Plasma sprayed nanostrucutred zirconia coatings deposited from different powders with nano-scale substructure

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Nanostructured materials have the potential to provide a quantum improvement in properties [1]. In the past decade, interest has been increasing in the preparation and characterization of nanostructured ceramic coatings [2–5]. In this study, 3 mol% Y_2O_3 partially stabilized nano-scale zirconia particles (70–110 nm, Jiujiang Rarmeiya Advance Materials Co., China) were used to deposit zirconia coatings and the influence of spraying powders on coating quality was evaluated. Fig. 1 shows the transmission electron microscopy (TEM) morphology of the nano-scale zirconia particles. Before the plasma spraying, the nano-scale particles were reconstituted into three kinds of powders referred to as powder *a*, *b* and *c*. To obtain the blocky powder a (Fig. 2a), the nano-scale zirconia particles with 2.5 wt% PVC binder were pressed at 200 MPa. The mixed powder was then calcined at 800 °C for 1 h, and subsequently crushed and sieved through a 180-mesh screen. Fig. 2b and c show the scanning electron microscopy (SEM) morphologies of the two spray-dried powders reconstituted under different operational parameters (suspension composition, feeding rate and feeding pressure). Both were seen as spherical micro-scale sized powders as shown in Fig. 2. Since the operating temperature of the spray drying process was less than 200 °C [6], the spray-dried powders still remained nano-scale substructure. For powder *b*, more than 50 vol% particles were smaller than 15 μm. Besides, it was noted that powder *b* was porous and its cohesion was weak as shown in Fig. 2b. In contrast, powder *c* was dense and its size distribution was mainly in the range of 15–50 μm (see Fig. 2c).

The Metco A-2000 atmospheric plasma spraying equipment with F4-MB plasma gun (Sulzer Metco AG, Switzerland) was used to deposit the zirconia coatings. The powders were fed with a Twin-system 10-V (Plasma-Technik, Switzerland). During the spraying, compressed air was applied to cool the stainless-steel substrates, which were degreased ultrasonically in acetone and grit-blasted with alumina abrasive. All the zirconia coatings were deposited under identical conditions, as follows: (a) primary Ar gas flow was 35 slpm, (b) secondary H_2 gas flow was 12 slpm, (c) spraying distance was 120 mm, and power was 45.6 kW.

The Scanning Electron Microscopy observation revealed that the zirconia coatings deposited from the three reconstituted powders presented different microstructures as shown in Fig. 3. The coating deposited from the calcined and crushed powders was porous. Many pores were larger than 10 μm in this coating. Besides, some unmolten powders were reserved in the large size pores as indicated with arrows in Fig. 3a. During the spraying, a certain amount of large size powders bounced off the substrate. Its deposition efficiency was about 36% and ranked second place among the three reconstituted powders (see Table I). In the case of powder *b*, due to its porous microstructure and smaller grain size, its impulse toward the target surface was the lowest

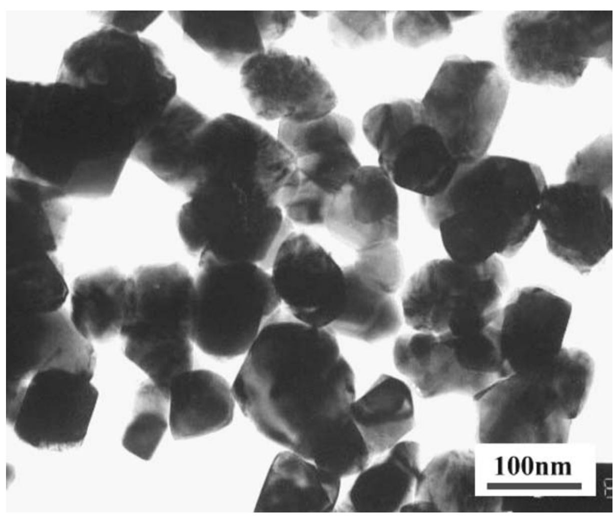

Figure 1 TEM micrograph showing the morphology of the nano-scale zirconia particles.

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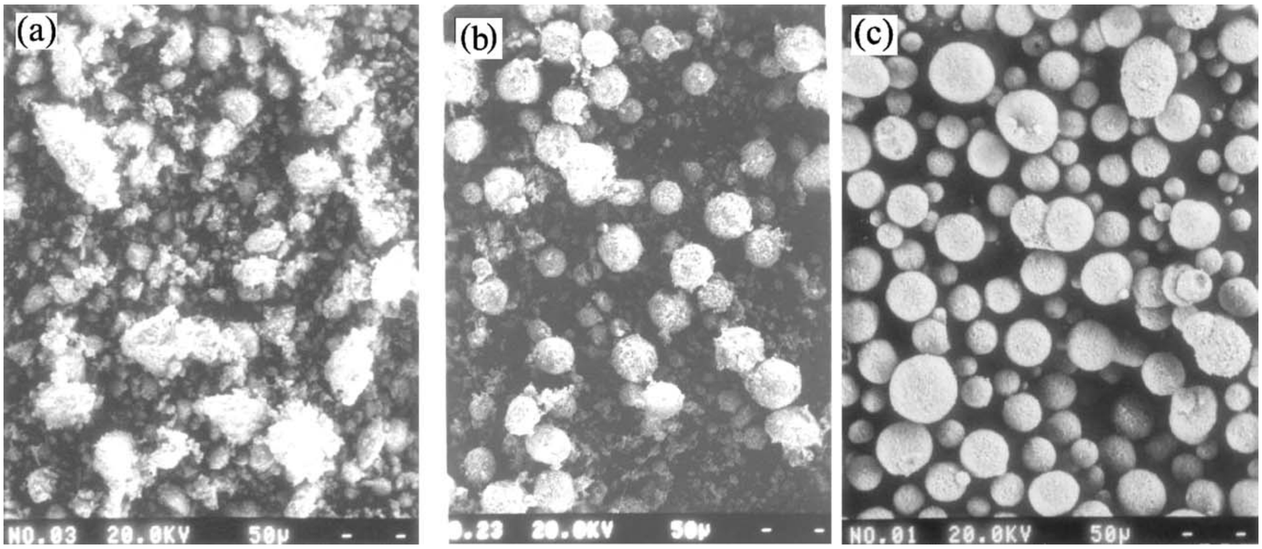

Figure 2 SEM micrographs showing the morphologies of the three reconstituted powders: (a) powder a, (b) powder b, and (c) powder c.

