Summer 6-26-2014

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Recommended Citation

[1] B.P. Bewlay et al., MRS Bulletin 28 (2003) 646-653. [2] S. Knittel, S. Mathieu, L. Portebois, M. Vilasi, T. Katrina, C. Rapin, C. Petitjean, P.-J. Panteix, S. Drawin, this Conference

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LIFETIME OF ENVIRONMENTAL/THERMAL BARRIER COATINGS DEPOSITED ON AN Nb/Nb_5Si_3-BASED ALLOY WITH FeB-MODIFIED M_7Si_6-BASED BOND COAT

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Key Words: Nb-silicide, bond coat, TBC, EBC, thermal cycling

To enhance the performance of aircraft engines, high temperature materials are required being capable to operate at temperatures significantly higher than the temperature limit of about 1150°C approached for Ni-based superalloys currently employed. Nb/Nb_5Si_3-based composites are promising candidates for turbine engine applications at temperatures up to 1300°C, exhibiting balanced mechanical properties and reduced density compared to Ni-based superalloys [1]. To use these composites in gas turbine combustion atmosphere, environmental/thermal barrier coatings (E/TBCs) are required to protect them against heat, degradation in flowing water vapour and chemical attack of calcium-magnesium-alumino-silicate (CMAS).

In this study, E/TBC systems of yttria partially stabilized zirconia (YSZ), gadolinium zirconate and a combination of Y_2SiO_5 and $Gd_2Zr_2O_7$ were applied on a Nb-silicide based alloy with the nominal composition of Nb-25Ti-8Hf-2Cr-2Al-16Si (at.%). The bond coat used was a FeB-modified M_7Si_6-based layer produced by pack cementation [2]. On the coated rectangular coupons, 150 – 200 µm thick YSZ and $Gd_2Zr_2O_7$ topcoats were deposited on one side of the sample using electron-beam physical vapor deposition (EB-PVD). Furthermore, specimens with FeB-modified M_7Si_6 bond coat were coated with 15 – 20 µm thick Y_2SiO_5 layers on both sides applying magnetron sputtering. These samples were subsequently annealed in vacuum at 1100°C to transform the amorphous yttrium silicate layers into crystalline coatings. Thereafter, an additional EB-PVD gadolinium zirconate topcoat was deposited again on one side. The lifetimes of the different E/TBC systems were determined performing thermal cycling tests at 1100 and 1200°C in air. The samples were placed in a hot furnace for one hour and subsequently removed to ambient environment applying air forced cooling. Cross-sectional microstructural examinations of thermally cycled specimens were carried out using scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS).

When thermally cycled at 1100°C, the different E/TBC systems exhibited lifetimes exceeding 1000 cycles. The YSZ, $Gd_2Zr_2O_7$ and Y_2SiO_5 + $Gd_2Zr_2O_7$ topcoats did not spall off during the maximum exposure time period. On the FeB-modified M_7Si_6 bond coat a (boron containing) silica scale formed with interspersed Ti-, Cr-, Fe- and Nb-oxides. At 1200°C, lifetimes exceeding 600 cycles were determined. With longer thermal cycling testing, severe oxidation occurred at the edges and rear side of the samples (without ceramic topcoat) due to local degradation of the oxidation protective coating. This resulted in breakaway oxidation of the Nb/Nb_5Si_3-based substrate causing substantial material recession. In the sample's center area, the topcoats were adherent to the thermally grown oxide scale consisting of silica and mixed oxides of iron, titanium and chromium.

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