Protective and High-temperature Coatings
Room Town & Country A - Session MA1-2-TuA

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

Moderators: Dr. Vladislav Kolarik, Fraunhofer Institute for Chemical Technology ICT, Germany, **Dr. Eli Ross**, Pratt & Whitney, USA

1:40pm **MA1-2-TuA-1 The Role of Circular Economy in Materials Science: Thermal Spray and Laser Coatings Originated from Abandoned Scrap for Protectiveness of Metallic Alloys at High Temperature***, **Tomasz Dudziak [tomasz.dudziak@kit.lukasiewicz.gov.pl]**, Filip Kateusz, Adelajda Polkowska,* Lukasiewicz - Krakow Institute of Technology, Poland **INVITED**

The role of recycling is growing from year to year, circular economy is a new trend that reach material science and technology. The number of wastes that are recycled globally is enormous and still is growing. To protect natural resources and natural environment the new processes that reduce impact on environment are highly seekable. In material science from years, Fe based scrap was introduced to a fresh melted iron ore to develop new grades, this process is still in use, since iron scrap is wieldy present. Often the metallic waste is present in the form of low grade steels as C45 or similar where mostly Fe is present with no additional elements. However in advanced steels i.e. stainless steels, many of valuable elements exists, i.e. Cr. The element that is responsible for protective scale formation at high temperatures (up to 800 °C) leading to resistance of the exposed material in aggressive environments. The project: Additive manufacturing and Projected Parts by using Recycled Powder from scraps, with acronym RePoParts shows the answer how to process the waste according to circular economy, recycling process of steel wastes containing at least 12 wt.% Cr to fabricate a fine grain powder for Selective Laser Melting (SLM) process, a powder that helps develop new grades of coatings against wear, high temperature degradation. The work shows the data related to protectiveness of metallic alloys at high temperature when coatings from recycling process is used.

2:20pm **MA1-2-TuA-3 Advanced Chemical Vapor Deposition Technology for High Temperature Applications***, **Natasa Djordjevic [natasa.djordjevic@ihi-bernex.com]**, Anne Zhang, Hristo Strakov,* IHI Bernex AG, Switzerland

Recent research explores the potential of Chemical Vapor Infiltration (CVI) and Chemical Vapor Aluminizing (CVA) technologies to produce advanced coating solutions for high temperature applications and materials with enhanced performance at demanding conditions.

CVI is increasingly used for establishing coating solutions for fiber-reinforced composites, enabling deposition of interface layers or infiltration of ceramic matrices with different precursors at elevated temperatures. The technique allows production of materials with greatly enhanced properties such as thermal stability, mechanical strength, oxidation and corrosion resistance.

On the other hand, CVA is a modern advanced process for applying diffusion coatings on metallic-based turbine blades and vanes in the hot section of aero- and land-based turbines against oxidation and corrosion. The CVA process is capable of controlled alloying the coating with additional elements by using metal chlorides and tight control of the coating composition and on this way increasing the life time of such components.

This work will highlight the latest developments of different coating technology solutions for high temperature applications, including improvements in precursor chemistry, reaction kinetics, stoichiometry and process control. Emphasis will be placed on the challenges related to maintaining uniformity and quality of deposition in different geometries and the influence of the coating equipment in order to precise control the parameters.

2:40pm **MA1-2-TuA-4 Magnetron Sputtering of Advanced Multi-Elemental Aluminide Thin Films:Impact of Alloying with Refractory Metals and Cu***, **Vincent Ott [vincet.ott@kit.edu]**, Michael Dürrschnabel,* Karlsruhe Institute of Technology (KIT), Germany*; Tomasz Wojcik, Paul Mayrhofer, Helmut Riedl,* TU Wien, Austria*; Sven Ulrich, Michael Stüber,* Karlsruhe Institute of Technology (KIT), Germany

Intermetallic phases in the CsCl structure have promising properties for use in highly demanding environments. Major limitations are the synthesis of single-phase materials on one hand and the brittle failure at room temperature on the other hand. The RuAl phase in B2 structure is an outstanding candidate of this material class due to its ductile behavior at room temperature. A promising route for the synthesis as a thin-film material is offered by nanoscale multilayer coatings from which the targeted phase can be synthesized by a subsequent heat treatment. To further improve the resulting thin films properties and to reduce the Ru content, alloying can help to increase the maximum service temperature, improve ductility and at the same time maintain good oxidation resistance.

