Hard Coatings and Vapor Deposition Technologies
Room Grand Hall - Session BP-ThP

Hard Coatings and Vapor Deposition Technologies (Symposium B) Poster Session

BP-ThP-1 Low Stress AlTiN-Based Coating Systems, *C Charlton,* Kennametal Inc., USA; ***Joern Kohlscheen,*** Kennametal GmbH, Germany; *D Banerjee,* Kennametal Inc., USA

In this study, we deposited AlTiN coatings with reduced intrinsic stress for metal cutting applications. Stress management is important to maintain coating integrity during machining operations, especially at the cutting edge. Deposition was done in an industrial scale PVD unit using cathodic arc evaporation. Coating thickness was adjusted to about 3 µm. Al content in the metal fraction was varied between 60 and 70 atomic %. A reduction in compressive stress was achieved in four different ways: lowering bias voltage, layering of coating architecture, increasing pressure, and varying the cathode confinement ring system. Samples of cemented carbide and carbon steel strips were used for analyses. Chemical composition was measured by EDX. The microstructure of the obtained films was evaluated by x-ray diffraction (XRD). Stress was estimated using Stoney´s equation considering the resulting curvature of the partially coated steel strip. The values were validated using XRD peak shift measurements of the dominant cubic phase. It will be shown that a combination of bias and layer variation leads to an optimized ratio of low stress and wear resistance. Metal cutting data obtained by turning are showing that such coatings are able to outperform mono-layer coatings with higher stress.

BP-ThP-2 Multi-Target Co-Sputtering Deposition and Mechanical Properties of Ti-Zr-Based High-Entropy Alloy and Nitride Coatings, ***Shou-Yi Chang,*** *Y Hsiao,* National Tsing Hua University, Taiwan; *S Lin,* National Formosa University, Taiwan

Protective hard coatings with good mechanical properties and high thermal stability have been widely used in cutting tools and machinery components. Because of the strict conditions in practical applications, multi-component, nanocomposite and multilayered coatings have been developed to replace conventional single-phase, single-layered binary nitrides. Among them, multi-component high-entropy alloy and nitride coatings with a simple solid-solution structure have been intensively studies in recent years and been found to present excellent mechanical properties, thermal stability and wear resistance. In this study, several coatings of Ti-Zr-based quinary high-entropy alloys with the additions of Al, Cr, Mo, Hf, Nb, Ta, and/or V, and their nitrides with various nitrogen contents, were deposited using a multi-target co-sputtering system in an N2/Ar mixed atmosphere. The microstructures, crystal structures and chemical compositions of these coatings were characterized, and the mechanical properties were measured. Because of the effect of high mixing entropies, all the coatings presented an amorphous or a simple face-centered cubic solid-solution structure. The nitrogen contents of the coatings increased with N2/Ar flow ratio. The alloy coatings had a hardness of 6-8 GPa, while the nitride coatings with a low nitrogen content of about 20 at.% easily showed a hardness up to 16-20 GPa. With a high nitrogen content of 50 at.%, very large residual stresses caused the cracking of the coatings and needed to be reduced for preparing more robust and reliable coatings.

BP-ThP-3 $(Ti_{1-x}Y_x)B_{2+\Delta}$ Thin Films - Structural Evolution and Mechanical Properties, ***Martin Truchlý,*** *B Grancic,* Comenius University in Bratislava, Slovakia; *P Švec Jr.,* Slovak Academy of Sciences, Bratislava, Slovakia; *T Roch, L Satrapinskyy, V Izaii,* Comenius University in Bratislava, Slovakia; *M Harsani,* Staton s.r.o., Slovakia; *O Kohulak, P Kus, M Mikula,* Comenius University in Bratislava, Slovakia

The transition metals boride family offers a lot of stoichiometric modifications (TMB, TMB_2, TMB_6, TMB_{14}, etc.) with different crystalline structure and excellent physical properties. From the point of view of mechanical properties, TM diborides seem to be the most interesting. The best-known overstoichiometric TiB_{2+x} thin film prepared by magnetron sputtering exhibits extremely high hardness H > 40 GPa [1]. However, the application potential of TiB_{2+x} and other binary coatings (ZrB_2, NbB_{2-x}, and W_2B_{5-x}) and the use of their excellent mechanical properties are heavily limited. This is in particular a low fracture toughness expressed by the very high values of Young's modulus (500÷600 GPa) and low oxidation resistance due to formation of volatile boron oxide at 450°C.

Recently, Alling at al. [2] performed extensive theoretical study of 45 ternary diborides with AlB_2 type structure, where the possibility to obtain beneficial age hardening through isostructural clustering, including spinodal decomposition in $M^1_{1-x}M^2_xB_2$ ($M^{1,2}$ = Mg, Al, Sc, Y, Ti, Zr, Hf, V, Nb, Ta) were presented. It has been shown that a significant influence on the formation of a metastable alloy, in which thermally-induced processes led to isostructural clustering, accompanied by age hardening is combination of lattice mismatch between binary constituents and bulk modulus of resulting ternaries.

According to aforementioned results, $(Ti_{1-x}Y_x)B_{2+\Delta}$ seems to be potential candidate for films with clustering tendency what can bring interesting mechanical behavior and extend the possibilities of application potential of diborides.

Here, we present experimental methods and analyzes to investigate structure evolution and mechanical behavior of ternary systems $(Ti_{1-x}Y_x)B_{2+\Delta}$ prepared by magnetron co-sputtering. We discuss the relationship between chemical composition, structural evolution and mechanical properties of as-deposited and annealed thin films based on results obtained from scanning electron microscopy (SEM), X-ray diffraction analysis (XRD), transmission electron microscopy (TEM), and nanoindentation measurements.

[1] M. Mikula et al., The influence of low-energy ion bombardment on the microstructure development and mechanical properties of TiB_x coatings Vacuum 85 (2011) 866–870.

[2] B. Alling et al., A theoretical investigation of mixing thermodynamics, age hardening potential, and electronic structure of ternary $M^1_{1-x}M^2_xB_2$ alloys with AlB_2 type structure. Sci. Rep. 5, 9888; (2015)

This work was supported by the Slovak Research and Development Agency [grant number APVV-17-0320], and Operational Program Research and Development [project ITMS: 26210120010].

BP-ThP-4 Post-annealing of (Ti,Al,Si)N Coatings deposited by High-Speed Physical Vapor Deposition (HS-PVD), *K Bobzin, T Brögelmann, C Kalscheuer, T Liang,* ***Martin Welters,*** Surface Engineering Institute - RWTH Aachen University, Germany

Gas turbine engines operating in environments containing solid particles such as sand, dust and ice particles are challenged by the problem of solid particle erosion (SPE), which causes contour changes especially on compressor blades. Consequently, the performance and efficiency of the engines as well as the maintenance intervals will be reduced. In order to minimize the effects of SPE and to extend the lifetime of compressor blades, the application of erosion resistant coatings represents a promising way.

