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# Effect of Critical Plasma Spray Parameter on Characteristics of Nanostructured Yttria Stabilised Zirconia Coatings

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**Abstract:** Nanostructured Yttria stabilized zirconia (YSZ) coatings were deposited using air plasma spraying (APS) as a function of critical plasma spray parameter (CPSP). Microstructural characteristics e.g. phase distribution, porosity, microhardness, were evaluated for the deposited coatings. These coatings were found to consist of bi-modal microstructure. It was found that, with the increase of CPSP, hardness of coatings increased and porosity decreased. It has also been found that the coatings have only tetragonal zirconia phase at lowest and highest CPSP values.
**Key words:** Coatings, Plasma spraying, Thermal barrier coatings, Nanostructured YSZ coatings, CPSP.

## 1. Introduction

Thermal spray coatings have a wide variety of industrial applications. For example, gas turbine engine blades and vanes are coated with zirconia based thermal barrier coatings (TBCs) to reduce operating temperatures of above components and increase their durability (1, 2). Low thermal conductivity and high thermal expansion coefficient of zirconia makes it an ideal material for TBC applications. Because of low inherent mass, nano particles cannot be directly thermally sprayed and hence they are reconstituted and agglomerated into micrometer sized particles before spraying via spray drying and sintering processes. The nanostructured coatings typically are bimodal in nature with well dispersed inclusions of partially and unmelted regions in the fully melted matrix. The partially melted regions are generally tough and improve the overall mechanical properties of nanostructured coatings (3). It was observed that the effect of particle size distribution in nanostructured feedstock powders on amount of partially melted regions in plasma sprayed coatings and foundthat feedstock powder with a broad particle size distribution maintains some of its nanostructure character in coatings, whereas a feedstock with a narrow particle size distribution loses a major proportion of its nanostructure character (4). In another work (5), it was studied that the mechanical properties of plasma sprayed nanostructured YSZ coatings as a function of fraction of unmelted regions. It was investigated that the mechanical properties of nanostructured yttria stabilized zirconia (YSZ) coatings using an instrumented indentation technique and found that the microstructure of the nanostructured coating, which is different from a conventional coating, has a significant effect on the anisotropy of mechanical properties (6). The thermo-physical properties of conventional and nanostructured YSZ coatings deposited by air plasma spraying were studied by and it was found that the agglomerated feedstock with internal submicron size porosity may significantly affect porosity related properties, such as thermal diffusivity (7). The microstructure and thermal cycling behaviour of air plasma sprayed nanostructured YSZ thermal barrier coatings was studied and it was observed from the results of the cyclic oxidation experiments that the nanostructured coating had a longer thermal cycling lifetime to exhibit the promising thermal cyclic oxidation resistance (8).

## 2. Experimental Procedure

Commercially available nanostructured 7wt. % yttria stabilized zirconia feedstock powders used in this study are obtained from Inframat Corporation, USA. The feedstock powders are thermally sprayed to produce their corresponding coatings using Sulzer Metco 3 MB air-plasma spray (APS) equipment. Mild steel (MS) rectangular coupons were used as the substrates. During the spraying process, substrates and surfaces of the coatings are cooled by compressed air. Just before spraying, the substrates are grit blasted with alumina at a high pressure and ultrasonically cleaned using ethanol or iso- propanal in order to remove remaining dust or grease from the surface of substrates. During the process, the material to be deposited is injected in powder form using nitrogen ($N_2$) as carrier gas. A bond coat of Ni-Al is used in the case of APS sprayed coatings to improve the adhesion. The final coatings with the thickness of approximately 200-300 µm are sprayed on to mild steel (M.S) substrates of 30 mm X 25 mm X 5 mm. Several cross sectional samples are cut from these coated coupons to prepare the specimens and these are polished for studying mechanical and physical properties on the cross section of the coatings.

## 3. Results and Discussion

### 3.1 Effect of CPSP on Microstructure

The nanostructured yttria stabilized zirconia (YSZ) powders (Nanox S4007) used for coating deposition contain 7wt. % yttria ($Y_2O_3$) and 93wt. % zirconia ($ZrO_2$).The coatings are deposited at different CPSP values. Fig. 1(a-f) shows microstructure of top coat at different CPSP values. The coating can be seen to be containing a large number of micro cracks and is relatively porous. Note that the nanostructured YSZ coatings contain fully melted as well as unmelted regions. It appears that the unmelted regions relieve the stresses around them so that micro cracking is reduced in their immediate neighbourhoods.

