MM 32: Topical Session High Temperature Materials III

Time: Wednesday 16:45–18:00 Location: IFW A

Topical Talk MM 32.1 Wed 16:45 IFW A

The formation and growth of Secondary Reaction Zones in coated 4th generation Ni-base Blade Alloys — •Catherine Rae and Aya Suzuki — Department of Materials Science and Metallurgy, Cambridge, CB2 3QZ, UK

Secondary Reaction Zone (SRZ) formed under aluminized and Pt-aluminised coating have become an increasing problem in advanced single crystal superalloys. The distinctive morphology grows by a discontinuous precipitation reaction similar in many ways to recrystallisation, and destroys the distinctive fine $\gamma\gamma$' microstructure. In thin sections of HP turbine blades this can reduce the load-bearing cross section of a blade by as much as 10%. The morphologies and growth kinetics of the Secondary reaction zones formed between the Plat-Aluminised coating and 4th generation Ni-base superalloy substrates have been investigated. Three alloys were studied with systematically varying Ru content in the range of 2-5 wt%. At the lowest Ru content sporadic formation of SRZ was observed, whilst the higher Ru-containing alloys formed a continuous SRZ within the first hour of exposure at 1100°C. These alloys also showed more rapid SRZ growth, regardless of the original surface finish. EBSD analysis revealed that the higher Ru-containing alloys nucleate many more grains of the SRZ and this leads to a deeper penetration depth into the substrate. Orientation relationships between the coating and the SRZ reveal possible nucleation routes for the SRZ grains. These have been investigated using Focussed Ion Beam sectioning and the extraction of sections for TEM analysis.

MM 32.2 Wed 17:15 IFW A

Load rate dependence of the mechanical properties of thermal barrier coating systems — •Nikolay Zotov[1], Marion Bartsch[2], and Gunther Eggeler[1] — [1]Institut für Werkstoffe, Ruhr Universität Bochum, 44780 Bochum — [2]Institut für Werkstoff-Forschung, DLR Köln, 51147 Köln

Thermal barrier coatings (TBC), composed of yttrium-stabilized zirconia (YSZ) ceramic top coat (TC) and intermetallic NiCoCrAlY bond coat (BC) are commonly used as protective coatings of Ni-based high temperature gas engine components. Nanoindentation techniques are increasingly applied for determining the TBC mechanical properties on a nanometre scale. However, little is known about the load-rate dependence of the mechanical properties, which is important for better understanding of cyclic thermal fatigue experiments. Nanoindentations with different load rates omega were performed on polished cross-sections of TBC, deposited by EB-PVD on IN625 substrates (S), using a XP Nanoindenter (MTS) equipped with Berkovich diamond tip. The Young's modulus (E) of the TC is independent of omega, while E for the BC and the S decreases with omega. The hardness (H) of the TC and the BC increases, while H for the S decreases with omega. From the dependence of H on omega, creep power-law exponents c = 0.24(11) and c = 0.023(6) for the TC and the BC were determined. For all TBC components, a decrease with omega of the power-law exponents n and m, describing the loading and unloading nanoindentation curves, is observed.

MM 32.3 Wed 17:30 IFW A

Micro bending tests on EB-PVD YSZ thermal barrier coatings — •Carolin Pfeiffer[1], Mathias Göken[1], and Ernst Affeldt[2] — [1]Lehrstuhl Allgemeine Werkstoffeigenschaften WW I, Institut für Werkstoffwissenschaften, Universität Erlangen-Nürnberg, Martensstrasse 5, 91058 Erlangen — [2]MTU Aero Engines GmbH, Dachauer Str. 665, 80995 München

Thermal barrier coatings (TBCs) are widely used for protection of turbine components from high temperatures. Since the application of thermal barrier coatings can reduce the substrate temperature by up to 200°C, the gas inlet temperature has risen accordingly and the TBCs have become critical for engine operation. The mechanical properties and the microstructural evolution during operation are essential for the estimation of remaining lifetime of the coating. However, the understanding of this subject is still not sufficient.

In order to investigate the mechanical properties of the ceramic thermal barrier, a bending test rig has been developed which is capable of testing small specimens in a four-point bending mode. The tests are monitored with a high resolution camera, which allows a non-contact determination of the sample deflection by digital image correlation.

The sample material has been heat treated at various temperatures for a range of times, in order to determine the sintering effect on the materials properties. In addition, the material is examined by compression and nanoindentation, in order to study the influence of the size of the tested volume on the values obtained.

MM 32.4 Wed 17:45 IFW A

Oxygen vacancies in yttria-stabilized zirconia: defect configurations and charge states — •Volker Haigis, Felix Hanke, and Matthias Scheffler — Fritz-Haber-Institut, Berlin

Yttria-stabilized zirconia (YSZ) is a standard material for thermal barrier systems, where it is used to shield critical parts of combustion engines from high temperature environments. This application of YSZ is due to its low thermal conductivity and its phase stability over a wide temperature range [1]. Doping of zirconia (ZrO_2) with yttria (Y_2O_3) introduces oxygen vacancies which play a crucial role in stabilizing the technologically relevant tetragonal structure. In spite of some work on structural properties [2], the current understanding of the material at the atomic scale is sparse. Here, we characterize the oxygen vacancies, including their charge states, defect configurations, and concentration in YSZ in an oxygen atmosphere. Relevant defect arrangements are identified, and the respective Gibbs free energies are calculated using *ab initio* atomistic thermodynamics. In addition to standard density functional theory, the GGA+U method is used to analyse the stability of vacancy charge states. We construct a phase diagram giving the thermodynamically stable configurations as a function of the Fermi level, temperature, and oxygen pressure. It is discussed whether non-stoichiometric compositions (more or less than one vacancy per two yttrium atoms) are to be expected at finite temperatures and pressures, and hence under technologically relevant conditions.

[1] A.G. Evans *et al.*, J. Eur. Ceram. Soc. **28**, 1405 (2008)
[2] A. Eichler, Phys. Rev. B **64**, 174103 (2001)