In the present work, (Ti,Al,Si)N coatings with different Si contents were deposited onto martensitic steel X3CrNiMo13-4 used for compressor blades by High-Speed Physical Vapor Deposition (HS-PVD) technology. Morphology of the coatings investigated by scanning electron microscopy (SEM) shows a dense microstructure with coating thicknesses up to s ≈ 20 µm. Owing to hollow cathode discharge (HCD) and the transport function of the plasma-forming gas Ar, which are specific in HS-PVD deposition processes, high deposition rates ds/dt > 20 µm were achieved. The coated samples were then post-annealed in N_2 atmosphere with bias voltage induced Ar plasma directly in the coating chamber. The annealing temperature, time and atmosphere were varied. The post-annealing effects on the microstructure, indentation hardness as well as chemical and phase compositions were investigated by energy dispersive spectroscopy (EDS), X-ray diffraction (XRD) and nanoindentation, respectively. The erosion resistance of annealed, as-deposited and uncoated samples was investigated using a fine sand blasting facility. Basing on measured erosion rates and inspection of the eroded surfaces, a much higher erosion resistance of the (Ti,Al,Si)N coated samples compared to uncoated substrates could be revealed. Moreover, the post-annealing process led to a further improvement of the erosion resistance. Therefore, the thick (Ti,Al,Si)N coatings deposited by HS-PVD in combination with a post-annealing in N_2 atmosphere provide a high potential for the protection of compressor blades against SPE.

BP-ThP-6 Discrete Thin-film Multilayer Structures of TiB_2 and ZrB_2 Ceramics for Super-hard and Tough Coating, *A Ghimire,* National Tsing Hua University, National Dong Hwa University, Taiwan; ***Ming-Show Wong,*** National Dong Hwa University, Taiwan; *S Chang,* National Tsing Hua University, Taiwan

Multilayer films consisting alternating ZrB_2 and TiB_2 layers with nanometer scale bilayer thickness λ (7nm ~ 1nm) were deposited on silicon substrate by using unbalance magnetron dc sputtering system. The effect of bilayer thickness design on the structure and mechanical properties of the resulting multilayer films has been investigated. The films of bilayer thickness 6 nm and 7 nm possess polycrystalline structure with low crystallinity, however, below 6 nm bilayer thickness, highly [001] textured films with high intensity XRD peaks were witnessed to be lying between ZrB_2 and TiB_2 [001] phase. For 6 nm ~ 2nm bilayer samples, there also exist a unique X-ray diffraction peak along with the alloy phase which is distinct than the conventionally observed superlattice peaks in most of the multilayer works. The hardness increment concurs with the phase transition to aforementioned unique structure. The maximum hardness reached up to 44 GPa for the 2nm bilayer sample with a compressive stress of 4.9 GPa. Over the explored range of λ, all the multilayer films generated shorter cracks than single layer TiB_2 and ZrB_2 films upon Vickers indentation fracture test. Furthermore, the microstructure and growth mechanism of ZrB_2/TiB_2 multilayer system by cross sectional TEM analysis is discussed.

BP-ThP-7 Effect of Bias Voltage on Mechanical Properties of Zr–Si–N Films Fabricated through HiPIMS/RFMS Cosputtering*, **Yung-I Chen**, Y Zheng,* National Taiwan Ocean University, Taiwan*; L Chang,* Ming Chi University of Technology, Taiwan

A previous study has fabricated Zr–Si–N films with Si content of 2–10 at.% through the co-deposition of high-power impulse magnetron sputtering (HiPIMS) and radio-frequency magnetron sputtering (RFMS). The mechanical properties, hardness and Young's modulus, of the HiPIMS/RFMS co-sputtered Zr–Si–N films exhibited linear relationships to their compressive residual stresses. In this work, a negative bias voltage of 50–150 V was applied on the substrates to increase the compressive residual stress of the Zr–Si–N films and the effects on mechanical properties were investigated. The results indicated that the compressive residual stress was increased from −5.0 to −8.8 GPa as increasing the bias voltage from 0 to −150 V; however, the hardness and Young's modulus values exhibited decreasing trends varying from 34.4 to 28.3 GPa and 369 to 299 GPa, respectively, which were accompanied with the decrease in the Si content of the fabricated films from 3.2 to 0.4 at.%.

BP-ThP-11 The Effects of Pulse Frequency on the Growth of Diamond Using Pulse Microwave Plasma CVD*, **Yi Zeng**, Y Sakamoto, T Maruko,* Chiba Institute of Technology, Japan

Diamond has many excellent properties such as high hardness, and high thermal conductivity. Usually diamond is grown on 973-1273 K substrate. However high temperature may cause the film to break or peel off. Pulse oscillation plasma can reduce electron temperature and gas temperature while maintaining electron density. For this purpose, pulse oscillation is used to reduce the synthetic temperature. In this study research of diamond deposition at lower substrate temperature using pulse microwave CVD apparatus and the effect of the pulse frequency on growth rate and quality of the deposit.

Diamond synthesis use pulse microwave CVD. Use Si (100) as the substrate. The pretreatment method is scratched with diamond powder and then clean under ultrasonic environment with acetone. Microwave adopt two modes of continuous oscillation and pulse oscillation. The duty ratio is 50%. The pulse frequency is 250,500,750,1000Hz, respectively. Adjust the microwave output power to control the substrate temperature at 673 K under each condition. The substrate temperature during synthesis is measured by the thermocouple mounted on the bottom of the substrate holder. the flow rate of CH4-CO-H2 is 2-25-200 sccm, and synthesis time is 5 hours. For the synthetic pressure, 5.3kPa is used for pulse oscillation, and 1.3kPa is used for continuous oscillation. Analysis of the surface and section of diamond films are observed by SEM. Qualitative evaluation is carried out by Raman spectroscopy. The plasma state is evaluated by emission spectroscopic analysis by OES.