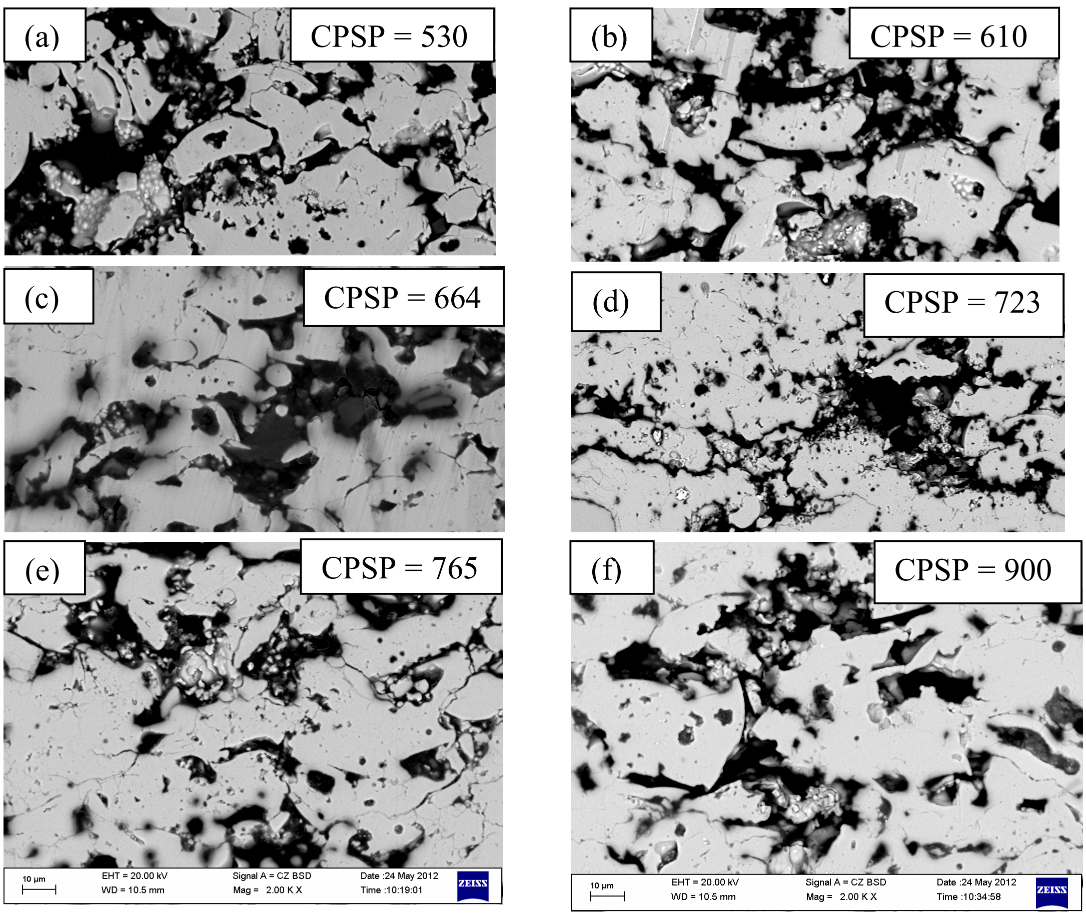


**Fig. 1(a-f). SEM images of microstructu re of nano YSZ coating at different CPSP values.**

Furthermore, possibly because of higher porosity level in powders, the nanostructured coatings contain significantly large number of small pores of 1 micron diameter or less. It can also be seen that the morphology of the unmelted region is similar to that of the feedstock particle, i.e. it is an agglomeration of loosely bounded nano particles. Note that the micro cracks, particularly those running perpendicular to coating-matrix interface are beneficial in accommodating the strains arising from thermal mismatch between the top coat, bond coat, and the substrate.

### 3.2 Effect of CPSP on Microhardness and Porosity

The microhardness values of 5.12 ± 0.35 GPa and 8.6 ± 0.45 GPa have been obtained for APS sprayed nano-structured YSZ coatings at 100 g load ($HV_{100g}$) and at CPSP values of 530 and 900, respectively. Note that the microhardness of the nanostructured YSZ coating is increasing with increase of CPSP as shown in Fig. 2. Porosity values of 10.5 ± 1.1% and 5.3 ± 1.34% have been observed at CPSP value of 530 and 900, respectively. It can be seen that porosity of the YSZ coating decreasing with the increase of CPSP as shown in Fig. 3.

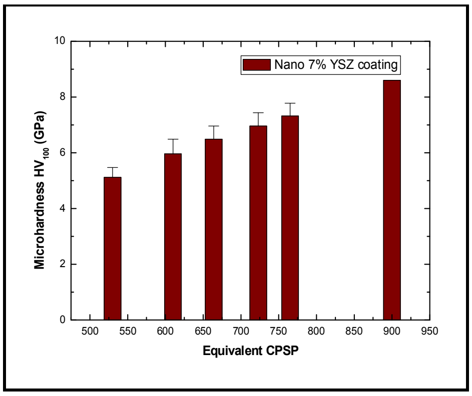


**Fig.2. Variation of microhardness of nanostructured YSZ coating as a function of equivalent CPSP.**

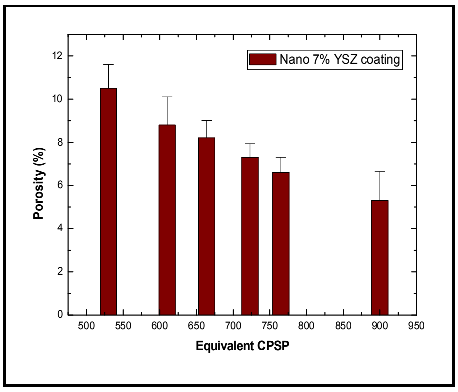


**Fig.3. Variation of porosity of nanostructured YSZ coating as a function of equivalent CPSP**

### 3.3 Effect of CPSP on Phase Characteristics

Phase analysis is also done for as-sprayed nanostructured YSZ coatings deposited at lowest and highest CPSP values of 530 and 900, respectively. Fig.4 and Fig.5 show the XRD spectra of nanostructured YSZ coatings deposited at lowest and highest CPSP values. It can be seen from figures that nanostructured YSZ coatings deposited at lowest and highest CPSP values have only tetragonal zirconia phase.

