# Microstructure and Properties of Plasma Sprayed Nanostructural $ZrO_2$ Coatings

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*Abstract*- **Plasma sprayed zirconia deposits have been employed in wide applications for thermal protection. Recently, the use of nanostructural surface represents an alternative for improving the performance of these coatings. The present paper reviewed the works in this field at our research group, including synthesis of nanostructural $ZrO_2$ powders, influence of spraying parameters on microstructure and properties of nanostructural $ZrO_2$ coatings. Significant achievements in this field are, (1) a bimodal microstructure of coatings was formed from nanostructural agglomerated $ZrO_2$ particles, (2) nanostructural $ZrO_2$ coating exhibited improved mechanical properties and thermal shock resistance, as well as lower thermal diffusivity, (3) the surface bioactivity of nanostructural $ZrO_2$ coatings was also identified.**

## I. INTRODUCTION

Significant advancement has been made in the preparation of nanostructural coatings for different applications. Nanostructural yttria stabilized zirconia coatings are noted ones [1,2]. It was reported that plasma sprayed nanostructural coatings are built up successive accumulation of partially molten powder particles reconstituted with nanostructural zirconia powders. The thermal shock resistance of plasma sprayed nanostructural zirconia coating is higher than that of conventional one due to the nanostructure [3]. Zirconia coatings with superior wear resistance and more durable when compared with the conventional thermal sprayed coatings open a wide range of research and industrial application opportunities [2]. The present paper provides a brief review of the issue related nanostructural yttria stabilized zirconia coatings deposited by plasma spraying.

## II. CURRENT RESULTS

### A. *Bimodal microstructure of coating*

Figure 1 depicts the typical surface and cross-section views of plasma sprayed nanostructural $ZrO_2$ coatings. It can be seen that all the grains on the top surface of as-received nanostructural coatings were less than 100 nm, and grains grow into typical columns with diameter around 100 nm [Fig.1a]. The nanostructural coating not only possessed the splat lamellae which was similar with the conventional coatings, but also contained equiaxial grain with splats, as

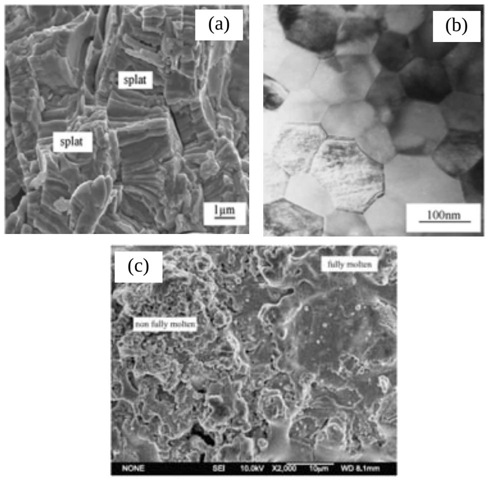


Fig. 1. Microstructure of nanostructural $ZrO_2$ coating: (a) cross-section, (b) and (c) surface

shown in Fig.1b. The similar microstructure has been also observed by other authors and defined as “bimodal microstructure”[1]. As shown in Fig.1c, the complex bimodal microstructure was consistent with that of the powders proceeded by plasma jet, which was related to the difference in the melting degree of the nanostructural powders reacting from synchronous effect of grain size difference and the temperature heterogeneity of plasma jet. It is important to point out that by controlling the bimodal structure, it is possible to engineer coatings with pronounced different in microstructural characteristics and mechanical performance.

### B. *Bimodal microstructure of coating Improved mechanical properties*

The tribological properties of plasma sprayed $ZrO_2$ coatings using nanostructure powder and optimized parameters were tested under sliding against steel and compared with those of the coating sprayed using commercially available powder. The results obtained showed that the friction coefficients were almost the same for both coatings. However, the nanostructural coatings were more resistant. The wear rates of the nanostructural coatings are in the range from one-fourth to four-fifths of the conventional $ZrO_2$ coating [3,4]. The improvement in wear resistance of the nanostructural coatings could be mainly ascribed to the decrease in micrometersized defects, such as pores, interlamellar and interlamellar cracks in the coatings, which resulted in improved mechanical properties [4,5].

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### C. *Enhanced thermal shock resistance*

The thermal shock resistance of nano- and conventional $ZrO_2$ coatings was conducted by heating them in a furnace for 30 min at a series of temperature up to 1300 °C, followed by subsequent dropping in cool water for 10 min. The results obtained showed that the number of thermal shock cycles to failure of the nanostructural $ZrO_2$ coating was about two and three times as large as that of the conventional coating [6]. It is pointed that the thermal shock behavior of the nanostructural coating was different from that of the conventional coatings. For the nanostructural coating, the vertical crack was predominant crack mode, which resulted in the superior thermal shock resistance. In contrast to this, in the conventional $ZrO_2$ coating, the long vertical cracks were not observed under the same experiment condition. The obvious horizontal cracks were formed near the interface of top coat/bond coat, which determined to its lower coating cycling number of thermal shock [6].

The thermal diffusivity of  coating was determined by the laser-flash method and the results showed that the thermal diffusivity of the nanostructural $ZrO_2$ coating was 1.8-2.54 $\times10^{-3}$ $cm^2/s$ between 200 and 1200 °C, while the thermal diffusivity of conventional coating was 2.25-3.57$\times10^{-3}$ $cm^2/s$. The lower thermal diffusivity of coatings is very important as used for thermal protection [7].

### D. *Enlarged bioactivity*

Plasma sprayed $ZrO_2$ coating has superior performance due to the formation of non-transformation tetragonal phase during plasma spraying. It has been used to form composite coatings with bioactive hydroapatite and brittle bioglass. No bioactivity of plasma sprayed $ZrO_2$ coatings was reported [8]. The surface morphology of the as-sprayed nanostructural $ZrO_2$ coating is shown in Fig. 2a. From Fig. 2a, it can be seen that nanostructural surface with grain size less than 100 nm was observed. After immersion in simulated body fluid for 28 days, the coating surface was covered by some worm-like microcrystals in Fig. 2b, which is one the typical morphologies of the apatite formed in vitro [9]. However, no apatite was formed on the surface of the polished coating whose nanostructural surface was removed, implying the significance of nanosized grains for its bioactivity.

## III. CONCLUSIONS

Nanostructural yttria stabilized $ZrO_2$ coating has been deposited by plasma spraying and exhibits a bimodal microstructure, formed by particles that were fully melted and semi-melted in the plasma jet. Improved mechanical properties and thermal shock resistance of coatings can be obtained. The bioactivity of coating was also identified.

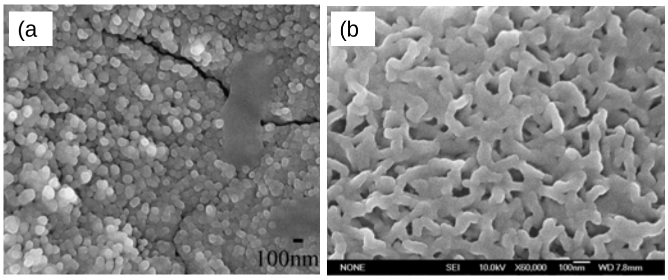


Fig. 2. SEM views of as-sprayed (a) and immersed in simulated body fluid for 28 days (b) nanostructural $ZrO_2$ coatings.

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