As a result of SEM observation, the crystal size of diamond by pulse oscillation is larger than continuous oscillation. Although the pressure staying at 5.3kPa, the orientation of the crystal changes from (100) to (111) as the pulse frequency increases. The growth rate of pulse oscillation is 1.5-3 times faster than continuous oscillation. The growth rate is 0.3-0.6μm/h when pulse oscillation is used. Under the condition of this experiment, the growth rate of 500Hz was maximum. In the OES, Hα has the highest emission intensity at 500 Hz. Comparing the Hα emission intensity and the film growth rate, it is recognized that the film growth rate tends to be faster with the condition of high emission intensity. In the Raman spectra, D band (1350 cm^{-1}) and G band (1580 cm^{-1}) are observed under any conditions. On the condition at 500 Hz and 1000 Hz, apparent peak 1000-1200cm^{-1}can be observed. This peak is caused by the miniaturization of diamond crystal. It can be concluded that crystal size is miniaturized by pulse frequency 500Hz and 1000Hz.

BP-ThP-12 Analysis of Reaction Gas States on Synthesis of Boron Doped Diamond by HF-CVD*, **Takuya Maruko**, Y Sakamoto,* Chiba Institute of Technology, Japan

Boron doped diamond (BDD) electrodes are expected to be applied to various applications. The performance of BDD electrodes varies depending on the amount of doped B in diamond. Therefore, it is necessary to synthesize BDD which controlled amount of B in diamond depended on the used applications. In synthesis of BDD, B_2H_6, $B(CH_3)$, $B(OCH_3)_3$ are often used as B dopants, nevertheless there is a disadvantage that B_2H_6 and $B(CH_3)_3$ are toxic. Conversely, $B(OCH_3)_3$ has the advantage of lower toxic relatively. However, it is difficult to control $B(OCH_3)_3$ flow rate, because $B(OCH_3)_3$ is liquid and introduced into the chamber by evaporation or bubbling. Therefore, if it is possible to control the amount of doped B in diamond by in-situ measurement of the reaction gas states, it is considered that more efficient production of BDD electrodes are possible.

In this study, the BDD synthesis was performed by HF-CVD using $B(OCH_3)_3$ as a B source, and analysis of reaction gas states using QMS during synthesis was attempted.

BDD was synthesized by HF-CVD using H_2-CH_4-$B(OCH_3)_3$ as a reaction gas. The $B(OCH_3)_3$ flow rate was varied from 0.1 to 0.4 sccm and CH_4 / H_2 ratio was 2%. The synthesis pressure was 4 kPa, filament temperature was 2273 K. The reaction gas states were measured using QMS. The deposits were evaluated using SEM, XRD, and Raman spectroscopy.

As a result of observation of deposits, facets of diamond crystals were observed under all conditions from surface observation by SEM. The peaks of diamond were recognized in the XRD patterns of the deposits under all conditions. The peaks due to B-doped diamond were recognized in the Raman spectra of the deposits for all synthesis conditions. Therefore, the synthesis of BDD was confirmed under all conditions. Additionally, the position of the peak caused diamond at 1333cm^{-1} in the Raman spectrum was changed lower wavenumber with increasing of the $B(OCH_3)_3$ flow rate. This result suggests that the amount of doped B in the diamond was increased with increasing of the $B(OCH_3)_3$ flow rate.

As a result of measurements of reaction gas states during synthesis by QMS, it was confirmed that peak of OCH_3 molecule was decomposed from $B(OCH_3)_3$. Additionally, the peak height of OCH_3 increased with increase of $B(OCH_3)_3$ flow rate.

In summary, the correlation was confirmed between the peak height of OCH_3 molecules measured from QMS and amount of B in diamond.

BP-ThP-13 Effects of Boronizing Pretreatment on the Adhesion of B-doped Diamond on Ti Substrates*, **Yuuta Izu**,* Chiba institute of Technology, Japan*; T Sakuma,* Ogura Jewel Industry, Japan*; A Suzuki, T Maruko,* Chiba Institute of Technology Graduate School, Japan*; M Imamiya, Y Sakamoto,* Chiba Institute of Technology, Japan

BDD is an ideal electrode material because the potential window is wide, the background current is extremely low and it is insoluble in any solution. Ti / BDD electrodes are promising for application in wastewater treatment, because it has advantages of both materials. However, the delamination occurs at the intermediate layer between BDD coating and Ti substrate. Consequently, it is necessary to design intermediate layer having high bond dissociation energy.

Since the bonding dissociation energy is TiB > TiB_2 > TiC, the introducing Ti-B into the intermediate layer of the BDD on the Ti substrate can be expected to be improved the adhesion strength between the Ti substrate and the BDD film.

The boronizing of each Ti substrate with different reaction time and deposition of BDD on each Ti substrate with different reaction time were conducted using a mode-conversion type microwave plasma chemical vapor deposition apparatus, which is able to consistently process boronizing pretreatment and deposition of BDD, with solution of trimethyl borate as boron source.

From the results of chemical bonding analysis by X-ray photoelectron spectroscopy of the surface of each Ti substrate after the boronizing, it was observed that the amount of synthesizing Ti-B increased with the increase of the boronizing time. In adhesion strength of each BDD / Ti, increasing adhesion strength was accompanied the increase of boronizing time upto 20 minutes. However, adhesion strength at 30 minutes of boronizing time was decreased more than at 20 minutes.

It is considered that the adhesion strength was decreased by progressing hydrogen embrittlement was indicated.

BP-ThP-14 High Entropy Nitride Thin Film ($(Cr_{0.35}Al_{0.25}Nb_{0.12}Si_{0.08}V_{0.20})N_x$ for Tribological Characteristics at High Temperature, ***Yu-Chia Lin***, *J Duh,* National Tsing Hua University, Taiwan

High entropy nitride thin films have already been reported because of its outstanding mechanical properties. In this study, adding self-lubricating element Vanadium in high entropy nitride system improved the wear performance due to the formation of Magnéli phase. High entropy nitride thin films $(Cr_{0.35}Al_{0.25}Nb_{0.12}Si_{0.08}V_{0.2})N_x$ with different nitrogen ratio were fabricated by controlling the nitrogen flow ratio in a radio frequency magnetron sputtering system. The variation of nitrogen ratio in thin film will affect the mechanical properties or even the crystal structure, thus investigating the difference of material characteristic induced from different nitrogen ratio become essential.

The chemical composition of as-deposited coatings was detected by a FE-EPMA. The crystal structure was evaluated from a Grazing Incidence XRD. The layer thickness of nitride thin films was measured from SEM. The mechanical properties at ambient temperature and high-temperatures were evaluated by a nano–indenter. The tribological properties were tested by ball-on-disc wear test in a high-temperature tribometer. The results of annealing test in air were also addressed in this study. Finally, a high entropy nitride thin film with the favorable wear performance in high temperature will be briefly discussed. It is expected to be a potential candidate applied in high temperature wearing industry.

