Surface Engineering - Applied Research and Industrial Applications

Room Pacific D - Session G2-2-WeA

Surface Modification of Components in Automotive, Aerospace and Manufacturing Applications II

Moderator: Dr. Jan-Ole Achenbach, KCS Europe GmbH, Germany

2:20pm **G2-2-WeA-2 Effect of Different Diffusion Treatments on the Surface Properties of Austenitic Stainless Steels**, ***Phillip Marvin Reinders***, *P. Kaestner, G. Bräuer,* Technische Universität Braunschweig, Germany

The aim of the present study is to investigate the influence of plasma diffusion treatments with different process gases on the surface properties of austenitic stainless steels. This is necessary to functionalize austenitic stainless steels as a material for hydrogen applications, such as bipolar plates in the proton-exchange membrane fuel cell (PEMFC).

For this purpose, the austenitic stainless steel X2CrNiMo17-12-2 (AISI 316L) was modified by low temperature plasma diffusion treatment. The experimental investigations focus on improving the corrosion behavior and the interfacial contact resistance (ICR) of the modified boundary zone. Nitrogen and carbon as well as the combination of both were used as process gas in a temperature window from 390 to 450 °C.Own preliminary work has shown that temperatures above this could lead to an increase in corrosion current, which can be explained by the formation of chromium nitrides. While lower treatment temperatures can possibly lead to inhomogeneous nitriding zones.

In order to evaluate the properties with respect to corrosion resistance, the samples were exposed to potentiodynamic polarization measurements. The ICR was determined under surface pressure between two copper electrodes coated with gold. The diffusion zone was analyzed by X-ray diffraction (XRD) and Glow Discharge Optical Emission Spectroscopy (GDOES). In addition, standardized surface analytics, like Scanning Electron Microscopy (SEM) combined with Energy Dispersive X-ray spectroscopy (EDX) have been applied.

The results show a clear influence of the treatment temperature and the process gases on the studied properties. Plasma diffusion processes based on nitrogen show a significantly higher influence of the treatment temperature than those based on carbon. The plasma carbonized samples show a corrosion rate up to two orders of magnitude lower than the nitrided samples (between 10^{-4} and 10^{-5} A/cm²) in potentiodynamic measurements. But the IRC is significantly increased after the corrosion measurement from lower than 20 up to more than 100 mΩ*cm². The nitrocarburized samples combine the properties of both individual processes and show a comparatively low corrosion rate at low temperatures in combination with low IRC values at increased temperatures.

2:40pm **G2-2-WeA-3 Fine-Tuning of PVD Conditions for Tools Used in Automotive and Manufacturing Applications**, ***Miha Cekada***, *A. Drnovsek, M. Drobnic, M. Panjan, P. Panjan,* Jozef Stefan Institute, Slovenia **INVITED**

Tools used in automotive and manufacturing applications come in different shapes and sizes. The deposition of a protective PVD coating is relatively straight-forward for shank tools (drills, mills, reamers) since a standard planetary mounting enables to set up a more or less uniform batch. Other types of tools (stamps, saw blades, powder compaction tools) have more complex shapes, which complicates mounting and reduces the uniformity of the batch. Thus a standard protocol for a uniform batch of shank tools may have to be adapted depending on the specific collection of tools.

There are several features that influence the coating properties on the surface of tools, despite having been coated in the same batch. The tool shape and size dictate the rotation type (single, double, triple rotation) which in turn strongly influences the microstructure. In high ionization rate processes, such as cathodic arc evaporation, electric field concentration on sharp edges can substantially locally increase the coating thickness; that can be a critical issue in reaming when micrometer-sized tolerances are required. Yet another parameter is the vertical position of tools in the chamber with border areas (top/bottom) where the thickness quickly decreases. A similar effect is observed at shaded areas which are often the working surfaces of some tools, such as dies. In addition to new tools, reground tools can be coated too, which requires more steps to prevent subsequent re-coating.

These features will be addressed based on daily experience in our job coating activities. We will show the dependence of coating thickness, roughness, growth defect density and microstructure. These observations should serve as a guide to reduce unwanted influences and optimize the local coating properties. Our own results will be supported by results published by other authors; nevertheless, these data are relatively scarce since they are often retained as secret know-how within a job coating facility.

