

Chapter 4

Thermal Barrier Coatings on the Base of Samarium Zirconates

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ABSTRACT

The zirconates of rare earth elements, such as Sm₂Zr₂O₇, can be an alternative material for zirconia modified by yttria (8YSZ) usually used as an insulation layer in thermal barrier coatings (TBC) systems. This chapter describes the morphology of feedstock zirconate powder, internal morphology and selected properties of different samarium zirconate TBC systems. These included: composite TBC coatings of Sm₂Zr₂O₇ + 8YSZ type with different ratio of both used to coatings deposition powders (25/75, 50/50 and 75/25) as well as the TBC of double ceramic layer (DCL) type with an 8YSZ internal layer and an outer layer of Sm₂Zr₂O₇ type, and a monolayer TBC based on Sm₂Zr₂O₇. Another presented subject is related to the oxidation resistance of TBC systems during static oxidation test at temperature 1100°C. In this case, the special emphasis was taken on the characterization of thermally grown oxides (TGO) zone thickness where the most important phenomena related with overall live-time of TBC systems usually take place.

INTRODUCTION

According to definition of The International Union of Pure and Applied Chemistry (IUPAC) the rare earth elements include 15 lanthanides (lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium) scandium and yttrium, which tend to occur in the same ore deposits as the lanthanides and has similar chemical properties (Charewicz, 1990; Klupa, 2012; Hurst, 2010).

Rare earth elements are plentiful in Earth's crust; however, their name is associated with discovery them in rarely occurring minerals (Charewicz, 1990). Their found widespread use in many industries. The best examples of their use are modern electronics, new hybrid or fully electric vehicles, materials

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for permanent magnets and lasers (Klupa, 2012). Another area where for years it is observed the re-search on the use rare earth elements is energy storage systems such as SOFC (solid oxy-fuel cell) and aircraft engines industry with special attention to thermal barrier coating (TBC) systems, what is the main subject of the presented chapter.

TBC is a multilayer system, build with few types of materials with completely different physico-chemical properties. It allows to achieve a level of properties that would not be obtainable for each of these materials separately.

TBC system is consist of external ceramic layer called as topcoat (TC), its most important mission is insulation properties and corrosion resistance, next is zone of thermally growth oxides (TGO) which forms the alumina (α -Al₂O₃) which is responsible for the oxidation properties, then is the aluminium reach metallic bond coat layer (BC) ((Ni, Co)CrAlY or aluminides of Pt and Ni) which has to bonding of the ceramic layer and protect the based material against oxidation. The aim of based material is a transfer of thermal and mechanical stresses (Bakan & Vaßen, 2017; Curry, 2014; Gupta, 2014).

Since over 40 years 6-8 mol% yttria-stabilized zirconia (8YSZ) has been the material of choice for ceramic top coats, as it has the exceptional combination of desired properties. In recent years mainly four different ceramic material groups have been suggested as new topcoat materials. Among them: hexaaluminates, perovskites, zirconia doped with different rare-earth (RE) cations (defect cluster zirconia) and pyrochlores (properties shown in Table 1). Other materials were also taken into account, like for example, silicates (ZrSiO₄), mullite, garnets (YAG and YAM) and (Ca_{1-x}Mg_x)Zr₄(PO₄)₆. However, their typically low coefficient of thermal expansion (CTE) excludes the possibility of their application (Bakan & Vaßen, 2017; Curry, 2014; Gupta, 2014).

The outer ceramic layer is obtained mainly by air plasma spraying (APS) suspension plasma spraying (SPS) or electron-beam physical vapor deposition (EB-PVD) method, the comparison of those method is set up in the Table 2 (Gupta, 2014; Bernard et al., 2017). Its primary function is to provide a thermal barrier, but the extremely aggressive thermochemical environment in which it must work, need to meet other relevant requirements (Clarke & Phillpot, 2005) those are among others:

1. *Ability to experience large deformations without failure*
2. *Compatibility of deformation*

Table 1. Properties of selected topcoat materials

	Example of Materials			
	Hexaaluminates: LaMgAl ₁₁ O ₁₉	Perovskites: BaZrO ₃	Dopped Zirconia: 5 wt.%CaO+ZrO ₂	Pyrochlore: La ₂ Zr ₂ O ₇
T _m (Melting point)	-	2963K	T _{softening} =2558K	2573K
λ (thermal conductivity)	1,7 W m ⁻¹ K ⁻¹ (1273K)	3,42 W m ⁻¹ K ⁻¹ (1273K)	-	1,56 W m ⁻¹ K ⁻¹ (1273K)
α (thermal expansion coefficient)	10,1×10 ⁻⁶ K ⁻¹ (293-1273K)	8,1×10 ⁻⁶ K ⁻¹ (293-1273K)	9,91×10 ⁻⁶ K ⁻¹ (293-1273K)	9,1×10 ⁻⁶ K ⁻¹ (293-1273K)
C _p (heat capacity)	0,86 J g ⁻¹ K ⁻¹ (1273K)	0,45 J g ⁻¹ K ⁻¹ (1273K)	-	0,49 J g ⁻¹ K ⁻¹ (1273K)
E (Young's modulus)	-	181 GPa (293K)	-	175 GPa (293K)

Cao, Vassen & Stoeber, 2014.

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