BP-ThP-15 Search of New $(Al_{0.25}Cr_{0.3}Nb_{0.1}Si_{0.08}Ti_{0.1}Mo_{0.17})N_x$ Coatings for Feasible Application at High Temperature, ***Wei-Li Lo***, *J Duh,* National Tsing Hua University, Taiwan

Recently, mechanical and tribological properties of high entropy alloy(HEA) and HEA nitride coatings have been widely discussed, yet the high-temperature tribology of HEA nitride coatings have not been investigated. In this study, $(Al_{0.25}Cr_{0.3}Nb_{0.1}Si_{0.08}Ti_{0.1}Mo_{0.17})N_x$ coatings with various nitrogen ratios were fabricated on Inconel 718 substrate by RF magnetron sputtering.The chemical composition analysis of $(Al_{0.25}Cr_{0.3}Nb_{0.1}Si_{0.08}Ti_{0.1}Mo_{0.17})N_x$ coating was carried out using a FE-EPMA. The cross-sectional microstructure was observed by a FE-SEM. The phases of the HEA nitride coatings were verified by a Grazing Incidence XRD. The intrinsic mechanical properties of the coatings were measured by a high-temperature nano-indentor. The high-temperature tribological properties were estimated by a ball-on-disc tribometer equipped with a Al_2O_3 ball at high temperature.

$(Al_{0.25}Cr_{0.3}Nb_{0.1}Si_{0.08}Ti_{0.1}Mo_{0.17})N_x$ coating with a specific nitrogen ratio exhibits favorable mechanical properties, which could be attributed to the formation of stable crystalline structure. In addition, the MoO_3 Magnéli phase could be observed at elevated temperature, which also improves the high-temperature tribological properties by providing a lubricating surface. Surface morphology and microstructure of the wear track were observed by FE-SEM and HR-TEM. The elemental redistribution and phase transformations in the wear track were analyzed by XPS and XRD. Finally, a HEA nitride coating with optimal high-temperature mechanical and tribological properties will be investigated and discussed.

BP-ThP-18 e-Poster Presentation: The Role of Vacancies in the W-N System, *F Klimashin,* ***Paul Heinz Mayrhofer***, TU Wien, Institute of Materials Science and Technology, Austria

Our experimental and computational investigations afford an insight into the role of vacancies in the structure–properties relationship within the binary system tungsten–nitrogen. The vacancies on metal and nitrogen lattice sites favour the formation of the face-centred cubic structure. The lower the synthesis temperature, the lower the needed nitrogen partial pressure to stabilise the cubic structure. Among cubic γ-$W_{0.50}N$ and γ-$WN_{0.50}$, also compositions with nearly 1:1 stoichiometry were prepared. Our results indicate clustering of vacancies on metal and nitrogen lattice sites rather than single-phased structures of NaCl (mechanically unstable) or NbO (nearly twice as high elastic modulus as experimentally observed) types. All cubic structures show hardness values of 30–33 GPa (up to 37 GPa on austenitic steel) with the tendency to slightly higher values for lower N/W ratios. In contrast, higher N/W ratios tend to increase fracture toughness, as for example 3.4 MPa√m is obtained for γ-$W_{0.5}N$ but only 2.4 MPa√m is obtained for γ-$WN_{0.5}$. Coatings with a 1:1 stoichiometry, where clustered vacancies seem to be present, exhibit 2.8 MPa√m. The fracture toughness clearly scales with the compressive residual stresses, which clearly increase with the N/W ratio.

BP-ThP-19 Probing Defected Layers of MoN/TaN and TiN/WN Superlattices, ***Nikola Koutna***, *J Buchinger, R Hahn,* Institute of Materials Science and Technology, TU Wien, Austria*; J Zálešák,* Erich Schmid Institute of Materials Science, Austrian Academy of Sciences, Leoben, Austria*; M Bartosik,* Institute of Materials Science and Technology, TU Wien, Austria*; M Friák, M Šob,* Institute of Physics of Materials, Academy of Sciences of the Czech Republic, Czech Republic*; D Holec,* Montanuniversität Leoben, Austria*; P Mayrhofer,* Institute of Materials Science and Technology, TU Wien, Austria

Superlattices composed of coherently stacked materials with bi-layer periods in the nm range are an important concept to alter energetic, structural, mechanical, or electronic properties of coatings. Exceptional performance and hardness enhancement beyond the limits of the superlattice building components has been demonstrated for a series of nitride-based superlattices, e.g., TiN/AlN, TiN/CrN, TiN/NbN, TiN/VN, TiN/TaN or AlN/CrN. Yet the fundamental structure-stability-elasticity relationships and their origin remain mostly unknown for superlattices combining even simple binary transition metal nitrides. The complexity of these multilayered systems mainly stems from a strong driving force of transition metal nitrides for vacancies.

Our combined first-principles and experimental study focuses on two cubic-based multilayered systems: MoN/TaN and TiN/WN. MoN, TaN, and WN are often used to improve ductility, but they are metastable (MoN, TaN), or even unstable (WN) in a perfect stoichiometric configuration. Vacancies play an important role for these binaries, since they can largely improve their thermodynamic stability, ensure mechanical stability, or even eliminate (some) soft phonon modes (i.e., contribute to a vibrational stabilisation). By employing Density Functional Theory calculations, we reveal the impact of vacancies on the structural stability as well as on the electronic structure and elastic constants. Theoretical findings are corroborated with X-ray diffraction patterns, energy-dispersive X-ray spectroscopy as well as nanoindentation data. Furthermore, we formulate design rules for MoN/TaN and TiN/WN multilayered coatings with superior elastic properties and/or exceptional tensile strength.

BP-ThP-20 Investigation of CVD Stability Windows for Tungsten Carbide Phases, ***Katalin Böör***, *J Gerdin,* Uppsala University, Sweden*; R Qiu,* Chalmers University of Technology, Sweden*; M Boman,* Uppsala University, Sweden*; E Lindahl,* Sandvik Coromant R&D, Sweden

Tungsten carbides are widely used in bulk materials such as cemented carbides, primarily due to their high hardness and chemical resistance. Although there has been extensive research on tungsten carbides, their potential as materials for wear and corrosion resistant coatings has not been widely utilized yet. A few attempts have been made to deposit tungsten carbides with chemical vapor deposition. Typically WF_6, H_2 and a hydrocarbon such as propane were used as precursors. Usually, multiple metallic or carbide phases were obtained such as W, W_3C, W_2C, WC_{1-x} or WC. In addition to the metallic or carbide phases amorphous carbon was also observed to be formed in some cases during the CVD process. Single-phase coatings, however, have only been obtained in a few cases and it has been difficult to control the microstructure and/or morphology of those.