To achieve this goal, thermally activated phase formation in nanoscale multilayer precursors is used to obtain single phase multi elemental aluminides with tailored properties. The partial substitution of Ru with the stable oxide forming alloying element Cr or with the Ru affine element Hf, while maintaining the Al content at 50 at%, is aiming at improving the oxidation resistance and mechanical properties. On the other hand, alloying the RuAl-phase with Cu shows the extent to which properties are influenced by the introduction of a ductile material. In-situ HT-XRD is used to observe the phase formation during the heat treatment of single phase (Ru, Me)Al (RM=Cr, Hf, Cu) and the resulting microstructure, characterized by TEM-methods, is linked to their mechanical and oxidative properties.

3:00pm **MA1-2-TuA-5 Oxygen Concentration Governs High-Temperature Oxidation Behavior of $(Cr_{0.5}Al_{0.5})(O_YN_{1-Y})$ Thin Films***, **Pauline Kümmerl [kuemmerl@mch.rwth-aachen.de]**, Felix Leinenbach, Janani Ramesh,* RWTH Aachen University, Germany*; Daniel Primetzhofer,* Uppsala University, Sweden*; Marcus Hans, Jochen M. Schneider,* RWTH Aachen University, Germany

In (TM,Al)(O,N) (TM = Ti, V) thin films, the addition of oxygen enhances the thermal stability as for the decomposition into the hexagonal and cubic phases mobility on the metal and nonmetal sublattices is required, while for (TM,Al)N decomposition the activation of diffusion on the metal sublattice is sufficient. Little is known about the oxidation resistance of (TM,Al)(O,N) thin films; thus a systematic study of the influence of the O concentration in (Cr,Al)(O,N) on the oxidation resistance and oxide scale formation is presented here.

$(Cr_{0.5}Al_{0.5})(O_yN_{1-y})$ thin films were grown by reactive high power pulsed magnetron sputtering where the O content was systematically varied through adjustment of the O_2 partial pressure leading to compositions of $(Cr_{0.50}Al_{0.50})_{0.49}N_{0.51}$, $(Cr_{0.48}Al_{0.52})_{0.48}(O_{0.15}N_{0.85})_{0.52}$, and $(Cr_{0.44}Al_{0.56})_{0.46}(O_{0.40}N_{0.60})_{0.54}$. The oxidation behavior was investigated as a function of the O concentration at 1000 °C, 1100 °C, and 1200 °C for up to 16 h.

During oxidation an Al-rich oxide scale is formed. Between the $(Cr_{0.5}Al_{0.5})(O_yN_{1-y})$ thin films and the scale, the formation of a an Al-depleted and O-enriched region is observed whereby the geometric extent and the level of porosity were strongly time and temperature dependent. At 1100 °C after 16 hours of oxidation the oxide scale thickness on $(Cr_{0.48}Al_{0.52})_{0.48}(O_{0.15}N_{0.85})_{0.52}$ was with 369± 48 nm significantly smaller than the 513± 96 nm and 462± 53 nm thick scale layers measured on $(Cr_{0.50}Al_{0.50})_{0.49}N_{0.51}$ and $(Cr_{0.44}Al_{0.56})_{0.46}(O_{0.40}N_{0.60})_{0.54}$, respectively. Furthermore, chemical environment dependent DFT calculations are performed to determine the species specific energy requirements for vacancy formation and mass transport in an effort to elucidate the time and temperature dependent oxidation behavior.

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