Journal of the European Ceramic Society xxx (2017) xxx–xxx

Contents lists available at www.sciencedirect.com

Journal of the European Ceramic Society

journal homepage: www.elsevier.com/locate/jeurceramsoc

Calcium-magnesium-alumina-silicate (CMAS) resistant Ba_2REAlO_5 (RE = Yb, Er, Dy) ceramics for thermal barrier coatings

Liangliang Wei [a,b], Lei Guo [c,d,*], Mingzhu Li [c,d], Hongbo Guo [a,b,**]

[a] School of Materials Science and Engineering, Beihang University, Beijing 100191, China
[b] Key Laboratory of Aerospace Materials & Performance (Ministry of Education), Beihang University, No. 37 Xueyuan Road, Beijing, 100191, China
[c] School of Materials Science and Engineering, Tianjin Key Laboratory of Advanced Joining Technology, Tianjin University, Tianjin, China
[d] Key Lab of Advanced Ceramics and Machining Technology of Ministry of Education, Tianjin University, No. 92, Weijin Road, Tianjin 300072, China

ARTICLE INFO

Article history:
Received 8 February 2017
Received in revised form 22 May 2017
Accepted 2 June 2017
Available online xxx

Keyword:
Ba_2REAlO_5
Thermal barrier coatings (TBCs)
Calcium-magnesium-alumina-silicate (CMAS)
Crystalline layer

ABSTRACT

Calcium-magnesium-alumina-silicate (CMAS) attack has been a great challenge for the application of thermal barrier coatings (TBCs) in modern turbine engines. In this study, a series of prospective TBC candidate materials, Ba_2REAlO_5 (RE = Yb, Er, Dy), are found to have high resistance to CMAS attack. The rapid formation of a continuous crystalline layer on sample surface contributes to this desirable attribute. At 1250 °C, Ba_2REAlO_5 dissolve in the molten CMAS, accumulating Ba, RE and Al in the melt, which could trigger the crystallization of celsian, apatite and wollastonite crystals. Especially, the formation of the crystalline layer in the Ba_2DyAlO_5 sample is the fastest. This study also reveals that Ba is a useful element for altering CMAS composition to precipitate celsian. Thus, doping Ba^{2+} in yttria partially stabilized zirconia or other novel TBCs might be an attractive way of mitigating CMAS attack.
© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

Modern turbine engines employ thermal barrier coatings (TBCs) to protect hot-section metallic components and to increase the engine inlet gas temperature [1–4]. However, higher operating temperature has brought about new material issues. At elevated temperatures, silicate debris (fly ash, sand, volcanic ash, runway debris, etc.) ingested into the engine melt and adhere to TBC surfaces that can be as hot as 1200 °C. The molten glass penetrates into the TBCs causing them to spall-off, exposing the metallic components to dangerous high temperature and corrosion environment [5–11]. These deposits are mainly composed of CaO, MgO, Al_2O_3 and SiO_2, and they are generically termed CMAS. Recently, CMAS attack is becoming a significant challenge for the application of the TBCs. Hence, CMAS failure mechanism and its protection have been the focus of efforts to develop TBCs for modern gas engines.

Yttria partially stabilized zirconia (YSZ) TBCs have been the first line of defense in the hot-section of engines [1–3,12–15]. The mechanisms by which CMAS attacks YSZ TBCs have been documented in the literature [5,7,10,16–20]. They mainly involve two aspects, i.e. thermo-chemical and thermo-mechanical damage. Research has indicated that molten CMAS can readily dissolve YSZ grains, leading to the enrichment of Y^{3+} and Zr^{4+} in the CMAS glass. The re-precipitated ZrO_2 gains are depleted in Y_2O_3 due to the low solubility of Zr^{4+} in the molten CMAS compared with Y^{3+} [5,7,16]. The Y-lean tetragonal ZrO_2 transforms to monoclinic ZrO_2 upon cooling accompanied with large volume increase that can severely damage the TBCs. Additionally, thermo-mechanical damage cannot be ignored. The CMAS-impregnated TBCs reveal low strain-tolerance, which increases thermal misfit stress during thermal cycling that TBCs experience in-service causing premature coating failure [9,18,19]. Therefore, YSZ TBCs could not work well at high temperatures when CMAS is present.