In order to achieve a better control on the characteristics of the coating, a deeper understanding on the influence of the CVD process parameters on the resulted coatings is needed. A systematic study carried out to find the stability window of the single phases in a CVD process will be presented. The study will include the phase content, the microstructure, the morphology of the deposited single-phase tungsten carbide coatings and the growth kinetics behind.

The tungsten carbide thin films were deposited using WF_6, C_2H_4, H_2 as precursors with Ar as the carrier gas on different metallic and ceramic substrates in a newly constructed hot-wall CVD reactor. XRD, GI-XRD, SEM, XPS and TEM- analysis were used to characterize the coatings.

BP-ThP-22 Photocatalytic Activity of Metal Oxide Thin Films Deposited by MS-PVD and Layer-by-Layer for Hydrogen Production by Water Splitting, *P Rivero,* Public University of Navarra, Spain*;* ***Jose Antonio Garcia***, Universidad Publica de Navarra, Spain*; R Rodriguez,* Public University of Navarra, Spain*; J Esparza,* AIN, Ingeniería Avanzada de Superficies, Spain*; G Garcia Fuentes,* Public University of Navarra, Spain

Two different deposition techniques, Magnetron Sputtering Physical Vapour Deposition (MS-PVD) and Layer-by-Layer (LbL) technique, have been utilized to compare the photocatalytic activity of various metal oxides, including single metal oxides: Fe_2O_3, WO_3, binary metal oxides: $SrTiO_3$, and a combination of these compounds. The coatings were deposited on stainless steel (AISI 304) substrates, glass slides and silicon wafers. Photocatalytic activity has been tested by visible spectrophotometry, through monitoring the degradation of Methylene Blue under direct exposure to simulated solar light. Additionally, UV-Vis-NIR spectrophotometry tests have been carried out to measure the changes in the resultant light absorbance of the oxide films. Further characterization has been performed, including Field Emission Scanning Electron Microscopy (FE-SEM), X-Ray Diffraction (XRD), chemical composition profiles by Glow Discharge Optical Emission Spectrometry (GD-OES), corrosion performance by potentiodynamic polarization tests, light interferometry, contact angle measurements and wetting properties. Finally, an exhaustive study of the mechanical properties of the thin films has been carried out.

BP-ThP-23 Nanocomposite (Ti,Al,Cr,Si)N HPPMS Coatings for High Performance Cutting Tools*, K Bobzin, T Brögelmann, N Kruppe, M Carlet,* ***Matthias Thiex,*** RWTH Aachen University, Germany

During the machining of high-speed steels, thermal and mechanical loads occur, which can influence the performance and cause damaging of the cutting tools. Due to their high hardness, wear resistance and toughness, hard coatings are used to improve productivity. The development of a complex coating (Ti,Al,Cr,Si)N for cutting tools and comprehensive analyses of them are the main objectives of the current research. The coating deposition was conducted in an industrial scale coating unit using a hybrid technology, consisting of direct current and high power pulse magnetron sputtering (dcMS/HPPMS). Cemented carbide was used as substrate material. To enhance the cutting performance, a nanocomposite architecture was developed, which consists of crystalline (Ti,Al,Cr)N phases in an amorphous Si_3N_4 matrix. The amorphous matrix aims to reduce the oxygen diffusion into grains and thus, to increase the oxidation resistance. Reduced grain sizes can further improve the mechanical properties such as the resistance of the coating against plastic deformation. The oxide reaction layer formed on the coating's surface upon exposure to the atmosphere has a significant influence on the tool performance. Thus, the design of a diffusion resistant coating system was proceeded by the synthesis of a thin oxynitride toplayer (Ti,Al,Cr,Si)ON, which is not sufficiently studied in the literature. The oxidation behavior of the coated samples under atmospheric conditions and the phase stability under inert gas atmosphere were comprehensively analyzed at high temperatures up to T = 1,300°C. Under both conditions, detailed analysis on diffusion between the workpiece material AISI M2 and the bilayer coatings were additionally performed. By reducing the pulse duration of the HPPMS cathodes, the non-metal to metal ratio was taken into account to study its influence on the reaction layer. Furthermore, the influence of cathode power and bias voltage on the coating properties was investigated. The microstructure was investigated by transmission electron microscopy (TEM). Sputter depth profiles determined using X-ray photoelectron spectroscopy (XPS) and X-ray diffraction (XRD) were applied after the heat treatments. Based on the results, the incorporation of oxygen tends to modify the nanocrystalline morphology of the nitride interlayer having grain sizes of $d \approx 10$ nm to an amorphous microstructure, which is characteristic for the oxynitride top layer. The coated samples possess high oxidation resistance and diffusion resistivity. Moreover, the coating systems exhibit a significant phase stability.

BP-ThP-26 Low Temperature Titanium Boron-Carbide Based Thin Film Coatings by Plasma Enhanced Chemical Vapor Deposition on Surface Microstructure Controlled WC-Co*,* ***Takeyasu Saito,*** *D Kiyokawa, K Fuji, N Okamoto,* Osaka Prefecture University, Japan*; A Kitajima, K Higuchi,* Osaka University, Japan

Chemical vapor deposited (CVD) or physical vapor deposited (PVD) hard material carting technique is widely used for molds and cutting tools, which plays an important role in a lot of manufacturing industry. For example, titanium carbide (TiC), titanium nitride (TiN) and titanium carbonitride (TiCN) is used in order to increase lifetime or to decrease friction coefficient of molds, tools etc. Recently, titanium borinitride-based hard coating films (TiBCN) have been attracted much attention.

The film prepared by thermal CVD typically carried out around 1000°C has good uniformity and mechanical properties, which restricts substrates having low melting points, and also causes deformation of substrates. Plasma enhanced chemical vapor deposition (PECVD) has some merits like lower deposition temperature (< 500°C) than thermal CVD, however, the films usually have low adhesion strength.

In this study, TiBCN coatings were formed by PECVD with $TiCl_4/CH_4/BBr_3/N_2$ reaction system. Growth rate, surface morphologies, crystallographic properties, and composition ratio/chemical states were evaluated by surface profiler, FE-SEM, XRD, and XPS. Several surface pretreatment methods were investigated to increase surface roughness to enhance adhesion strength, which include, CF_4 plasma etching and aqua regia ($3HCl:HNO_3$) etching.

Figure 1 shows XRD results of TiBC thin films from $TiCl_4/BBr_3/CH_4$ with different CH_4 concentration. Clear TiB_2 peaks were recognized and C(004) peak became recognized when the C/Ti ratio is over 3. Figure 2 shows XRD results of TiBN thin films from $TiCl_4$/ BBr_3/N_2 with different N_2 concentration. TiN(110) increased and TiB_2(101) became weak with increasing N/Ti ratio. Both TiN and TiB_2 peaks exist, suggesting that deposited films contain Ti, B and N when N/Ti ratio =3,5. Based on the results shown in figs. 1 and 2, the deposition properties of TiBCN thin films will be discussed.

