Protective and High-temperature Coatings
Room Golden State Ballroom - Session MA-ThP

Protective and High-temperature Coatings (Symposium MA) Poster Session

MA-ThP-1 Predictive Modeling and Experimental Validation of Phase Formation in High-Entropy Alloys Thin Films, ***Salah-eddine Benrazzouq (salah-eddine.benrazzouq@univ-lorraine.fr)**, J. Ghanbaja, S. Migot, J. Pierson, V. Milichko,* Institut Jean Lamour - Université de Lorraine, France

High-entropy alloys (HEAs) introduce a new class of materials that challenge existing theories on phase stability due to their complex, multi-element composition. Initially theorized to gain stability from the significant entropy associated with mixing five or more elements, these alloys have garnered interest for their potential applications. However, the scientific community has yet to develop a robust model that can predict with certainty which element mixtures will form a single-phase alloy. In this investigation, we try some predictive model grounded in thermodynamics to forecast the phase behavior of high-entropy alloys (HEAs). By computationally analyzing the enthalpies of binary compounds, the model identifies combinations of elements likely to form single-phase alloys. This method has successfully pinpointed all previously known single-phase HEAs and excluded compositions that result in multiple phases. Moreover, we have experimentally validated numerous new single-phase alloy compositions proposed by our model.

Subsequently, this work employed X-ray diffraction (XRD) and high-resolution transmission electron microscopy (HRTEM) to characterize the structural and microstructural properties of the films, specifically the Cantor alloy (CrMnFeCoNi) with additional elements like Pt, Cu, Ti, Zr, Al, and Ag. We found that the CrMnFeCoNi base alloy, along with its Pt and Cu variants, retained a homogeneous FCC crystalline structure. In contrast, the Al-modified films underwent a phase transformation from FCC to a mixed FCC+BCC structure and eventually to a singular BCC phase. The Ti and Zr variants exhibited amorphous structures at certain concentrations, whereas the Ag-doped films presented a multiphase structure with silver precipitates embedded in the Cantor alloy matrix.

Our findings show that some alloys consistent alignment between the predicted phases using thermodynamic criteria and the actual observed phases, even when the synthesis conditions are far from equilibrium. This consistency suggests a significant role of underlying thermodynamic factors in determining the phase stability of HEAs thin films.

MA-ThP-3 Optimizing Temperature Stability in Non-Reactively Sputtered (Hf,Ta,Ti,V,Zr)B-C-N Coatings by Design of the Non-Metal Sublattice, *A. Kretschmer, **Alexander Kirnbauer (alexander.kirnbauer@tuwien.ac.at)**,* TU Wien, Institute of Materials Science and Technology, Austria*; R. Frost, D. Primetzhofer,* Uppsala University, Sweden*; H. Rojacz, E. Badisch,* AC2T Research GmbH, Austria*; M. Hans, J. Schneider,* RWTH Aachen, Germany*; P. Mayrhofer,* TU Wien, Institute of Materials Science and Technology, Austria

In the past, we have studied the system (Hf,Ta,Ti,V,Zr)B-N with exceptional hardness and thermal stability, but the coatings contained a significant amount of C impurities, which may have influenced the properties [1]. To investigate the impact of C in this system, we have deposited new coatings with a TiN target, on which we placed diboride and/or carbide pieces of the metals Hf, Ta, V, and Zr. We have varied the composition by using either only diborides, only carbides, or different mixtures of the two material types to make 5 coatings containing either N and B, N and C, or all three. The B concentration varies between 42 and 0 at%, the C content between 25 and 0 at%, and the N content is stable at around 30 at% in all coatings. The Ti makes up roughly 20 at%, while the other metals are in the range between 2 and 5 at%. X-ray diffraction (XRD) shows a weakly textured single-phase fcc solid solution in all coatings. The FWHM of the 200 reflex ranges from 2 ° in the C-free coating down to 0.5 ° in the B-free coating, indicating different grain sizes. This is confirmed by transmission electron microscopy, revealing fine columnar growth in the 2.3 to 3.2 µm thick coatings, with especially fine grains in the B-richer coatings. Electron diffraction confirms that no secondary phases are present. We annealed the coatings in a vacuum furnace at 1000, 1200, and 1400 °C for 10 min, followed by XRD and nanoindentation. The coatings stay stable up to 1200 °C and start decomposing at 1400 °C. The as-deposited hardness of all coatings lies between 36 and 38 GPa, and is maintained after annealing at 1000 °C. After annealing at 1200 °C, the coatings containing only C or only B both soften to ~34 GPa, while the coatings with both C and B do not lose any hardness at this temperature. Only after annealing at 1400 °C does the hardness of all coatings drop below 30 GPa. The exceptional thermal stability of the solid solution was confirmed by atom probe tomography, which shows no onset of decomposition despite the high B content even after annealing at 1200 °C. Only after the 1400 °C annealing, a TiB_2 phase is formed.