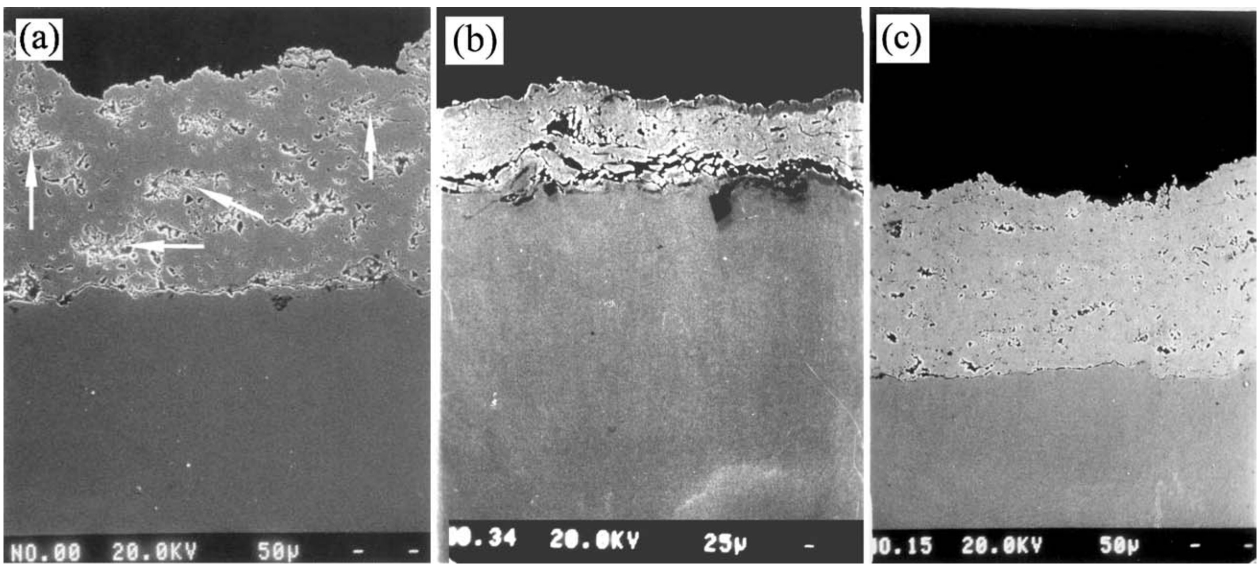

Figure 3 SEM micrographs showing the morphologies of the plasma sprayed zirconia coatings deposited from the three reconstituted powders: (a) coating a, (b) coating b, and (c) coating c.

among the three reconstituted powders. The deposition efficiency of powder b was only 19%, which ranked next to powder a. From Fig. 3b, a wide, long crack was observed clearly, which indicated that the bonding between the coating and the stainless-steel substrate was bad. In this study, powder c possessed the best flowability and the highest impulse, resulting from its proper size distribution, dense microstructure and good cohesion. As a result, powder c had the highest deposition efficiency among the three reconstituted powders. It was as high as 49% as listed in Table I. Corresponding coating deposited from powder c presented the best quality as reflected by its excellent microstructure (Fig. 3c) and the highest Vickers microhardness (Table I).

TABLE I Deposition efficiencies of the three reconstituted powders and the Vickers microhardness of the corresponding coatings

Number	a	b	c
Deposition efficiency of powder (%)	36	19	49
Vickers microhardness of coating (GPa)	5.3 ± 0.8	3.5 ± 1.0	8.6 ± 0.3

Vickers microhardness tests were performed on the polished cross-section surfaces of three kinds of plasma sprayed coatings with a 1.96 N normal load and a dwell time of 15 s. All the reported microhardness values came from the mean of 20 indentations. Compared with the other two coatings, coating c had the highest Vickers microhardness as listed in Table I. It can be explained in terms of the lowest porosity and the best cohesion of coating c. The microhardness of the coating a was still much higher than coating b although there were many large size pores in coating a. Based on the experimental results, it can be concluded that among the influence factors on coating quality, the density of reconstituted powder is more important than its shape. Plasma sprayed coatings are built up of a large number of molten splats. It is widely accepted that a higher particle velocity before impacting the target surface may be expected to give molten splats excellent deformation, which leads to better bonding and results in lower porosity in the final coating.

In this study, three kinds of plasma sprayed zirconia coatings were deposited from three reconstituted powders with nano-scale substructure. The deposition efficiencies of the three reconstituted powders and the Vickers microhardness of the corresponding coatings were measured. Based on the experimental results, it is emphasized that the deposition efficiency of reconstituted powders and the quality of plasma sprayed coatings are highly dependent on the size distribution, density and the cohesion of the reconstituted powder. That is, optimization of spraying powder must be considered in order to obtain high quality nanostructured coating.

Acknowledgment
The authors wish to thank the financial support from the Basic Research Program of the Korean Science & Engineering Foundation (No. R01-2002-000-0035-0 (2002)).

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Received 23 September 2003
and accepted 18 March 2004