BP-ThP-27 Performance of the CrAlSiN and Hydrogen free DLC Combined Hard Coatings Deposited on Micro Tools Cutting Printed Circuit Board*, D Wang,* MingDao University, Taiwan*;* ***Li-Chi Hsu****, J Hung,* Aurora Scientific Corp., Canada*; W Chen, W Ho,* MingDao University, Taiwan

Coating systems, including CrAlSiN coatings and various CrAlSiN +DLC combined coatings were deposited using a cathodic arc evaporation system. All the coatings were finished by using technology of modified pulsed current output to the arc evaporators. The DLC coatings were obtained with graphitic target and various mixture of N_2+ Ar gases. All the coating systems with the effects of various conditions on the properties and performance in field of machining printed circuit boards were studied. The properties of the CrAlSiN coating was used as a reference coating. The various CrAlSiN+DLC coatings were evaluated using ball-on-disc wear tests. The wear behavior of the CrAlSiN+DLC combined coatings was affected by the various mixture of N_2+ Ar gases. The hardness of the CrAlSiN+DLC combined coatings increase up to 40GPa as compared to CrAlSiN coating of 35GPa. Furthermore, the cutting performance of micro tools with the various coatings were evaluated by cutting the PCB board. Micro tool with CrAlSiN coatings increased the significant amount of cutting distance as compared to the blank tool. Meanwhile, the tools deposited with CrAlSiN+DLC combined coatings showed the maximum cutting distance of the PCB board which helped to improve tool wear and cutting performance.

Keywords: Pulsed current, cathodic arc evaporation, CrAlSiN, DLC

BP-ThP-28 Study and Characterization of the Vanadium Carbide Interlayer Deposited by Laser Cladding over Carbon Steel for CVD Diamond Growth*, D Damm, R Pinheiro, J Gomez,* National Institute for Space Research (INPE), Brazil*; A Contin,* Federal University of Goiás (UFG), Brazil*; R Correia,* Federal University of São Paulo (UNIFESP), Brazil*; R Volu,* Institute for Advanced Studies (IEAV), Brazil*;* ***Vladimir Jesus Trava-Airoldi,*** National Institute for Space Research (INPE), Brazil*; G de Vasconselos,* Institute for Advanced Studies (IEAV), Brazil*; D Barquete,* Santa Cruz State University (UESC), Brazil*; E Corat,* National Institute for Space Research (INPE), Brazil

Vanadium carbide has been used in the industry to improve the steel properties. It was extensively studied and explored by Toyota a few decades ago. Vanadium has high hardness, as well as carbides forming ability, chemical compatibility with carbon steel and CVD diamond and an intermediate thermal expansion coefficient (TEC) between these materials. These characteristics make vanadium carbide attractive as an intermediate layer for CVD diamond applications. There are many techniques to obtain a vanadium carbide interface such as thermodiffusion and sputtering. In this work, we will discuss the vanadium carbide deposition by laser cladding on carbon steel surface. The main problems in growing CVD diamond directly on steel surface are related crystallinity, purity and adhesion. The crystallinity issue is due to the fact that the gas phase carbon goes in to the steel substrate bulk causing its embrittlement and reducing diamond growth rate. The problem regarding purity is related to the transitions metals present in the steel surface (such as iron and cobalt) that inhibit the sp3 bond over the sp2 bond, providing the appearance of graphite on CVD film that reduces the film quality. As for the Adhesion challenge, the TEC mismatch results in a high residual compressive tension in the diamond film, which causes delamination during cooling. Therefore, an intermediate layer is necessary to create a transition zone able to relieve the thermal residual stress and also to act as a diffusional barrier. The laser cladding was selected because of its rapid processing, excellent metals adhesion by melting, good surface finish reducing roughness and capacity to preserve the original properties of the material substrate interacting only with the up layers of the material. In this study, we analyze vanadium carbide phase formation by varying systematically the following parameters: resolution (300 – 900 DPI); scanning speed (100 – 500 mm/s); and output power (40 –

125 W). For the substrate we used AISI D6, AISI O1 and AISI M2 steels. The HFCVD films were grown using the following parameters: 2 sscm of CH_4; 98sccm of H_2; 2h deposition process time; 700°C and 5mm of work distance. The results of LCVC coating and HFCVD films characterizations were obtained by X-ray diffraction, scanning electron microscope field emission (SEM-FEG) and Raman spectroscopy.

BP-ThP-30 Optimization for Adhesion Properties of c-BN Films Coated with HiPIMS*, **Ihsan Efeoğlu**, Y Totik, A Keleş,* Ataturk University, Turkey

Friction and wear are one of the most important problems for machine components working in contact with each other. In order to reduce friction and wear, films with desired properties are usually coated on the surface of component. One of the most phenomena of these coatings is c-BN films. Although c-BN films have superior properties, their low adhesion property needs to be improved. Therefore, in this study, optimum adhesion properties were investigated for c-BN film coated with HiPIMS. Taguchi L9 orthogonal array test setup was used to determine the optimum adhesion. The scratch tester was conducted to define adhesion property. Three different parameters (N_2 content, duty cycle and B_4C target voltage) and three different levels for each parameter have been selected in Taguchi. The results obtained from the experiments were converted to signal/noise rate (S/N) and used to optimize the adhesion value of c-BN films. These values are in order of N_2 content, duty cycle and B_4C target voltage 3.5 sccm, 4.5% and 900V, respectively. Verification coating and test were performed for the optimum values obtained.

BP-ThP-31 Si-DLC Films Prepared by Magnetron Sputtering under Different Working Pressure*, **Chaoqian Guo**, S Lin, Q Shi, C Wei, H Li, W Wang, M Dai,* Guangdong Institute of New Materials, China

Si-DLC films were prepared on cemented carbides by high power impulse magnetron sputtering combined with middle-frequency magnetron sputtering. A graphite target providing carbon source was driven by high power impulse magnetron sputtering while silicon was originated from two SiC targets powered by middle-frequency magnetron sputtering. Mechanical and tribological properties of Si-DLC films deposited under different working pressure were studied. Scanning electron microscope, Raman spectroscopy and X-ray photoelectron spectroscopy were applied to investigate film microstructure and bonding states of elements. Nanoindentation, scratch tester and tribometer were used to test films' mechanical and tribological properties. The results showed that working pressure affects Si-DLC films' structure and properties greatly.