[1] Kretschmer, A., Kirnbauer, A., Pitthan, E., Primetzhofer, D., Yalamanchili, K., Rudigier, H., & Mayrhofer, P. H. (2022). High-entropy alloy inspired development of compositionally complex superhard (Hf,Ta,Ti,V,Zr)-B-N coatings. *Materials & Design*, *218*, 110695. https://doi.org/10.1016/j.matdes.2022.110695

MA-ThP-4 Unravelling Diffusion Processes and Morphology Changes of Ternary and Quaternary Diborides During High-Temperature Oxidation, ***Sophie Richter (sophie.richter@tuwien.ac.at)**, A. Bahr, T. Glechner, T. Wojcik,* Christian Doppler Laboratory for Surface Engineering of high-performance Components, TU Wien, Austria*; S. Kolozsvári, P. Polcik,* Plansee Composite Materials GmbH, Germany*; O. Hunold, J. Ramm,* Oerlikon Balzers, Oerlikon Surface Solutions AG, Liechtenstein*; D. Primetzhofer,* Department of Physics and Astronomy, Uppsala University, Sweden*; P. Felfer,* Department of Materials Science and Engineering, FAU Erlangen, Germany*; H. Riedl,* Institute of Materials Science and Technology, TU Wien, Austria

Transition metal diborides (TMBs) are currently in the focus of diverse academic and industrial research studies, as they obtain a unique mix of properties. Here, especially their mechanical strength, chemical inertness, but also electrical conductivity is in focus [1]. However, the oxidation resistance is a weak point in binary TMBs and strongly limits a broad application. Therefore, to improve the oxidation resistance of transition metal diborides (TMB_2) at high temperatures (T > 1000 °C), alloying approaches using silicon (Si) as a strong oxide-forming element have been successfully established [2,3]. However, both ternary (TM-Si-B) and quaternary (e.g., TM-Mo-Si-B by alloying TMB_2 with $MoSi_2$) diborides have shown pore formation due to phase transitions and diffusion processes during oxidation above 1100 °C. Over extended periods of time (t > 1000 h), these pores significantly weaken the protective function of these coatings and depict a major challenge. In this study, physical vapor deposited ternary and quaternary transition metal diborides are investigated to study the influence of different alloying elements on the pore formation. In more detail, the influence of additional elements such as Mo or Ta based on disilicide alloying to TMBs is in focus. High-resolution techniques such as transmission electron microscopy (TEM), elastic recoil detection analysis (ERDA), Rutherford backscattering spectrometry (RBS), and atom probe tomography (APT) are used to gain insights on the prevailing phase transformations, diffusion processes and hence pore formation. These results are correlated with mechanical analysis to assess the tolerance with respect to porosity.

[1] M. Magnuson et al., Review of transition-metal diboride thin films, Vacuum. 196 (2022) 110567.

[2] T. Glechner et al., Influence of Si on the oxidation behavior of TM-Si-B2±z coatings (TM = Ti, Cr, Hf, Ta, W), Surf. Coat. Technol. 434 (2022) 128178.

[3] A. Bahr et al., High-temperature oxidation resistance of ternary and quaternary Cr-(Mo)-Si-B2-z coatings — Influence of Mo addition, Surf. Coat. Technol. 468 (2023) 129733.

MA-ThP-5 Influence of Mo on DCMS and HiPIMS Deposited $TiB_{2\pm z}$ Thin Films, ***Anna Hirle (anna.hirle@tuwien.ac.at)**, P. Dörflinger, R. Hahn, T. Wojcik,* Christian Doppler Laboratory for Surface Engineering of High-performance Components, TU Wien, Austria*; S. Kolozsvári, P. Polcik,* Plansee Composite Materials GmbH, Germany*; O. Hunold,* Oerlikon Balzers, Oerlikon Surface Solutions AG, Liechtenstein*; H. Riedl,* Institute of Materials Science and Technology, TU Wien, Austria

Titanium diboridethin films deposited by physical vapor deposition are typically attributed to inherent brittleness. Theoretical predictions by DFT assessing the elastic constants revealed that the formation of ternary Ti-Mo-$B_{2\pm z}$ might be a suitable approach to gain a less brittle character.

