Surface Engineering - Applied Research and Industrial Applications

Room Grand Exhibit Hall - Session GP

Symposium G Poster Session

GP-2 Oxidation Resistance of Cr_2N and Cr_2WN Coatings Deposited on Ferritic Stainless Steel, *S Yang,* ***Yung-Ting Huang,*** National University of Kaohsiung, Taiwan*; Y Chang,* National Formosa University, Taiwan*; D Lin,* National University of Kaohsiung, Taiwan

Bipolar plate is a key component of solid oxide electrolysis cells, which increases the power density and decreases the costs of the stacks. In general, high operating temperature cause a severe oxidation to decline electrical conductivity. Although Crofer 22 APU (ferritic stainless steel) was developed specifically for SOFC interconnect applications, the oxidation rate is not sufficiently low to enable uncoated Crofer22 APU interconnects to meet the current 40,000 h SOFC lifetime requirement. Therefore, Crofer 22 APU also requires a protective coating both to retard the oxidation rate and to prevent the volatile chromium species.

In this study, Cr_2N and Cr_2WN coatings were selected as the protective coatings deposited on Crofer 22 APU ferritic stainless steel by cathodic arc evaporation. Oxidation kinetics of the Cr_2N- and Cr_2WN-coated samples was evaluated via isothermal tests in atmospheric furnace at 800°C for 1,000 h. Morphology and cross sections of scales were examined under a field-emission scanning electron microscope in both backscattered and secondary electron modes. Coating phase assemblies were assessed using X-ray diffraction. High resolution transmission electron microscopy was utilized for a close examination of the coating/alloy interfacial chemistry. The results showed Cr_2N and Cr_2WN-coatings on Crofer 22 APU possessed denser structure and excellent adhesion between coating/alloy. The top scale of Cr_2N and Cr_2WN-coatings belong to spinel structure, but Cr_2WN-coating had higher manganese content than Cr_2N-coating after 1,000 h oxidation. In addition, Cr_2WN-coating possessed smooth surface of scale due to W-doping to decrease surface roughness. After 1,000 h oxidation, both Cr_2N and Cr_2WN-coatings had bilayer scales were Cr_2O_3 and $(Mn,Cr)_3O_4$. Both Cr_2N and Cr_2WN-coatings had excellent anti-oxidation performance; moreover, Cr_2WN-coating had the lower oxidation rate constant than Cr_2N-coating.

GP-4 Synergetic Effect Improved Deposition of Titanium Nitride Films, *C Chang,* Ming Chi University of Technology, Taiwan*; C Ho,* MingDao University, Taiwan*; P Chen,* Da-Yeh University, Taiwan*; W Chen, D Wang,* MingDao University, Taiwan*;* ***Wan-Yu Wu,*** Da-Yeh University, Taiwan

Cathodic arc deposition (CAD) has been widely used in industry for high quality thin film coatings. However, the CAD also produces macro particles or droplets during the deposition process. leading to the degradation of the film properties. Lately, a newly developed physical vapor deposition process known as high power magnetron sputtering (HiPIMS) was found to have the capability of yielding highly ionized flux of both gas and sputtered materials by applying a high power in short pulses to the target. As a result, a smoother and denser thin film with better adhesion to the substrate can be obtained, leading to enhanced mechanical, electrical, and optical properties. However, it was also found the deposition rate of the HiPIMS process was much slower than conventional dc magnetron sputter deposition and CAD. Therefore, a hybrid deposition system combining CAD and HiPIMS was studied in this paper to gain synergetic effect. The two processes were used alternatively in different sequences. Titanium nitride (TiN) film was deposited in such hybrid system to investigate their microstructure and the mechanical properties, including surface roughness, hardness and friction coefficient. We demonstrate that the hybrid deposition system provides a synergetic effect of combining the advantages and compensates the diadvantages of these two deposition techniques. It was found that the macro particles are suppressed. Enhanced hardness was observed in CAD based TiN thin film.

GP-5 Fuel Cell Hot Runner-layer Composite Carbon Bipolar Plates, *S Wu,* MingDao University, Taiwan*;* ***Ai-Huei Chiou,*** National Formosa University, Taiwan*; Y Huang,* Fujian University Of Technology, China

Bipolar plate is one of the important components of proton exchange membrane fuel cell (PEMFC), which in addition to the fuel and the gasifying agent supplied to the reaction zone may be external, and has removed the product, collect current, and as a mechanical support structure of the cell stack . Weight and cost of the proportion of the bipolar plates accounted for 60% and 30% of the battery. Therefore, by using cheap materials and lightweight design to improve the flow channel, will greatly reduce the weight, size and cost of the battery. Therefore, the present study used a lightweight inexpensive PMMA sheet as a bipolar plate body molding material, the use of hot pressing technology has been formed on the upper layer of the PMMA sheet of conductive graphite carbon powder , made of composite bipolar plate. And by hot pressing temperature, time and pressure control, work out the optimum parameters. At the same time, also made out of composite bipolar plate corrosion resistance, electrical conductivity and surface material graphite adhesion effect analysis.