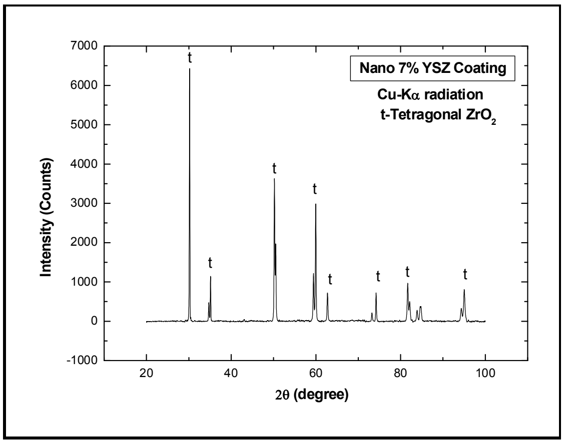


**Fig.4. XRD spectra of nanostructured YSZ coating deposited at CPSP of 530**

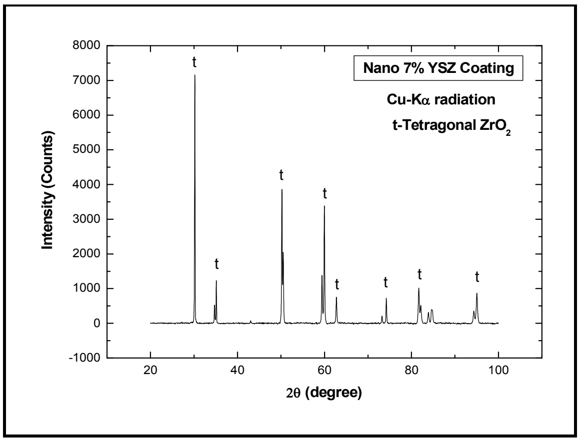


**Fig. 5. XRD spectra of nanostructured YSZ coating deposited at CPSP of 900**

## 4. Conclusions

In the present work, microstructural characteristics, microhardness, porosity and phase characteristics of nanostructured YSZ coatings deposited by air plasma spraying have been studied. It has been found that APS sprayed nanostructured YSZ coatings exhibit bi-modal microstructures having fully melted, partially melted and unmelted regions. In addition, micro hardness and porosity measurements have been used to characterize these coatings. It is found that hardness of nanostructured YSZ coatings increases and porosity decreases with the increase of CPSP. It has also been found that nanostructured YSZ coatings deposited at lowest and highest CPSP values have only tetragonal zirconia phase.

## References


1. Miller, R. A. (1987), Current status of thermal barrier coatings-An overview, Surface Coatings and Technology, Vol. 30, No. 1, pp. 1-11.
2. Chen, H., Zeng, Y., Ding, C. (2003a), Microstructural characterization of plasma- sprayed nanostructured zirconia powders and coatings, Journal of European Ceramic Society, Vol. 23, No. 1, pp. 491-497.
3. Aw, P.K., Tan, B.H. (2006), Study of microstructure, phase and microhardness distribution of HVOF sprayed multi-modal structured conventional WC-17Co coatings, Journal of Materials Processing Technology, Vol. 174, No. 1, pp. 305-311.
4. Lima, R. S., Kucuk, A., Berndt, C. C. (2001), Evaluation of microhardness and elastic modulus of thermally sprayed nanostructured zirconia coatings, Surface and Coatings Technology, Vol. 135, No. 2-3, pp. 166-172.
5. Lima, R. S., Karthikeyan, J. S., Kay, C. M., Lindemann, J., Berndt., C. C. (2002), Microstructural characteristics of cold-sprayed nanostructured WC-Co coatings, Thin Solid Films, Vol. 416, No. 1, pp.129-135.
6. Racek, O., Berndt, C.C. (2007), Mechanical property variations within thermal barrier coatings, Journal of Surface & Coatings Technology, Vol. 202, No. 1, pp. 362-369.
7. Soltani, R., Coyle, T.W., Mostaghimi, J., Lima, R.S., Moreau, C. (2008), Thermo-physical properties of plasma sprayed Yttria Stabilised Zirconia Coatings, Journal of Surface & Coatings Technology, Vol. 202, No. 1, pp. 3954-3959.
8. Sun, J., Zhang, L., Zhao, D. (2010), Microstructure and thermal cycling behaviour of nanostructured yttria partially stabilized zirconia (YSZ) thermal barrier coatings, Journal of RARE EARTHS, Vol. 28. Special Issue, Dec. 2010, pp. 198-201.


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