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Overview on Thermal Barrier Coatings Application and Development

Ran Li, MinLiang Zhang
College of Mechanical Engineer, Shanghai University of Engineering Science
Shanghai 201620, China

Abstract: *This paper mainly summary the application and development of thermal barrier coatings (TBC) in last decades. TBCs have been widely used in automotive, gas turbine, solid oxide fuel cell and other fields. It can protect substrate materials from high temperature oxidation and corrosion meanwhile increasing lifetime of parts and improving the work efficiency. At last, the development trend of TBC was referred on the TBCs materials and structures.*
Key words: *thermal barrier coatings, application field, development trend*

I. Introduction

Higher operation temperature or more difficult work environment in Land-based Turbine, automotive industries, metals processing industries lead coatings were used widely. The corrosion and oxidation in the high temperature can give rise to part fatigue and failure in the above fields. Some coatings like thermal barrier coatings help to increase thermal efficiency and mitigating oxidation and corrosion, so extending the component life and improving the economy [1-3]. But few papers explain the application of TBC for part of automotive, gas turbine in details. Therefore this study summarizes the application and development tendency of thermal barrier coatings.

II. Thermal barrier coatings (TBC)

The structure of thermal barrier coatings is the metal substrate, metallic bond coating and ceramic top coating. Top coatings play an important role for wear protection, chemical resistance and heat protection. TBC usually deposited over a MCrAlY bond coat as a low-thermal-conductivity ceramic layer. Yttria (Y_2O_3) is the most widely used stabilizer for TBC at the present time, and the material is commonly known as yttria-stabilized zirconia (YSZ). It exhibits resistance to the thermal shock and thermal fatigue up to 1150℃[4,5]. The geometry and size, chemical composition, and applications/characteristics of ZrO_2-Y_2O_3 are shown in Table 1.

Table 1 parameters of ZrO_2-Y_2O_3

AMPERIT	Grain Size in um or specification	Chemistry/Powder Type	Typical Properties and Application
827.853	PM 819-20	ZrO_2-Y_2O_3 93/7 Agglomerated and sintered	1. APS 2. Max.operating temperature 1320°C 3. Color, Yellow 4. Very good thermal shock resistance and thermal insulating properities 5. Hot corrosion resistant 6. Used for thermal barrier coatings in aircraft, stationary gas turbines and engine applications like combustion liners and airfoils, etc

YSZ is generally deposited by plasma spraying and electron beam physical vapor deposition (EBPVD) processes. It can also be deposited by HVOF spraying for applications. Thermal barrier coating failure stems from one or more of the following mechanisms [1, 6]:
(1) Attack of the MCrAlY bond coat by O_2 (the ZrO_2 is transparent to O_2), resulting in swelling and ceramic spalling

(2) Sintering of the ZrO_2, which reduces the strain-relief devices
(3) Improper ZrO_2 powder or spraying conditions that result in a higher than desired mono-clinic phase content
(4) An abrupt vertical wall of ceramic at the coating peripheral edge, which acts as a stress raiser for coating failure when exposed to deep thermal cycles
(5) Corrosive attack of the ceramic by impurities in fuels
(6) Instability and degradation of the thermally grown oxide layer of Al_2O_3 at the bond coat/ceramic interface.

III. Application of the coatings in high temperature

3.1 Automotive
Thermal barrier coatings are widely used on piston crowns, cylider heads, valves, exhaust ports in the automotive industries currently. Because these components are usually subjected to high-temperature fatigue. Such as piston crowns are often coated, not only for purposes of engine performance but also to extend component life. The thickness of coatings is commonly less than 0.2 mm.
TBC is also used for improving the performances in the Turbochargers and disc brakes. As to turbochargers, the exhaust gases are usually combined with the incoming air, adding heat to that already developed by compressing the air. As to disc brakes, the more frequency and severe brake, the more heat will be produced and the more possible to heat fatigue. So the use of TBC benefits the disc brake performance [1, 7].