GP-6 Oxinitride Coatings for Milling Tools, ***Joern Kohlscheen,*** Kennametal GmbH, Germany*; V Derflinger,* Oerlikon Balzers, Oerlikon Surface Solutions AG, Liechtenstein

Industrial manufacturing has to adapt to an increasing share of difficult-to-cut materials like stainless steels and nickel based alloys. Well-established nitride coatings like TiAlN have limitations in friction behavior and high temperature stability. To overcome some of these limitations, oxide and oxinitride thin films are becoming more popular in PVD coating research and application. The Al-O system is generally considered as first choice and has been studied intensively. In the present work, a well proven AlTiN base layer was modified by adding one or more AlON and AlCrON layers with a thickness of up to 1 micron. Deposition was done by cathodic arc PVD using a commercial system on carbide samples (WC/Co). Al cathode material was evaporated in a plasma of pure oxygen or an oxygen/nitrogen gas mixture. Basic mechanical properties of the resulting multi-layers were determined by universal hardness testing. Structural analysis was done by SEM and XRD. It will be shown that oxidic top layers have quantifiable effects on friction and wear behavior. AlTiN/AlON multi-layers seem to be more resistant against abrasive wear than mono or bi-layer (nitride/oxide) coatings of comparable thickness. The main effect of the oxidic top layer(s) seems to be reduction of the friction in the cutting process. Milling of mild steel (dry and wet) was performed to test the wear behavior of the coated carbide inserts (ISO P). Thermal cracking at the cutting edge could be significantly reduced when oxide top layers were added.

GP-8 Phase Composition, Microstructure Evolution and Wear Behavior of Ni-Mn-Si Coatings on Copper by Laser Cladding, ***Peilei Zhang,*** *X Liu, H Yan,* Shanghai University of Engineering Science, China

Three Ni–Mn–Si coatings were synthesized on copper plate by laser cladding. There are Mn_5Si_2, Mn_5Si_3, Mn_3Si, Ni_3Si, Ni_2Si, Cu_3Si, Mn_3Ni_2Si and $Mn_6Ni_{16}Si_7$ in three coatings. Ni_2Si and Ni_3Si were found in Coating 1# and 2# and there is not any $MnSi_{1.75-x}$ phase in three coatings. Mn_3Ni_2Si phase was found in Coating 1# and $Mn_6Ni_{16}Si_7$ phase was found in Coating 2# and 3#. Phases in Coating 1# should be MnSi + MnNiSi. $Mn_{15}Ni_{50}Si_{35}$ and $Mn_3Ni_3Si_2$ were found in Coating 2#. $Mn_3Ni_3Si_2$ and Mn_3Ni_2Si were found in Coating 3#. Cu_3Si was found in all three coatings. The highest hardness which is about 1100 HV occurs in the clad layer of Coating 1#. Metal silicates (Ni-Si and Mn-Si) are the major factor in increasing the hardness of coatings. There are mainly Ni-Si metal silicates in Coating 1#, Mn-Si metal silicates in Coating 2# and 3#. Hardness of Ni-Mn-Si coatings depends on Ni-Si phases especially Ni_3Si in laser processing. The average friction coefficient for Coating 1#, Coating 2# and Coating 3# is 0.1964, 0.2393 and 0.2582, respectively. Ni-Si phase plays a more important role than Mn-Si in increasing the hardness and decreasing the friction coefficient of coatings.

GP-9 Assessment of Surface Integrity During Machining of Superduplex Stainless Steel Obtained With Three Different PVD Hard Coatings, ***Edinei Locks Junior,*** Católica SC, Brazil*; P Stolf, M Martins,* Centro Universitário Cátolica de Santa Catarina - CATÓLICA -SC, Brazil*; F Amorim, R Diego Torres,* Pontifícia Universidade Católica do Paraná - PUCPR, Brazil*; J Paiva,* Centro Universitário Católica de Santa Catarina - CATÓLICA -SC, Brazil

The Superduplex stainless steel (SDSS) are biphasic materials compound portion of ferrite and austenite with equal parts approximately as well as high levels of chromium and nickel in its chemical composition. This materials are usually employed as pipeline for offshore oil and gas industry. During the cutting process this material presents the follow combination: (i) It shows a tendency to work hardening the surface reflecting in microstructural modifications and residual stress on surface machined; and (ii) It presents high temperatures in the cutting region, resulting in a reduction of tool life. The goal of this work is to evaluate the surface integrity (work hardening and stress corrosion behavior) of the SDSS

obtained after machining process (finish turning) with cemented carbide tools coated with three different PVD coatings. The cemented carbide inserts were coated by Physical Vapor Deposition (PVD) with $Al_{50}Cr_{50}N/Ti_{95}Si_5N$, $Al_{50}Cr_{50}N$ and $Al_{67}Ti_{33}N$. The responses analyzed were tool wear, microstructural characterization, machined surface and stress corrosion analysis. The results indicate that aluminum-rich ($Al_{67}Ti_{33}N$) coatings improve the wear resistance of inserts in this type of machining as well as reduce the surface hardening levels of machined part, reflecting in a better stress corrosion resistance.

