Coatings for Use at High Temperatures
Room Pacific Salon 2 - Session A1-2-TuA

Coatings to Resist High-temperature Oxidation, Corrosion, and Fouling II

Moderators: Lars-Gunnar Johansson, Chalmers University of Technology, Sweden, **Shigenari Hayashi**, Hokkaido University, **Justyna Kulczyk-Malecka**, Manchester Metropolitan University

1:40pm **A1-2-TuA-1 Nano Coatings To Achieve Cost Effective And Long Lifetime SOFC Interconnects**, ***Jan-Erik Svensson,*** Chalmers University of Technology, Sweden **INVITED**

Ferritic stainless steel interconnects are widely used in solid oxide fuel cells (SOFC) due to a combination of low cost, compatible thermal expansion properties and ease of manufacturing. Nonetheless, their viability is hindered by several key technical hurdles. Most stainless steels suggested for SOFC applications rely on the formation of a fairly protective chromium oxide scale. However, in air side environments Cr species evaporation leads to material failure and insufficient lifetimes. Additionally even a protective oxide scale grows with time and since chromium oxide is only a moderate electronic conductor, this results in an increase of Area Specific Resistance (ASR). This work investigates nano coatings to mitigate both degradation mechanisms. FeCr steels have been coated with Co and/or Ce using Physical Vapor Deposition (PVD). The materials were exposed in air at 600-850 °C for up to 3000 h and oxide scale growth, chromium evaporation and electrical resistance were studied using mass gain data, the Cr-evaporation denuder technique and ASR measurements respectively. The effect of dual atmosphere exposure are also investigated. Exposed samples were additionally examined by Scanning Electron Microscopy/Energy Dispersive X-Ray (SEM/EDX) analysis. The results show that thin Co coatings effectively mitigate Cr volatilization. By adding Ce to the coating the performance was further improved as the oxidation rate was significantly reduced, thus resulting in substantially reduced ASR values. These results imply that the duplex, Co + Ce thin film coating is suitable for ferritic stainless steel interconnects in SOFCs.

2:20pm **A1-2-TuA-3 Influence of Ta Content on Properties of TiAlTaN Films**, ***Hongfei Shang,*** *T Shao,* State Key Laboratory of Tribology, Tsinghua University, China

Binary and ternary nitrides of transition metal elements, such as Ti, Cr, Zr, V, Nb, or Ta, exhibit outstanding mechanical, chemical, and thermal properties, and are utilized as protective coatings in machining, automobile and other industrial areas. Recently, alloying titanium aluminium nitride (TiAlN) with tantalum can improve cutting performance. Titanium aluminium tantalum nitride (TiAlTaN) films have been reported on improved mechanical and tribological properties.

In this work, a series of TiAlTaN films with different Ta contents were deposited using an ion beam assisted deposition. Microstructure of the as-deposited films was characterized by using X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS) and scanning electron microscope (SEM). Mechanical properties of the TiAlTaN films were also tested. Tribological behavior and corrosion performance of the TiAlTaN films were analyzed and compared to that of the TiAlN film. Results show that the TiAlTaN films demonstrated better mechanical properties, tribological behavior and corrosion resistance than the TiAlN film. Ta content has a great influence on the properties of the TiAlTaN films.

2:40pm **A1-2-TuA-4 Cr-Al-Si-N Quaternary Coating Applied on Zirconium Alloy: Combining Superior Resistance of High-temperature Steam Oxidation and Improved Mechanical Properties**, ***Fangfang Ge,*** *H Zhu, F Huang,* Ningbo Institute of Material Technology and Engineering, Chinese Academy of Sciences, China