3.2 Land-Based Turbine
The work environment of turbines may be in harsh, corrosive such as high-temperature deserts or offshore platforms. Plasma spray TBCs are of great use in the hot section of turbines, such as the combustor liner (cans), transition ring, splash plate, and fuel injector [7, 8]. TBCs are helpful for improving the thermal efficient and reduce the exposure temperature so that extending the component life and resisting oxidation and corrosion. A combustor liner with a 380 um thick TBC may last more than 30,000 h in a turbine at full load with metal temperature exposures up to 870 ℃

3.3 Metals processing industry
Mold coating play a significant role to cast metal products in the foundries. Thermal barrier coatings can control the flow of heat within a permanent mold and retard rapid chilling. But if oxygen is present, a slag will form and corrode most ceramics. Yttria is a very effective barrier against slag attack and other corrosive melts. A three-layer system ($NiCrAl/7wt\%Y_2O_3$-ZrO_2/Y_2O_3) is the proper coating withstanding the slagging corrosion.
Ancillary equipment used in foundry operations can also be improved through the use of high-temperature wear and corrosion-resistant coatings. Examples include conveyer rollers, bearing boxes, and ladle pivots [1, 7].

3.4 Solid oxide fuel cell
Solid oxide fuel cell (SOFC) is a kind of clean and high efficient electrochemical energy converter which converts the chemical energy of the gas into electricity directly. In order to reduce the production cost and improve the long-term stability of the solid oxide fuel cells, the operating temperature of the lower planar solid oxide fuel cell in the middle of the temperature range of 650-800℃is an important goal of the current research work.
YSZ is commonly used as solid electrolyte for SOFCs due to its attractive ionic conductivity at high operating temperature and good thermal and chemical stability in both oxidizing and reducing environments [10].

IV. The development tendency of thermal barrier coatings

The higher temperature requirement in gas turbine hot section, the thicker coatings (YSZ) deposited to increase thermal barrier capabilities. However, the increase of the coating thickness eventually reduces the thermal cyclic lifetime. For coating thickness increments from 300 to 635 um (0.012 to 0.025 in.), the thermal cyclic life is decreased by approximately 20% between 1000 and 1100℃[3]. Meanwhile for conventional YSZ, when the work temperature rise above 1200℃, significant phase transform and sinter effect give rise to loss of strain tolerance of coating and large volume increase. Therefore newer materials with lower thermal conductivity, rather high thermal expansion coefficient and chemical stability may replace YSZ in the future. The new materials include gadolinia-yttria-zirconate, samarium and neodymium-containing zirconates, perovskite, and pyrochlore materials [9]. Among the list of pyrochlore materials, gadolinium Zirconate ($Gd_2Zr_2O_7$) and lanthanum zirconate ($La_2Zr_2O_7$) are novel ceramic top coat materials. Because they can offer lower thermal conductivity, higher thermal expansion coefficient and Ca-Mg-Al-Silicate (CMAS) resistance [11-12]. But the further study and research need to be done in future.
Another interesting range is the structure study of TBC. Now the concept of double coating layers (DCL) has been widely investigated. DCL system consists of YSZ as bottom ceramic layer and gadolinium zirconate or

lanthanum zirconate as top ceramic layer. It is shown in Figure 1. Some papers have demonstrated that just single gadolinium zirconate or lanthanum zirconate layer system has lower thermal cycling lifetime than YSZ due to relatively low fracture toughness. Therefore YSZ as bottom ceramic layer can solve this problem. Table 2 shows the fracture toughness of YSZ, GZ and LZ. The better TBC structures will be continued studying in future.

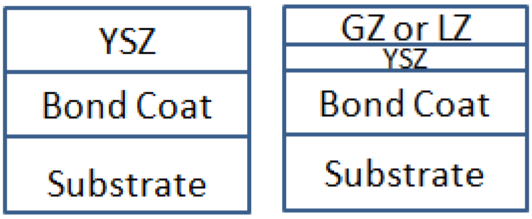

Figure 1 single layer coating (left) and double layer coating (right)

Table 2 fracture toughness of different materials

Material	YSZ	GZ	LZ
Fracture Toughness (MPa $m^{1/2}$)	2	1.02	1.1

V. Conclusion

Thermal barrier coatings (TBC) are used in high temperature application to protect components from high temperature fatigue, corrosion and oxidation. They are still an interesting topic in the automotive industries, land-based turbine and metal processing industry and solid oxide fuel cells field in future. Meanwhile new materials like pyrochlore materials and multilayer TBC structures like double coating layer system need to be investigated further.