3:20pm **G2-2-WeA-5 Development of Al_2O_3-B_2O_3-SiO_2 Glass for Space Shuttle Coating**, ***Jun-Yan Qiu***, *Y. Lee, C. You, G. Hung,* Ming Chi University of Technology, Taiwan; *R. Montecillo,* Ming Chi University of Technology, Taiwan, Philippines; *P. Chen, C. Tu, K. Feng,* Ming Chi University of Technology, Taiwan

The development of space technology, which includes information transmission, secure communication, and defense protection, will soon play an important role in every country. At present, the team is mainly engaged in the research and development of outer glass coatings for space shuttles. When space shuttles pass through the atmosphere, high temperatures up to ~1350 ℃ are generated on its surface resulting in thermal cracks, Thermal protection failure. Thus, the glass coating can protect the inner porous ceramic layer and act together as thermal insulation to form a thermal protection system (TPS). Borosilicate glass has a high softening point to achieve a wetting effect fit fiber brick and achieve a self-healing effect. In this study, we developed the Al_2O_3 added in the B_2O_3-SiO_2 glass coating.

The experimental results show that the transition temperature (Tg) of the B_2O_3-SiO_2 glass system (BS system) increases from 650 ℃ to 750 ℃ when the SiO_2 content increases. However, the XRD results show that the devitrification reaction occurs when the B_2O_3-SiO_2 glass with high silicon performance is sintered between 800 ℃ and 1200 ℃. Furthermore, when the sample was sintered at 1200 ℃, the crystal peak shifted from (101) to (004) orientation, which was confirmed in TEM. The FESEM microscopic images showed thermal cracks caused by devitrification transformation. Therefore, the proportion is adjusted by the ternary phase diagram of aluminum boron silicon. Adding Al_2O_3 to B_2O_3-SiO_2 glass suppresses devitrification, reduces thermal cracking, and increases glass transition temperature. DSC analysis observed that Tg increased from 750 ℃ to 950 ℃. The XRD results showed unstable α-cristobalite traced to be in the mullite phase, which proved that the addition of Al_2O_3 can suppress the formation of α-cristobalite, inhibit devitrification, and increase Tg. The FESEM microscopic images also showed a smooth morphology without cracks on the surface, indicating that the Al_2O_3-B_2O_3-SiO_2 glass system (BSA system) has stable properties.

In the past, thermal insulation aluminum-silicon fiber bricks were used, so the development of Al_2O_3-B_2O_3-SiO_2 glass is expected to match the thermal expansion coefficient of the substrate to achieve a stable bonding effect. Subsequent analysis of structural changes, microscopic images, thermal properties, and mechanical properties was performed. It is expected that glass coating materials with high glass transition temperature and Thermal shock resistance can be developed and can be applied as a coating for space shuttles.

3:40pm **G2-2-WeA-6 Analysis of the Temperature Variation of Bizarre Thermal Barrier Coatings and Their Impacts on Engine**, ***Thirunavukkarasu Raja***, P.S.V College of Engineering and Technology, India; *P. Sivanandi,* Government College of Technology, Coimbatore, India; *S. Dhandabani, V. Murugan,* Sri Ramakrishna Institute of Technology, India

The automotive industry today focuses on reducing the effects of global warming, supposedly caused by engine exhaust emissions. Ansys simulation and experimentation were used to study the TBC effects on engine performance and emissions. The two different novel thermal barrier coating compositions were identified in this study, and the same materials were coated on the engine pistons. According to transient thermal analysis, it is found that the temperature distributions on the coated surface were reduced by 35 % and 18 % for TBC-1 and TBC-2, respectively. Compared to conventional engines, TBC-1 and TBC-2 coated engines increased brake thermal efficiency (BTE) by 8.7% and 7.52% at full load. A decrease in brake-specific fuel consumption of 27.03 % and 18.91 % is identified for TBC-1 and TBC-2 coated engines. Based on the heat balance sheet, the energy conversion rate and useful work are increased by 3.5% and 2%, which ultimately decreases the emission of CO and HC due to complete combustion.

