

CORROSION OF E/TBCs: CHEMICAL INTERACTIONS OF CERAMIC MATERIALS WITH CMAS

Michel Vilasi, Université de Lorraine, CNRS, IJL, F-54000 Nancy, France

Michel.vilasi@univ-lorraine.fr

Justine Bonnal, Université de Lorraine, CNRS, IJL, F-54000 Nancy, France

Tuti Katrina Abdullah, Engineering Campus, USM, 14300 Nibong Tebal, Pulau Pinang, Malaysia

François Perrudin, CEA Marcoule - BP 17171 - 30207 Bagnols-sur-Cèze Cedex, France

Eric Schmucker, CEA Paris-Saclay – Gif sur Yvette, France

Victor Szczepan, ONERA, 29 Av. de la Division Leclerc - 92320 Châtillon, France

Stephane Mathieu, Université de Lorraine, CNRS, IJL, F-54000 Nancy, France

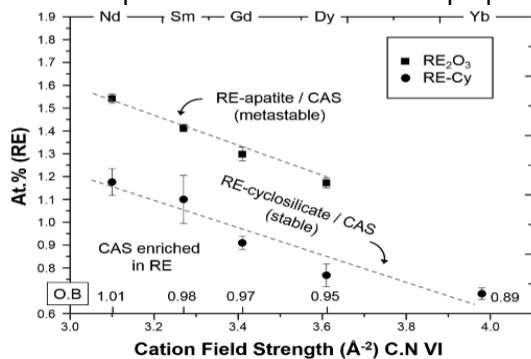
Pierre-Jean Panteix, Université de Lorraine, CNRS, IJL, F-54000 Nancy, France

Carine Petitjean, Université de Lorraine, CNRS, IJL, F-54000 Nancy, France

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The improvement of the efficiency of aeronautical engines has involved a constant increase of the working temperature through the years. Relevant materials had to be chosen in order to withstand such conditions, as monocrystalline nickel-based superalloys, or more recently the ceramic matrix composites (CMCs) which allow a significant weight gain and higher working temperatures. However, in all cases, the constituting materials are submitted to extreme conditions, causing several modes of degradations due to thermomechanical and thermochemical stresses. Consequently, protection has to be provided. Thermal Barrier Coatings (TBCs) made of yttria partially stabilized zirconia (YPSZ) with columnar structure are thus able to lower the temperature perceived at the surface of nickel superalloys, and rare earth silicates Environmental Barrier Coatings (EBCs) are required to protect CMCs against corrosion. The good adherence of both ceramic layers and the protection of the substrate must be ensured by a complex system consisting in a bond coat providing elements able to form a Thermally Grown Oxide (TGO) with a low growth rate (e.g. Al_2O_3 , SiO_2 , Cr_2O_3).

Amongst all the stresses endured by the E/TBC systems, one of the most predominant is due to thermochemical interactions with fine particles of sand, dust or volcanic ashes ingested by the aircraft engine, which may lead at high temperature to a liquid silicate mainly constituted of $\text{CaO-MgO-Al}_2\text{O}_3\text{-SiO}_2$ (CMAS). The degradation consists in (i) the dissolution of the E/TBC system in the melt and (ii) the precipitation of new phases. The aim of our studies is to determine the thermodynamic equilibrium reached during interactions of all the elements constituting the E/TBC with CMAS: (i) solubility limits of the species in the melt, and (ii) nature of the precipitated phases. For this, an original device has been developed in order to provide optimal reproducibility and allow fast attainment of thermodynamic equilibrium in high temperature interactions between a melt and a chosen material. The dissolution / precipitation scenarios of several oxides / silicates (ZrO_2 , RE_2O_3 , RE-silicates, Cr_2O_3 , Al_2O_3) have been studied in simplified liquid silicates considering physico-chemical parameters as basicity, redox state and viscosity (Figure 1) [1-3]. In situ electrochemical measurement brought further information on the reactions mechanisms and kinetics [4]. All the experimental results obtained during this study were used to elaborate a model describing the dynamic behavior of the system, i.e. the modification of the chemical composition of the melt, the stability or the dissolution of the passive layer vs time of immersion [5,6]. Relevant protection solutions can be proposed in order to improve the durability of the system.



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Figure 1 – RE solubility limits in $\text{CaO-Al}_2\text{O}_3\text{-SiO}_2$ melt at 1200°C (OB: optical basicity of Re_2O_3)