Reference

[1] J.R.Davis, Associates, Handbook of Thermal Spray Technology, USA: ASM international, 2004.

[2] Tabbetha A.Dobbins, Richard knight, and Merriite J.Mayo, HVOF Thermal Spray Deposited Y2O3-ZrO2 coatings for Thermal Barrier Applications. *Journal of Thermal Spray Technology*, 214 volume 12 (2), June 2003.

[3] Z. Mutasim and Y. Nava, Development and Performance Evaluation of Thick Air Plasma Sprayed Thermal Barrier Coatings, *Thermal Spray: Surface Engineering via Applied Research (Proceedings of ITSC 2000)*, C.C. Berndt, Ed., May 2000 (Quebec, Canada), ASM International, 2000, p1325–1330.

[4] Zhaoyun Chen, Zichao Dong, ”Isothermal oxidation behavior of a thermal barrier coating prepared using EB-PVD,” *Surface and Interface analysis*, pp. 377-383, December 2014.

[5] K.Bobzin, N.Bagcivan, T. BrogeImann, B.Yildirim, ”Influence of temperature on phase stability and thermal conductivity of single- and double-ceramic-layer EB–PVD TBC top coats consisting of 7YSZ, Gd2Zr2O7 and La2Zr2O7,” *Surface &Coating Technology,* vol. 237, pp. 56-64, 2013.

[6] Jing Wu, Hongbo Guo, Yuzhi Gao, Shengkai Gong, ”Microstructure and thermo-physical properties of yttria stabilized zirconia coatings with CMAS deposits,” *Journal of the European Ceramic Society,* vol. 31, pp. 1881-1888, 2011.

[7] Lech Pawlowski. The Science and Engineering of Thermal Spray Coatings: Second Edition. John Wiley & Sons, Ltd. 2008.

[8] P. Carpio, E. Rayón, L. Pawłowski, A. Cattini, ”Microstructure and indentation mechanical properties of YSZ nanostructured coatings obtained by suspension plasma spraying,” *Surface & Coatings Technology,* vol. 220, pp. 237-243, 2013.

[9] Robert Vaßen, Maria Ophelia Jarligo, Tanja Steinke, ”Overview on advanced thermal barrier coatings,” *Surface & Coatings Technology,* vol. 205, pp. 938-942, 2010.

[10] Xiaodong He, Bin Meng, Yue Sun. Electron beam physical vapor deposition of YSZ electrolyte coatings for SOFCs. *Applied Surface Science*. 254 , 7159–7164, 2008.

[11] C. Mercer, S. Faulhaber, A.G. Evans, ”A delamination mechanism for thermal barrier coatings subject to calcium-magnesium-alumino-silicate (CMAS) infiltration,” *Acta Materialia,* vol. 53 (4), pp. 1029-1039, 2005.

[12] Stephan Krämer, James Yang, and Carlos G.Levi, ”Infiltration-Inhibiting Reaction of Gadolinium Zirconate Thermal Barrier Coatings with CMAS Melts,” *The American Ceramic Society,* vol. 91(2), pp. 576-583, 2008.

[13] M.Tamura, M.Takashi, J.Ishii, ”Multilayered thermal barrier coating for land-based gas turbine,” *Journal of Thermal Spray Technology,* vol. 8(1), 1999.

[14] G.Moskal, L.Swadzba, M.Hetmanczyk, ”Characterization of microstructure and thermal properties of Gd2Zr2O7-type thermal barrier coating,” *Journal of the European Ceramic society,* vol. 32, pp. 2025-2034, 2012.

[15] Xinghua Zhong, Huayu zhao, Xiaming Zhou, ”Thermal shock behavior of toughened gadolinium zirconate/YSZ double-ceramic-layered thermal barrier coating,” *Journal of Alloys and Compounds,* vol. 593, pp. 50-55, 2014.