In the present study, the accompanying experiments to the theoretical investigations have been conducted. Three different target compositions were used for the non-reactive growth of ternary $Ti_{1-x}Mo_xB_{2\pm z}$ thin films: TiB_2/MoB 95/5 mol%, TiB_2/MoB 90/10 mol%, and TiB_2/MoB 80/20 mol%. The binary $TiB_{2\pm z}$ system was deposited with a TiB_2/C 99/1 wt.% target. In addition, direct current magnetron sputtering (DCMS) and high-power impulse magnetron sputtering (HiPIMS), were employed in order to investigate the influence of different deposition techniques – hence ionization degrees.

The structural and mechanical properties of the coatings were characterized by a broad variety of methods, such as scanning electron microscopy, X-ray diffraction analysis, and nanoindentation. The chemical composition was determined by inductively coupled plasma optical emission spectrometry and elastic recoil detection analysis. To verify the suggested enhancement on the brittle behavior of $Ti_{1-x}Mo_xB_{2\pm z}$ fracture characteristics such K_C or K_{IC}have been determined by cube corner indentation and in-situ micro-mechanical bending tests, respectively. Alloying of Mo leads to an increase in Ti content and a decrease in B content for both DCMS and HiPIMS deposited coatings. In contrast, the Mo content is significantly lowered while using HiPIMS. All coatings exhibit α-structured (SG191) $Ti_{1-x}Mo_xB_{2\pm z}$ solid solutions. An increased hardness for both binary and ternary thin films, with a maximum value of 45 ± 1 GPa ($TiB_{2\pm z}$) and a minimum 28 ± 0.8 GPa (~ 6 at.% Mo) can be obtained by using HiPIMS. Overall, this study highlights the influence of Mo additions on the structure-mechanical properties of $TiB_{2\pm z}$ using different growth techniques.

MA-ThP-7 Impact of the B/Ti-ratio on Microstructure, Mechanical Properties, and Thermal Stability of DCMS and HiPIMS TiB_2 Thin Films*, **Ludwig Enzlberger (ludwig.enzlberger@tuwien.ac.at),*** TU Wien, Institute of Materials Science and Technology, Austria*; M. Podsednik,* TU Wien, Austria*; S. Kolozsvari,* Plansee SE, Germany*; A. Limbeck,* TU Wien, Austria*; P. Mayrhofer,* TU Wien, Institute of Materials Science and Technology, Austria

Titanium diboride is widely known as a superhard material achieving an indentation hardness of 40 GPa and beyond. Coatings of TiB_2 produced by DC magnetron sputtering (DCMS) are typically in the superstoichiometric regime regarding the B/Ti-ratio in a range of $TiB_{2.4}$ to $TiB_{3.5}$. This surplus in Boron is attributed to a different radial distribution of Boron and Titanium during the deposition process and forms a tissue phase which is highly relevant for the material's mechanical properties.

A reduction of Boron content in the coating would thus mean a reduction of tissue phase formed and consequently a clear change in e.g., hardness or fracture toughness. Earlier works have already shown an increase in fracture toughness (measured by microcantilever bending) of DC-sputtered TiB_2 when reducing the B/Ti-ratio from 4.4 to 2.1. There have also been reports of even higher fracture toughness in understoichiometric $TiB_{1.43}$ produced through high power impulse magnetron sputtering (HiPIMS) and measured by cube corner indentation, while films grown by DCMS showed a decrease in K_C with decreasing B-content.

Here we address this discrepancy, via detailed studies of DCMS as well as HiPIMS developed $TiB_{2\pm z}$ thin films with B/Ti-ratios varying between 1.5 and 3.2. The stoichiometry of DCMS-grown films is adjusted by placing Ti-pieces at the target race track, while that of HiPIMS-grown films is adjusted by varying the pulse on-time. The B/Ti-ratios are measured by ICP-OES and the mechanical properties are characterized by nanoindentation (Hardness, Young's Modulus) as well as cube corner indentation for K_{IC}. Vacuum annealing treatments with subsequent detailed transmission electron microscopy studies as well as nanoindentation experiments clarify the impact of the B/Ti ration on these important characteristics.