4:00pm **G2-2-WeA-7 Novel High-Entropy Alloy Powders and Their Thermal-Sprayed Coatings for High-Temperature Applications***, **Shih-Hsun Chen,*** NTUST, Taiwan

With our experience in the research and development of metal materials, we will continue to develop various multi-principal high-entropy alloy powder materials and establish their technical capabilities for additive manufacturing. The alloy powders prepared by gas atomization method can ideally present the characteristics of homogeneous high-entropy alloy through the rapid solidification process, and achieve the most suitable process technology for high-entropy alloy products. Combined with the selected additive manufacturing technologies, such as plasma spraying process, it could implement the application and promotion of high-entropy alloys. The above-mentioned process is common and important technology in the industry. Although material research continues to innovate, there are not many researchers engaged in the development of thermal spray process technology. Therefore, this research will rely the established high-entropy alloy powder manufacturing technology, and the development experience of thermal spraying process, focusing on the development of new high-performance AlCrFeNiSi high-entropy alloy powder products and their applications via additive manufacturing technology. This project integrates high-entropy alloy composition design and powder manufacturing, and practical additive manufacturing of high-entropy alloy workpieces.The goal is to develop industrially applicable products and promote them into the industry.

4:20pm **G2-2-WeA-8 A Facile Fluoride Sealing Treatment to Improve Corrosion Resistance of Magnetism Alloy (AZ31B) Micro-arc Oxidation Layer***, C. Lee,* National Defense University, Republic of China*; J. Lee,* Lung Hwa University of Science and Technology, Taiwan*; S. Jian,* Ming Chi University of Technology, Taiwan*; **Ming-Der Ger,*** National Defense University, Republic of China

In this study, MAO treatment was used to generate a high corrosion resistance MAO layer on AZ31B magnesium aluminum alloy,During the MAO treatment, the coating will be solidified and contracted owing to thermal stress gradient, resulting in structural defects such as microcracks on the surface . Unfortunately, corrosive ions (such as Cl− and H+) will penetrate into the substrate through these structural defects, which deteriorates the protective performance. The porosity, pore size distribution and connectivity with the substrate play an important role in the performance of corrosion resistance.In order to maintain the integrity of the MAO layer, the surface of the MAO layer is sealed with a fluorine (NaF) compound containing, so that the MAO surface covers NaMgF3. The protective NaMgF3 cubic lattice fills the defects to optimize the corrosion resistance of magnesium aluminum alloys.

Scanning electron microscopy (SEM) microscope equipped with Energy Dispersive Spectrometer (EDS) was used to observe the surface of the MAO and fluoride post- sealing treatment coatings,and to detect the corrosion performance of the coating by the polarization curve (PDP), with salt spray test (SST) for a long time observe the occurrence of pitting corrosion in sealing treatment over time, decide the optimization degree of post-treatment. According to the surface morphology, the number of NaMgF3 by low-concentration short-term fluoridation post-treatment is small and only locally distributed, and the surface structure of the micro-arc itself does not change significantly. After high-concentration fluoridation for five mins The NaMgF3 particles are evenly distributed, and more particles go deep into the hole to achieve proper protection.

The relationship between the concentration of the fluorinated post-treatment solution and the soaking time has an extreme value on the corrosion efficiency of the micro-arc layer. The corrosion resistance is the best at a certain concentration. After soaking in 0.5 M fluorinated sealing solution for five mins. According to the polarization curve, icorr 1.08 x10-9, in SST, compared with the MAO layer without sealing treatment, the storage time can extend double, and after sealing, it can be stored for more than 480 hours without surface discoloration and pitting. Based on the above experimental results, can understand about fluoride sealing post-treatment, the appearance of pitting can be delayed, and it is confirmed that the fluoride sealing post-treatment by simple immersion can get crack free MAO coating on AZ31B magnesium alloy, raise up corrosion resistance optimization.

4:40pm **G2-2-WeA-9 Chemical Vapor Infiltration Technology for Coatings of Fibers and 3D Porous Bodies***, **Dennis Zywitzki**, H. Strakov,* IHI Bernex AG, Switzerland

With the increasing demand for fiber reinforced materials, chemical vapor infiltration (CVI) as a means to fabricate protective layers between the reinforcement and the matrix, is of increasing industrial interest. These layers can enhance the thermal stability of composites, for example in heat shields, or can be designed to strengthen or weaken the adhesion of the reinforcement to the matrix and thus tailor the mechanical properties. One main requirement to this technology is high infiltration rates and homogeneity. That’s why batch and continues coating concepts are developed and optimized.

In this context newly developed infiltration processes will be presented and the impact of the equipment design will be discussed. The reactor designs allows for example continuous processing of fiber tows of variable length and stable operation for complete infiltration of 3D porous bodies. Additionally, the modular concept allow a high flexibility in terms of gas feeds and deposited materials, and the extensions for industrial upscaling. CVI processes for the deposition > 1 µm thick BN, PyC and SiC films on SiC fibers were developed and show promising characteristics with regard to the infiltration rate and homogeneity.

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