In response to the strong demand for higher powder output and engine efficiency, there is a great need to increase the engine operating temperature. However, the accepted upper limit for YSZ TBCs use is 1200 °C. At higher temperatures, issues of accelerated sintering and phase transformation become more severe, largely decreasing the thermal insulation and durability of the TBCs [1–3,21–24]. Therefore, YSZ TBCs are unlikely to meet the long-term requirements for modern turbine engines even when the CMAS corrosion is not a concern. Additionally, in anticipation of better thermal insulation, there is a practical need for TBCs

* Corresponding author at: School of Materials Science and Engineering, Tianjin University, Tianjin, China.
** Corresponding author at: School of Materials Science and Engineering, Beihang University, Beijing, China.
E-mail addresses: glei028@tju.edu.cn, glei028@163.com (L. Guo), guo.hongbo@buaa.edu.cn (H. Guo).

http://dx.doi.org/10.1016/j.jeurceramsoc.2017.06.004
0955-2219/© 2017 Elsevier Ltd. All rights reserved.

Please cite this article in press as: L. Wei, et al., Calcium-magnesium-alumina-silicate (CMAS) resistant Ba_2REAlO_5 (RE = Yb, Er, Dy) ceramics for thermal barrier coatings, *J Eur Ceram Soc* (2017), http://dx.doi.org/10.1016/j.jeurceramsoc.2017.06.004

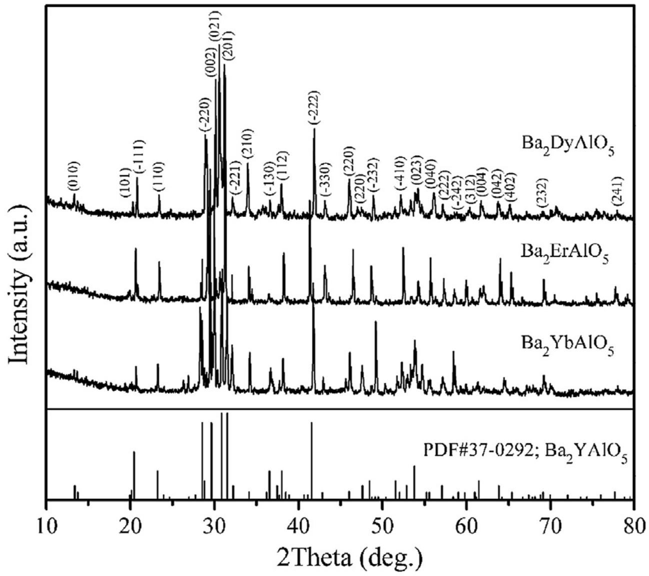

Fig. 1. XRD patterns of Ba_2REAlO_5 (RE = Yb, Er, Dy) ceramics.

with even lower thermal conductivity. Hence, high-temperature ceramics with low thermal conductivity have been examined for potential TBC applications. $RE_2Zr_2O_7$ (RE = rare earth element), Ba_2REAlO_5, $La_2Ce_2O_7$ and $Y_3Al_5O_{12}$ have low thermal conductivities due to the presence of high content of oxygen vacancies and have been proposed as prospective TBC materials [25–31]. Sine these TBC candidates are designed for possible operation above 1200 °C, the threat from CMAS attack might be much serious. Therefore, investigation on the corrosion behavior of newly developed TBC materials/coatings with CMAS deposits is essential.

