio, TX

In this paper, we present a systematic tribological and microstructural study of diamond-like carbon (DLC) coatings deposited using a newly developed process. This process utilizes a metal mesh to enclose the parts. When a pulsed voltage of a few thousand volts is applied to the mesh, pulsed glow discharge is generated in the mesh to accomplish the deposition. This process does not only result in a high rate deposition of a DLC coating, but it also allows the deposition on non-conductive parts such as polymers and ceramics. Using this method, we deposited DLC and Si-DLC coatings on 1018 steel under various conditions. The microstructure of these coatings was studied using SEM and Raman sectroscopy. Their erosion resistance was evaluated using a micro sand blaster with 50$\mu$m $Al_2O_3$ particles at various back pressures at two incident angles, 30˚ and 90˚. The coating corrosion resistance was evaluated using the polarization test, while the coefficient of friction and sliding wear resistance were studied using a pin-on-disc tribometer. For comparison purposes, a DLC sample was also prepared using the standard plasma immersion ion deposition (PIID) process. It was observed that the DLC deposition rate using the mesh method was over 10 times higher than that using the conventional PIID process. Most coatings showed higher resistance to erosion than uncoated 1018 steel. The coating also exhibited high polarization resistance, up to four orders of magnitude. In addition, all the DLC coated samples showed a coefficient of friction from 0.1-0.12 with negligible mass loss due to wear, in ambient conditions without lubricant. The research results show that this new method may be used for protection of low alloyed steel or low cost materials from wear, corrosion and erosion.

**Wednesday, May 13**

### 11:30 a.m. T-18 Adhesion of ZrCN Decorative PVD Coatings on Nickel Electroplated Substrates: Effect of Stresses

C. Zubizarreta, J.Goikoetxea, J. Barriga, U. Ruiz-Gopegui, and B. Coto, Fundación Tekniker, Eibar, Spain

Although PVD is one of the most powerful technologies for coating, there are characteristics that PVD on its own can not impart in an efficient way because they intrinsically require a coating of a high thickness that can not be cost-effectively applied by PVD. Some of these properties are, for example, the adequate protection of the substrate from corrosion, or the capability to level the surface of the substrate to give a shiny bright appearance. Nowadays this functionality is being applied mostly with approximately 20 microns electroplated nickel. Nevertheless, due to the stresses involved in PVD, the parameters of this process must be carefully selected in order to obtain quality products in terms of adhesion. In this work, nickel plated substrates from four different suppliers have been coated with ZrCN by Cathodic Arc Evaporation. The study of the correlation between the stresses induced by the PVD process and the adherence achieved between the PVD layer and the nickel plated substrates has been carried out. For this purpose, coatings of different thicknesses were applied. Adherence was evaluated and residual stresses were calculated using the Stoney equation after measuring the curvature radius when applying the coating on very thin substrates. On top of that, a preliminary study of the nickel plated substrates has been carried out, characterizing the substrates by means of microstructure, through optical microscopy and SEM, roughness, through AFM, composition, by GDOES, microhardness and residual stresses.

**Wednesday, May 13**

### 11:50 a.m. T-19 ALD-Deposited Nanometer Scale Metal Oxide Films as Adhesion Promoters for Sputtered Metal and Ceramic Coatings on PMMA

T. Kaariainen and D.C. Cameron, Lappeenranta University of Technology, Mikkeli, Finland

Magnetron sputtered metal and ceramic films have poor adhesion to certain polymer structures especially polymethylmethacrylate (PMMA). Because of ion bombardment and short wavelength vacuum ultraviolet (VUV) radiation from the plasma, the PMMA surface suffers scission of the molecule's side chain by degradation of the ester group, consequently weakening the mechanical properties of the polymer. Nanometer-scale metal oxide $Al_2O_3$ and $TiO_2$ films deposited by atomic layer deposition (ALD) were deposited on PMMA plates prior to magnetron sputtered Ti and TiC films. They proved to have a multifunctional role in enhancing the adhesion of the sputtered layer. The adhesion significantly improved with increasing ALD film thickness up to ~40 nm thickness at which point the adhesion strength reached the cohesive strength of the substrate material itself. Using infra-red spectroscopy (ATR-FTIR) to monitor changes in the bonding in the surface layers, it is shown that the ALD layers act both as a shield against ion bombardment and also against the effects of VUV radiation from the plasma and so prevents the structural changes in the PMMA which otherwise cause degradation of adhesion.