MA-ThP-8 Synthesis and Characterization of $AlMgB_{14}$ Thin Films*, **Erwin Peck (erwin.peck@tuwien.ac.at)**, A. Kirnbauer,* TU Wien, Institute of Materials Science and Technology, Austria*; S. Kolozsvari,* Plansee Composite Materials GmbH, Germany*; P. Mayrhofer,* TU Wien, Institute of Materials Science and Technology, Austria

When it comes to the protection of tools and the increase of their lifetime, protective coatings with high hardness, good wear resistance, and low coefficients of friction are commonly used. Typically, nitrides, carbides, and borides –specifically metal-diborides such as TiB_2, ZrB_2, and TaB_2 – are selected as protective coating materials.

Here, we concentrate on more complex borides, $AlMgB_{14}$, and study their microstructure, mechanical properties, thermal stability, and wear resistance.

$AlMgB_{14}$ is a very promising material with reported high hardness (even superhardness, > 40 GPa), high thermal stability, and very low coefficients of friction. We developed $AlMgB_{14}$ coatings by magnetron sputtering, using a single composite $AlMgB_{14}$ target, and varying the substrate temperatures between 300 and 600 °C. All of these coatings were amorphous in their as-deposited state with hardness increasing from 29.3±1.6 GPa to 42.1±1.5 GPa upon increasing the substrate temperature from 300 to 600 °C. Simultaneously, their indentation moduli only increase from 373±17 to 497±14 GPa and their residual compressive stresses vary between -2 and -3 GPa. Their fracture toughness values – derived from cube corner indentation experiments – increase from 3.72±0.46 to 5.15±0.22 MPa√m with increasing substrate temperature. To gain information about the thermal stability of the coatings, they were vacuum annealed up to 1050 °C and subsequently investigated by TEM, XRD and nanoindentation.

MA-ThP-9 Non-Reactive Magnetron Sputtering of Al-N Coatings*, **Balint Hajas (balint.hajas@tuwien.ac.at)**, A. Foki, T. Wojcik,* TU Wien, Institute of Materials Science and Technology, Austria*; D. Primetzhofer,* Uppsala University, Angstrom Laboratory, Sweden*; S. Kolozsvari,* Plansee SE, Germany*; P. Mayrhofer,* TU Wien, Institute of Materials Science and Technology, Austria

Hard protective coatings allow for increased lifetime of machining tools and more versatile applications. Although AlN-based coatings have a rich history in material science with various improvements for their production, little is known about non-reactive deposition using ceramic AlN compound targets. Aluminium nitride in its hexagonal close packed (hcp) wurtzite-type structure has the highest thermal conductivity among ceramic materials, a large electromechanical coupling factor and temperature stability, as well as a high acoustic velocity.

Reactive deposition of such AlN coatings is studied in-depth, showing that especially for sputtering the resulting microstructure and consequently properties (next to deposition rate) hugely depend on the N2-partial pressure used. Alternatively, such nitrides can also be prepared non-reactively using nitride compound targets. Here, we use powder metallurgically prepared AlN compound targets to prepare coatings with pulsed DC magnetron sputtering with a 3" target and a 6" target.

The primary investigations focused on how the mechanical properties such as hardness and indentation modulus depend on various deposition conditions, such as sputtering power density, pulse frequency, substrate temperature, substrate-to-target distance and plasma condition. Additionally, several experiments were conducted by adding H_2 to Ar to study the effect of a reducing agent during the ion-etching of the substrate as well as during the deposition of the AlN film. To counteract understoichiometry, we added sometimes N_2 as well.

Detailed investigations by X-ray diffraction reveal that all coatings were single-phase hcp-structured, with various amounts of an amorphous phase and/or a metallic Al, depending on the deposition conditions. The highest hardness obtained for such films is 26.9 GPa. With the addition of H2 to the working gas Ar, the discharge became more stable even for high power densities, allowing for a deposition rate of up to 1 µm/h.