GP-11 Surface and Interface Characterstics of CeO_2 doped Al_2O_3 Coating on Solution Treated and Peak Aged AZ91 Mg Alloy, ***Sanjeet Kumar**, D Kumar, J Jain,* Indian Institute of Technology Delhi, India

Mg alloy, being lightest among the engineering materials, has limited use in automotive, biomedical and structural industries due to poor surface mechanical properties. Protection against wear and corrosion may increase the use of Mg-alloys in various engineering applications. Wear and corrosion being the surface related phenomenon, surface modification by various techniques can be sought for improved performance. This paper investigates the deposition and estimation of surface and interface properties of thermally sprayed alumina based coatings. Effect of CeO_2 doping into Al_2O_3 based coatings is also explored. The elastic modulus and hardness at surface and interface both were measured using nanoindentation. In order to investigate the role of substrate microstructure on coating characteristics, the solution treated and peak aged samples of AZ91 Mg alloy have been used as a substrate material. The coatings were characterized using scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS), X-ray diffraction (XRD). The results indicate that peak aged substrate microstructure results in coating with better interfacial properties as compared to solution treated case. The role of ceria doping in manipulating the microstructure is discussed in detail.

GP-14 Vacancies in MONTAN – a Mechanism for Tuning the Hardness–toughness Relationship, ***Fedor F. Klimashin**, CDL-AOS TU Wien, Austria; M Arndt,* Oerlikon Balzers, Oerlikon Surface Solutions AG, Liechtenstein*; P Polcik,* Plansee Composite Materials GmbH, Germany*; L Lobmaier, N Koutná,* TU Wien, Austria*; D Holec,* Montanuniversität Leoben, Austria*; P Mayrhofer,* TU Wien, Austria

The cubic-structured nitrides of Mo and Ta exhibit excellent tribo-mechanical and electrical properties and are often used as alloying components for improving e.g. materials resistance against wear and oxidation. The outstanding properties both materials owe to their inherent driving force to form vacancies, which are commonly disregarded for any material.

Fusing Mo–N[1,2] with Ta–N[2] – experimentally and theoretically – we have investigated a novel quasi-binary materials system Mo–N–Ta–N. Its natural preference for point defects inherited from relative binaries can furthermore be significantly influenced e.g. by altering the chemical potentials. When dealing with the point defects, the *ab initio* studies are of a great significance: particularly to distinguish between the structures developing “without” point defects and with Schottky defects is anything but trivial experimental issue. Varying the type and volume density of vacancies we present the evolution of structure and mechanical properties of “MoNTaN” coatings. The insights into the origin of the observed phenomena allow us to tune the hardness–toughness relationship and hence design materials for applications requiring tailor-made properties.

References:

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GP-15 Effects of Solidification Behaviour on the Microstructure, Hardness and Corrosion Resistance Properties of Laser Alloyed Al-Fe-Si Coatings, *E Akinlabi,* ***Olawale Fatoba**, E Makhatha,* University of Johannesburg, South Africa

Aluminum and its alloys have been a successful metal materials used for many applications like commodity roles, automotive and vital structural components in aircrafts. A substantial portion of Al-Fe-Si alloy is also used for manufacturing the packaging foils and sheets for common heat exchanger applications. The present research was aimed at studying the morphology and distribution of the iron-containing intermetallics in the Al-Fe-Si alloy. These Fe-intermetallic compounds influence the material properties during rapid cooling by laser alloying technique and play a crucial role for the material quality. Thus, it is of considerable technological interest to control the morphology and distribution of these phases in order to eliminate the negative effects on microstructure. A 3 kW continuous wave ytterbium laser system (YLS) attached to a KUKA robot which controls the movement of the alloying process was utilized for the fabrication of the coatings at optimum laser parameters. The fabricated coatings were investigated for its hardness and corrosion properties. The corrosion performance was investigated in 0.5M H_2SO_4 and 0.5M NaCl solutions at 30^oC via Open Circuit Potential (OCP) and Linear Polarization techniques. The field emission scanning electron microscope equipped with energy dispersive spectroscopy (SEM/EDS) were used to study the morphology of the fabricated coatings and X-ray diffractometer (XRD) for the identification of the phases present in the coatings . The coatings were free of cracks and pores with homogeneous and refined microstructures. The enhanced hardness and anti-corrosion performances were attributed to metastable intermetallic compounds αAlFeMnSi, $Fe_2Si_2Al_2$, Fe_3SiAl_{12}, Al_5Fe_2, Fe_5Si_3, $Al_4Fe_5Si_6$ formed. Computational model used in this research authenticates reasonably with the experimental results.

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