BP-ThP-32 Multielement Rutile-structured AlCrNbTaTi-oxide Coatings Synthesised by Reactive Magnetron Sputtering*, **Alexander Kirnbauer**, C Koller,* TU Wien, Institute of Materials Science and Technology, Austria*; S Koloszvári,* Plansee Composite Materials GmbH, Germany*; P Mayrhofer,* TU Wien, Institute of Materials Science and Technology, Austria

A new alloying concept gained tremendous attraction in the field of materials research within the last years—so-called high-entropy alloys. These are defined as alloys with a configurational entropy of at least 1.5 R (R being the universal gas constant). To reach this specific value, the alloy ought to consist of at least 5 elements in a compositional range between 10 and 30 at.%. This concept may also be transferred to ceramic-based materials, in which the respective constituents are binary ceramics borides, carbides, nitrides ,or oxides—the latter of which are subject to the present study.

AlCrNbTaTi-oxide coatings were prepared by reactive magnetron sputtering in a lab-scaled deposition system using a single powder-metallurgically produced compound target (composition AlCrNbTaTi 20/20/20/20/20 at.%). Systematic variations of the O_2/Ar-ratio used for the deposition of these high-entropy films to determine basic structure-property–relationships.

The coatings crystallise partly in a single-phased rutile structure, are slightly enriched in Ta and exhibit nearly a MeO_2 stoichiometry with an oxygen content of ~64 at.%. The indentation hardness of ~20 GPa in the as-deposited state is for some of the coatings slightly higher than compared to binary or ternary oxides. The thermal stability was investigated by vaccum annealing treatments with subsequent XRD and indentation measurements to gain information about the evolution of the structure and the mechanical properties.

Our results clearly show that a high-entropy concept applied to oxide thin films using a single powder-metallurgically-produced compound target is a promising strategy in promoting single-phased and mechanically/thermally- stable AlCrNbTaTi oxide coatings.

BP-ThP-33 Magnetron Sputtering of Tungsten-containing /TiNxOy Multilayered Solar Selective Coatings*, **Siang-Yun Li**, Y Shen, K Chang, J Ting,* National Cheng Kung University, Taiwan

In this study, we prepared multilayer coatings of tungsten-containing TiNxOy having different compositions for use as solar selective absorbers. First, we sputtered a tungsten reflective layer on stainless steel substrate and W/TiNxOy layers havng two different compositions as the solar absorption layers. Finally, we sputtered HfO_2 as the outermost reflective layer. We adjusted the N/O ratio and film thickness to optimize the performance of TiN_xO_y multilayered solar selective coatings. The coatings were characterized using before and after 600-800 C heat treatment. Effects of the materials characteristics on the optical properties were discussed.

BP-ThP-34 Electron-configuration Stabilized (W,Al)B_2 Solid Solutions*, R Hahn, **Vincent Moraes**, P Mayrhofer,* Institute of Materials Science and Technology, TU Wien, Austria*; A Limbeck,* Institute of Chemical Technologies and Analytics, TU Wien, Austria*; P Polcik,* Plansee Composite Materials GmbH, Germany*; H Euchner,* Helmholtz Institute for Electrochemical Energy Storage, Germany

Recent investigations on boride based materials, pointed out, that WB_{2-z} - in its metastable α-structure (AlB_2-prototype) - draws an interesting base system for the development of ternary material systems with exceptional performances in the field of hard and tough coatings.

In this study, we present a combined experimental and theoretical study of the ternary diboride system $W_{1-x}Al_xB_{2-z}$. Tungsten rich solid solutions of $W_{1-x}Al_xB_{2-z}$ were prepared by physical vapor deposition and investigated for structure, mechanical properties and thermal stability. All crystalline films show hardness values above 35 GPa, while the highest thermal stability was found for low Al contents. In this context, the impact of point defects on the stabilization of the AlB_2 structure type is discussed, using ab initio methods. Most notably, we are able to show that vacancies on the boron sublattice are detrimental for the formation of Al-rich $W_{1-x}Al_xB_{2-z}$, thus providing an explanation why only tungsten rich phases are crystalline.

Keywords: $W_{1-x}Al_xB_{2-z}$, sputtering, vacancies, density functional theory

BP-ThP-35 Apparent Fracture Toughness of TiN Coatings with Alternating Stress Fields*, **Antonia Wagner**, J Buchinger,* TU Wien, Institute of Materials Science and Technology, Austria*; M Todt,* TU Wien, Institute of Lightweight Design and Structural Biomechanics, Austria*; D Holec,* Montanuniversität Leoben, Austria*; P Mayrhofer, M Bartosik,* TU Wien, Institute of Materials Science and Technology, Austria

In general, ceramic thin films show a low fracture toughness and tend to catastrophic brittle failure. One of the most important approaches to increase the crack growth resistance of ceramic components is to introduce compressive residual stresses. When considering coatings manufactured by physical vapor deposition the intrinsic residual stresses can be modified by applying a negative bias voltage to the substrate and hence altering the degree of ion bombardment. Depositing a chemically homogeneous material with a sequential variation of the bias voltage leads to a multilayer coating in the sense of residual stresses, whereas the material properties are kept more or less constant over the film thickness . This approach allows studying the effect of residual stresses on the fracture behavior of multilayers decoupled from other mechanisms like elastic mismatch.

Herein, TiN coatings are deposited on Si (100) substrates by reactive magnetron sputtering and different multilayer architectures with respect to the residual stress state are realized by changing between a bias voltage of -30V and -60V. The curvature of the substrate is measured and an analytical model based on Euler-Bernoulli-beam theory is applied to investigate the stress distribution within the coating. Fracture experiments are performed on micro cantilevers fabricated by focused ion beam milling which eventually are compared with fracture toughness estimations based on the calculated stress distributions.

BP-ThP-36 Synthesis and Structural Characterization of Nanostructured $CN_{0.1}$ Films Deposited by RF Magnetron Sputtering at Different Bias Voltajes*, **Arturo Lousa**, D Cano, C Villabos, J Esteve,* University of Barcelona, Spain

Nitrogen content of about 10% can be considered as the border between nitrogen doped amorphous carbon (DLC:N) and fullerene-like carbon nitride (CN_x) thin films. In this sense, this material can be a good alternative to reduce the high values of stress usually found in pure DLC coatings while keeping most of its good mechanical, tribological and biocompatible properties.

The present investigation is centered on the deposition of relatively thick films (0.5 mm) of $CN_{0.1}$with N concentration of around 10% by RF magnetron sputtering. Samples were deposited at negative bias voltage between –20 and –150 V in order to study the effect of different intensities of ion bombardment during the film growth on the film structure. Monocrystalline Silicon wafers were used as substrates for all the deposited samples, and CoCrMo substrates were occasionally used in order to test the applicability on biomedical components. These films were characterized by X-ray photoelectron spectroscopy, (XPS) Raman spectroscopy, FTIR scanning and transmission electron microscopy (HRTEM). Hardness an elastic modulus were measured by the nanoindentation technique.