Accident tolerant fuel claddings are extremely urgent to increase the safety margin of light water reactors. Cr-Al-Si-N quaternary coatings were proposed to increase mechanical properties and high-temperature steam oxidation resistance of Zr-based alloy. $(Cr_{60}Al_{30}Si_{10})_xN_{1-x}$ coatings with three kinds of microstructure, were prepared on Zr coupons, followed by evaluation of their mechanical properties and oxidation resistance under high-temperature steams. Moreover, to reveal the anti-oxidation mechanism, much examination was performed on the microstructure the oxidized samples. Compared to the "dense & columnar" coating, the "dense & featureless" coating exhibits a combination of the best mechanical properties and the highest oxidation resistance. It increases the H and the E^* of the uncoated Zr coupon by ~4 times has a and ~twice, respectively. After coated on the "dense & featureless" coating with the thickness of ~5 μm, the oxidation of the Zr coupon was completely suppressed in the 1000 °C steam for 15 min, and the thickness of the α-Zr(O) layer deceased by 40% - 92% in the 1200 °C steam for 30 min. Furthermore, a ~10 μm thick "dense & featureless" coating can prevent the Zr coupon from oxidizing in the 1200 °C steam for >1 h. By contrast, the "porous & columnar" coating can hardly provide any protection for the undeath Zr substrate in the high-tempeature steam. It demonstrates that the densely fine-grained or amorphous microstructure could effectively suppress the inner-diffusioin of O and favor the formation of a dense and coherent scale on surface, which would be highly desirable for the protection coatings of Zr claddings.

4:00pm **A1-2-TuA-8 Polyurethane Protective Coating with Self Polishing Property**, ***Mohammad Mizanur Rahman,*** King Fahd University of Petroleum and Minerals, Saudi Arabia

Waterborne Polyurethane (WBPU) coatings are widely used to protect metals from corrosion and fouling. Owing to restrictions on using toxic materials scientists are attempting to develop new, more environmentally-friendly coatings that maintain their performance over extended periods. Unfortunately, these coatings are inadequate to prevent metal corrosion and fouling under adverse conditions especially marine condition. Self-polishing coatings (SPC) are considered to be among the most effective technologies. Self-polishing coatings facilitate the continuous renewal of the surface and the release of active compound via a hydrolysis reaction or an ion exchange reaction with seawater. In this study, WBPU coatings were synthesized by in-situ polymerization. Synthesis and properties of coatings were investigated by Fourier transform-infrared spectrometer, proton-nuclear magnetic resonance and dynamic light scattering. The polishing rate of coating was determined from the reduction in dry film thickness after artificial seawater immersion under a dynamic condition. The corrosion and fouling resistance of coatings were also considered after certain interval.

4:20pm **A1-2-TuA-9 Production of a Zinc Impregnated Stainless Steel Surface Utilizing Cathodic Plasma Electrolytic Deposition (CPED) for Retardation of Cobalt Ion Deposition in High Temperature Aqueous Conditions**, ***Ciara Fox,*** *F Scenini, A Yerokhin, N Laugel,* University of Manchester, UK; *R Wain,* Rolls-Royce, UK

The majority of the radiation field present in light water nuclear reactors is the result of the build-up of radioactive cobalt species on structural components and this can lead to occupational radiation exposure to personnel during maintenance and inspections. However, it has been shown that zinc added to the high temperature coolant water hinders the deposition of aqueous cobalt cations onto the surface of stainless steel because it is preferentially incorporated into the inner spinel corrosion layer on stainless steel surfaces over cobalt. This work looks at the feasibility of preconditioning the stainless steel surface with zinc to remove the need for zinc additions into the coolant water.

In this work the surface modification of a 316 stainless steel to promote superficial zinc enrichment is explored. The modified alloy is created utilised Cathodic Plasma Electrolytic Deposition (CPED). The stainless steel work piece is used as the cathode in an aqueous electrolyte bath containing zinc cations and a voltage between 110V – 150V is applied to generate plasma discharges at the surface of the cathode. The superficial layer was characterised by scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDS), grazing angle X-ray diffraction (G-XRD) and glow discharge optical emission spectroscopy (GDOES) to identify the phases present on the treated samples.

The high surface temperatures generated during plasma discharges were shown to promote the diffusion of zinc which has been detected up to 3 micrometres in depth into the stainless steel substrate. In addition to zinc penetration into the stainless steel matrix, zinc is also deposited on the surface as a rough and porous zinc oxide coating which can be mechanically removed from the stainless steel surface. The effect of process parameters on zinc diffusion into the substrate as well as the treatment time and composition of the electrolyte, are discussed.

Author Index

Bold page numbers indicate presenter