MA-ThP-10 Effects of the Modulation Period and Ratio on Mechanical Properties and Oxidation Resistance of WB_2/AlB_2 Superlattices*, **Chun Hu (chun.hu@tuwien.ac.at),*** Institute of Materials Science and Technology, TU Wien, Austria*; R. Hahn,* Christian Doppler Laboratory for Surface Engineering of High-performance Components, TU Wien, Austria*; T. Wojcik, R. Janknecht, N. Koutná, P. Mayrhofer,* Institute of Materials Science and Technology, TU Wien, Austria

Superlattice structures offer a unique playground for simultaneous hardness and fracture toughness enhancements by tuning the layer thicknesses and volume ratio of the layer constituting materials. The superlattice effect has been widely studied within the cubic transition metal nitrides but nearly unexplored for hexagonal transition metal diborides (TMB). Here we focus on the nanolayered WB_2/AlB_2 system, where already one of the chosen materials, AlB_2, is nearly unreported despite its great potential for increasing the typically low oxidation resistance of TMB. Aiming to combine exceptional mechanical properties and oxidation resistance, we develop WB_2/AlB_2 superlattice thin films with different modulation periods (λ, 3-50 nm) and thickness ratios (η, WB_2/AlB_2=1, 2, 3). All superlattices reveal single-phase AlB_2-type structure. With the template effect of the WB_2 layers, the AlB_2 layers are supported for their crystallization as single phase AlB_2-type layers, even for deposition parameters which would otherwise result in a dual phase constitution of Al and AlB_{12}. TEM investigations of selected samples reveal clearly coherent interfaces between WB_2 and AlB_2 layers. Nanoindentation studies show that these WB_2/AlB_2 superlattice films facilitate the superlattice effect for hardness, which we rationalize with the shear modulus mismatch and modulation period. Among the WB_2/AlB_2 superlattices studied here, the one with λ of 3 nm and η of 2 shows the highest hardness (33.1 GPa), compared to the 26.6 GPa calculated from rule of mixing. Isothermal oxidation experiments demonstrate significantly improved oxidation resistance of WB_2/AlB_2 superlattices compared with WB_2 monolithic thin film.

MA-ThP-11 Effect of Preplaced Graphene and Graphite Films on Stellite 6 Metallurgical Coatings, *J. Sippel,* PG-MEC/ Universidade Federal do Paraná, Brazil; *W. de Oliveira,* Universidade Estadual de Ponta Grossa, Brazil; *J. Ribeiro da Cruz Alves,* Instituto Senai de Inovação - Sistema de manufatura e Processamento a laser, Brazil; ***Ana Sofia C. M. d'Oliveira (sofmat@ufpr.br)***, Universidade Federal do Paraná, Brazil

Protective coatings are a key player on a sustainable development of equipment with a longer and better service life**.** This goal motivates the search for better coatings offering the opportunity to put together new materials and efficient processing techniques. Carbon-based compounds are materials widely studied for their unique properties which are distinct from others engineering materials due to a variety of atomic arrangement. These materials exhibit excellent mechanical, thermal and tribological properties. An approach to use these materials is tailoring a metal matrix composite focusing on improved performance through the he distribution of carbon compounds in the matrix. This study is part of an ongoing project on the development of carbon-base compounds metallic matrix hardfacing coatings by Plasma Transferred Arc (PTA). PTA process is a hardfacing process that uses feedstock in the powder form that melts in a plasma arc column allowing for the customization of coatings. Although literature reports coatings reinforced with carbon compounds materials were produced by powder metallurgy before deposition by PTA. This work assesses the impact of pre-deposited layers of graphene and graphite on Co based (Stellite 6) coatings processed by PTA, particularly at the interface with the substrate. Deposition was carried out on AISI 304L stainless steel, with and without predeposited films of graphite and graphene, with a surface Sq roughness of 1.4 µm for better anchoring of the preplaced micro/nanoparticles of graphite and graphene, respectively. The geometry at the cross section of single beads showed the dilution of coatings with modifying particles being higher than pure that of Stellite 6 coating. EDS analysis showed an increased presence of iron in the coating, explained by increased dilution. EBSD characterization revealed a larger heat affected zone in the substrate of graphene-modified coating, exhibiting smaller grains due to recrystallization, comparing with others processed coatings, suggesting that this material increases thermal transfer from the plasma arc to the substrate. The Vickers microhardness shows graphite improves hardness and graphene reduces it. Nanoscratch testing on the coatings near the fusion line revealed lower wear rate in the graphene-modified coating when compared to the Co-based coatings with and without graphite. The contributions of this research include: (1) advances on identifying viable techniques for processing graphite and graphene enriched coatings, (2) understanding the influence of graphene and graphite in Stellite 6 hardfacing coatings.