Krämer et al. first indicated that $Gd_2Zr_2O_7$ has high resistance to CMAS attack [5]. $Gd_2Zr_2O_7$ dissolves in the CMAS melt, and within tens of seconds, Gd_2O_3 reacts with SiO_2 and CaO from the melt to crystallize an apatite silicate phase $Ca_2Gd_8(SiO_4)_6O_2$ and a $Zr(Gd,Ca)O_x$ fluorite phase. These compounds with high melting point form a continuous crystalline layer on the coating surface, suppressing further penetration of the molten CMAS. Then, the investigation revealed that the poor resistance of YSZ TBC to CMAS attack is due to its low Y_2O_3 content. Padture et al. increased the Y^{3+} content in YSZ TBCs and found that the CMAS penetration is effectively arrested mainly attributed to the precipitation of apatite phase [32,33]. Others compositions have also been found to have excellent CMAS resistance, such as $La_2Ce_2O_7$, $La_2(Zr_{0.7}Ce_{0.3})_2O_7$, $LaMgAl_{11}O_{19}$ and $GdPO_4$ [34–40]. The rationale behind the desirable property is to precipitate apatite with the help of enough RE_2O_3 content. Ba_2REAlO_5 has ultralow thermal conductivity, and the previous investigation indicated that Ba_2REAlO_5 is promising TBC candidate [28–30]. Additionally, they are expected to have excellent CMAS resistance due to the high RE_2O_3 content. However, no report on the CMAS corrosion behavior of this type of materials can be found in the open literature.

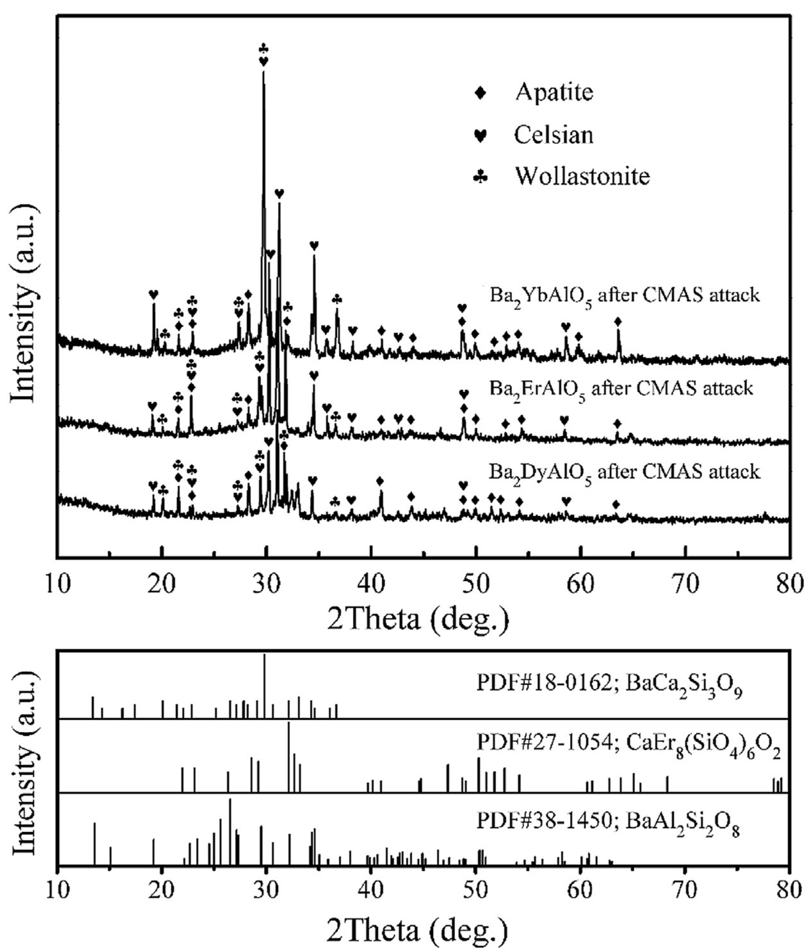

Fig. 2. XRD patterns of the Ba_2REAlO_5 (RE = Yb, Er, Dy) sample surfaces after heat treatment (1250 °C, 4 h), and the standard XRD PDF cards of $BaAl_2Si_2O_8$ celsian, $Ca_2Er_8(SiO_4)_6O_2$ apatite and $BaCa_2Si_3O_9$ wollastonite.

Download English Version:

https://daneshyari.com/en/article/5440363

Download Persian Version:

https://daneshyari.com/article/5440363

Daneshyari.com