The deposition rate was 0,5 mm/h. Films showed a columnar structure with atomic composition of 10% N and 90 % C, with a relative composition of sp^3 C-C bonds which decreased slightly as the negative bias voltage was increased. The Raman spectra were deconvoluted in four Gaussians showing more complex contributions than the two conventional G and D. The FTIR results corresponds to electrical conductive samples, with an absorption band corresponding to four different vibration modes of the C-N bonds. The HRTEM diffraction patterns of selected area reveal an essentially amorphous condition. However, as the bias is smaller, some ordering is observed oriented parallel to the substrate. The images of bright field show a homogeneous aspect with a coherent interface and a uniform thickness, with a presence of a distribution of nanometric clusters in an amorphous matrix, denser and with smaller cluster size as the negative bias voltage decreases. Hardness values are in the range of 21–24 GPa, and the modulus of elasticity are in the range of 140–180 GPa with a slight tendency to increase as the negative bias voltage is increased.

BP-ThP-37 An X-ray Diffraction Study on CrAlN and CrAlSiN PVD Coatings*, **Jan Latarius**, D Stangier, C Albers, K Berger, M Elbers, A Sparenberg, G Surmeier, M Paulus, C Sternemann, W Tillmann, M Tolan,* TU Dortmund University, Germany

As the demand for highly resistant tools for milling and drilling applications is rising, this translates to more sophisticated coatings, to cope with special requirements as high temperature or corrosion resistance. Very promising candidates are coatings produced by physical vapor deposition (PVD).

Here, CrAlN based PVD coatings have proven to be quite capable to match the claims and CrAlSiN as a possible successor might feature improvement in many critical aspects like hardness, wear resistance, thermal and mechanical stability. These macroscopic properties are reflected in microscopic structural properties and can therefore be studied through means of X-ray diffraction (XRD) by determination of phase composition, residual stresses, micro strains and crystallite size, etcetera.

We present an XRD study on different CrAlN and CrAlSiN PVD coatings. These coatings were produced with varied bias potentials and tempered under air at temperatures between room temperature and 1000° C. The coatings were investigated at beamline BL9 at the synchrotron light source DELTA (Dortmund, Germany). The phase composition, micro strain and crystallite size were determined. The CrAlSiN coatings show a much higher oxidation temperature indicating great benefits of doping with silicon.

BP-ThP-41 Influence of Oxygen Addition on Microstructure and Properties of TiAlN*, **Damian Mauritius Holzapfel**, M Hans,* RWTH Aachen University, Germany*; A Eriksson, M Arndt,* Oerlikon Balzers, Oerlikon Surface Solutions AG, Liechtenstein*; D Primetzhofer,* Uppsala University, Sweden*; J Schneider,* RWTH Aachen University, Germany

Industrial cutting and forming processes have high demands regarding chemical and mechanical properties of coatings, to serve as effective wear protection. Coatings in the TiAlN-system are widely used in industry. In this study TiAlN and $(TiAl)_z(O_xN_{1-x})_{1-z}$ thin films were deposited by cathodic arc evaporation onto cemented carbide substrates. Structure and composition were investigated by X-ray diffraction, scanning transmission electron microscopy, elastic recoil detection analysis and atom probe tomography. The effect on microstructure and properties as influenced by O were characterized.

BP-ThP-42 An Investigation on Synthesis of Novel Oxide-Based Superhard Cr-Zr-O Coatings*, M Mohammadtaheri, Q Yang, Y Li, **Jesus Corona-Gomez**,* University of Saskatchewan, Canada

Synthesis of ternary Cr-Zr-O coatings was performed on silicon wafers and glass substrates by Reactive dual radio-frequency (RF) magnetron sputtering technique. The zirconium concentration of coatings changed in a range of 0-10 at. % by tuning the RF power of Zr target. The correlation between the chemical composition, crystal structure, phase composition, and hardness of coatings was investigated by Energy Dispersive Spectroscopy (EDS), X-ray diffraction (XRD), Raman spectroscopy, and Nanoindentation, respectively. Annealing procedures were conducted for 3 hours at 300, 700, 800, and 1000 °C to evaluate the structural stability of the Cr-Zr-O coatings. The results indicated that incorporation of zirconium increases the crystallization temperature of coatings and the excess of zirconium transferred the coatings to a completely amorphous structure. The superhardness (Hardness ≥ 40 GPa) in Cr-Zr-O system was achieved in a specific chemical composition where the Zr content was about 2 at. %. According to the XRD results obtained after annealing treatments, it was confirmed that the zirconium was in a super-saturated solid solution state in the chromium oxide crystal structure where the superhardness was achieved. However, the thermal stability of Cr-Zr-O coatings was higher than pure chromium oxide coatings, their structure was not stable at a temperature higher than 700 °C and their high hardness dropped to 30 GPa after 3 hours annealing at 800 °C. A heat treatment at 1000 °C is required to completely segregate Zr from the chromium oxide crystal structure to create a ZrO_2-Cr_2O_3 composite microstructure in the superhard coatings.

BP-ThP-43 Study of Erosion on Metals and Ceramic Coated Metals Using Magnetron Sputtering Process*, S Hill, D Mihut, A Afshar, Z Grantham, S Sanchez-Lara, **Christopher D. Raffield**, N Cordista, S Sanchez Lara,* Mercer University, USA

Solid particle impact erosion is a progressive loss of the materials' mass that results from repeated impact of the erodent particles on the material surface. Materials selection for equipment components working in this type of aggressive environmental condition is a great challenge. These materials must possess high strength, hardness, toughness, corrosion resistance but also high erosion resistance. This study uses an impact erosion tester to observe the effects of accelerated erosion on aluminum 6061 alloy and 4140 heat treated steel and assess their erosion behavior improvement after coating with titanium nitride and chromium nitride ceramics. A two phase mixture of water/sand is circulated in a custom test fixture and allowed to impact test coupons at specified angles. The set of experiments uses multiple sand concentrations, a fixed liquid flow rate, and a constant impact angle during the testing procedure to determine the improvement of erosion with the thin film coating. The ceramic thin film coatings on the samples are deposited using magnetron sputtering equipment, the thickness of the coatings is measured using a profilometer and the compositional structures of the coatings are characterized using X-Ray diffraction. The coating morphology and thin films adherence was investigated using Scanning Electron Microscopy (SEM).

Author Index

Bold page numbers indicate presenter