MA-ThP-12 Modified High Hardness Steel Coating for Biomass Combustion Boilers, ***Alina Agüero Bruna (agueroba@inta.es)***, Ctra. Ajalvir km 4, Spain; *M. Gutierrez, S. Rodríguez,* Instituto Nacional de Técnica Aeroespacial (INTA), Spain

Biomass is a renewable, CO_2 neutral source of energy. However, the efficiency of biomass combustion plants is not as high as that currently obtained with fossil fuels. Biomass plants currently operate at a maximum temperature of 550º C in order to reduce corrosion caused by the very aggressive species present in biomass combustion. In the European project BELENUS, new materials and coatings are being evaluated, aiming to increase the operating temperature to 600 ºC and consequently the plant efficiency. Among the different coatings that are being studied, a high hardness steel modified with Al, applied by HVOF thermal spray has shown a very promising performance in the laboratory when exposed to a model biomass environment including KCl deposits, for 8000 h. Moreover, the coating has also been tested in pilot plants burning eucalyptus and wheat straw at 600º C for 2000 h and the results indicate high resistance to corrosion. Microstructure analysis of the tested samples by SEM, EDS and XRD, was performed in order to study the coating evolution in these environments as well as the protection and degradation mechanisms.

MA-ThP-13 Effect of Austenite Stability on Pack Aluminizing of Stainless Steels, ***Bryant Hernandez (bdh@cpp.edu)***, *C. Sullivan, L. Rodriguez, V. Ravi,* California State Polytechnic University, Pomona, USA

Austenitic stainless steels are extensively used in a range of engineering applications. When high temperatures are involved, oxidation is an issue that may affect service life. In certain use conditions, phenomena such as molten salt attack may also be relevant. Under these adverse operating conditions, it would be advisable to modify the surface of stainless steel components for ensuring reliability and additional life. In this study, the surfaces of stainless steels were aluminized using the halide-activated pack cementation process. The particular focus of this study was to investigate the relationship between the stability of austenitic stainless steels and aluminide coating characteristics, e.g., thickness and morphology. Aluminizing of SS 304 and SS 330 resulted in mass gains per unit area. An inverse relationship between the austenite stability of these stainless steels and the respective aluminide coating thicknesses was obtained. Other stainless steels being studied include SS304L, SS301, and SS302B. It is notable that these alloys have lower austenite stabilities than SS 304 and SS 330. The results of these studies will be discussed and placed in context with respect to previous studies from this group and others. The results of these studies will provide valuable insights for industrial applications where the surfaces of austenitic stainless steels need to be protected against high temperature degradation.

MA-ThP-14 Co-Deposition of Chromium and Silicon on Nickel, and Iron-Based Alloys, ***Catherine Sullivan (cdsullivan@cpp.edu)***, *B. Hernandez, L. Rodriguez, A. Coronado, V. Ravi,* California State Polytechnic University, Pomona, USA

Halide activated pack cementation is a surface modification process in which, typically, a single element is deposited onto the surface of an alloy and subsequently incorporated into the substrate through diffusion. For some applications, it would be desirable to co-deposit more than one element simultaneously onto the substrate surface. During service life, this co-deposited surface would offer improved resistance to degradation in high temperature environments. The current study focuses on chromium-silicon codeposition process studies via halide activated pack cementation. Coatings containing chromium are expected to improve the corrosion resistance of the alloy, while the presence of silicon should improve the erosion resistance, thereby providing a dual benefit when co-deposited. The results of the co-deposition process for pure nickel and selected ferrous alloys will be presented and discussed. The discussion will incorporate coating characterization including phase analysis using x-ray diffraction, microstructural characterization using optical and scanning electron microscopy, and elemental analysis using energy dispersive spectrometry.

MA-ThP-15 Corrosion Behavior of Galvanized Coils in Coastal Warehouse Environment, ***Baiyou Fang (Fangby88@163.com)***, Baosteel-NSC Automotive steel Sheets Co., Ltd, China

To investigate the corrosion failure of packed galvanized coils in a coastal warehouse, a scanning electron microscope with energy disperse spectroscopy and a Raman spectrometer were employed to observe corrosion morphologies of rusty surfaces and detect their chemical compositions. In general, two types of rusts were distinguished, the white grey and the red brown, in which the white corrosion product was a mixture of ZnO, $Zn(OH)_2$, $Zn_4SO_4(OH)_6$ and $Zn_5(CO_3)_2(OH)_6$, and the brown one was mainly composed of γ-FeOOH. In light of these, the corrosion mechanism was determined for the galvanized sheets. Due to the day-and-night temperature difference and high humidity, condensation took place readily, providing electrolyte for corrosion process. Further the zinc coatings react with O_2, H_2O, CO_2 and SO_2 depositing on the surface of galvanized sheet during the initial stage of corrosion, resulting in the white corrosion product. After the exhausting of galvanizing effect in the local area, the steel substrate started to corrode, and thus the red brown product formed.

MA-ThP-16 Development of Zr-Ta Anticorrosion Coatings for Nuclear Applications Using PVD HiPIMS Technology, ***Cécile Marsal (cecile.marsal@cea.fr)***, Commissariat à l'Énergie Atomique et aux énergies alternatives Centre de Saclay, France

Reprocessing of spent fuel is essential to establish a sustained nuclear cycle, as it enables reusable materials to be recycled and waste to be limited. This retreatment requires the use of nitric acid, which is particularly corrosive for the materials making up the equipment used for fuel reprocessing. However, most of the materials that efficiently passivates in the reprocessing media are expensive, which hinders their direct use. Alternatively, they can be used as coating, the protective performance on which may be further enhanced by mixing two or more complementary elements.

In this study, the corrosion resistance in a nitric acid environment of zirconium-tantalum and zirconium-chromium coatings of distinct compositions on 304L stainless steel was scrutinized. Coatings were elaborated by High-Power Impulse Magnetron Sputtering (HiPIMS), using a tandem target setup allowing for combinatory synthesis of high quality adherent coatings made of Cr-Zr or Ta-Zr solid solutions. The adherence, composition and microstructure of coatings were then characterized by SEM and XRD. Immersion tests in nitric acid demonstrated the appreciable gain in substrate protection with respect to the aggressive environment used for fuel reprocessing.

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MA-ThP-17 Study on Physical Phenomena During Precise Cutting with Novel WCCo/cBN Composite Cutting Tools Equipped with Various Anti-Wear Coatings, ***Szymon Wojciechowski (szymon.wojciechowski@put.poznan.pl)***, *R. Talar, P. Zawadzki,* Poznan University of Technology, Poland

Recent research on the development of modern tool materials with improved cutting-performance focuses on the production of hybrid materials combining the advantages of carbides and superhard materials (cBN and PCD). Examples of such materials are novel WCCo/cBN composites obtained by pulse-plasma sintering (PPS). However, the preliminary studies reveal that during cutting of hard-to-cut materials with these novel WCCo/cBN cutting tools an intense built-up-edge (BUE) formation, together with adhesion wear can appear. Thus, in order to improve the cutting ability of WCCo/cBN materials, the anti-wear coatings can be applied. This work is focused on the analysis of physical phenomena and tool wear during turning of spheroidal cast iron with coated (with TiN and TiAlN coatings) and uncoated WCCo/cBN tools. The conducted studies involved the evaluation of a fundamental cutting process physical indicators, as cutting forces and vibrations. Moreover, an updated Merchant cutting model was applied for a determination of the average coefficient of friction on the rake face. The proposed approach considered both the shearing forces related to the chip formation mechanisms, as well as the edge forces related directly to rubbing phenomena occurring between the flank face of a tool and workpiece. Ultimately, the tool wear mechanisms and tool life of the uncoated and coated WCCo/cBN inserts were identified and compared with ones obtained during cutting with a coated and uncoated cemented carbide tools. The obtained results showed the presence of a built-up-edge (BUE) on the flank face of the uncoated WCCo/cBN tool throughout the entire range of cutting speed. In the case of WCCo/cBN inserts with TiN and TiAlN coatings, a BUE was also observed, however, its intensity was significantly lower comparing to that obtained during cutting with the uncoated BNDCC tool. The highest tool life was obtained during grooving with the WCCo/cBN inserts with TiAlN coatings and then with WCCo/cBN inserts equipped with TiN coatings. The tool life obtained for a cemented carbide inserts with TiAlN coating was significantly lower than that for a WCCo/cBN TiAlN insert.

Author Index

Bold page numbers indicate presenter