DOI: 10.1017/S1431927606067729
Microsc Microanal 12(Supp 2), 2006

Microstructural Study of Metastable ZrO_2-Al_2O_3 and ZrO_2-Y_2O_3-Al_2O_3 Coatings Deposited Using Solution-Precursor Plasma Spray (SPPS) Process

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Hot-section metallic components of aircraft and industrial gas-turbine engines are often protected by ceramic thermal barrier coatings (TBCs). TBCs help reduce the temperature of the underlying component substrate, thereby prolonging the service life of the components [1]. Recently, solution-precursor plasma spray (SPPS) has been used to deposit highly durable TBCs in the ZrO_2-Y_2O_3 system [2]. The SPPS process, where solution precursor is atomized directly into a plasma jet, is an effective way of producing metastable ceramics coatings [3]. In this study we have used the SPPS process to deposit metastable ceramic coatings in the ZrO_2-Al_2O_3 and the ZrO_2-Y_2O_3-Al_2O_3 systems. These coatings show extended solubilities and unusual microstructures, and TBCs made in these systems may offer better thermal and environmental protection compared to conventional TBCs.

Coatings in one binary (ZrO_2-10 mol%Al_2O_3) and two ternary (ZrO_2-3.6mol%Y_2O_3-10mol%Al_2O_3 and ZrO_2-3.6mol%Y_2O_3-10 mol%Al_2O_3) compositions were prepared using the SPPS process. These coatings show rich variety of metastable phases. As-sprayed coatings in all systems are predominantly nanostructured (grain size < 100 nm), and made mostly of *t*-ZrO_2 ($P4_2/nmc$) (Fig. 1a). The Al^{3+} solute appears to stabilize the tetragonal ZrO_2 phase in the binary and the ternary coatings. These coatings also contain some orthorhombic ($Pbc\ 2_1$ *or Pbcm)* and monoclinic ($P2_1/c$, only binary) ZrO_2 grains (Fig.1a), and Al-rich amorphous phases at grain-boundaries (Fig. 1b) and inside the ZrO_2 grains (Fig. 2b). After a prolonged heat-treatment (1400 ˚C, 30 h) the binary and ternary coatings were found to contain α-Al_2O_3 precipitates, and the *t*-ZrO_2 was found to destabilize into the *m*-ZrO_2 phase. In addition to *t*-ZrO_2, amorphous Al_2O_3, γ-, γ'- and δ-Al_2O_3 are present in the as-sprayed ternary coating with 10mol%Al_2O_3 (Fig. 2A), but only α-Al_2O_3 is present in the ternary coating with 20 mol%Al_2O_3. The ternary coatings after heat treatment at 1400^0C (30 h) showed that *t*-ZrO_2 is mostly stable, and only alumina phase to precipitate out is α-Al_2O_3. Heat treatment at a higher temperature 1500^0C (30 h) results in the transformation of *t*-ZrO_2 to *m*-ZrO_2. A new Y_2O_3 phase was found in both ternary coatings after heat treatment at 1500 ˚C, 30h (Fig. 3a-3f). Using SADP and CBED that phase was identified as tetragonal (*I4mm*) Y_2O_3, with lattice parameters *a*=0.702 nm and *c*=0.597 nm.

References

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[4] This work was supported by the Office of Naval Research (Grant No. N000014-02-1-0171) and Naval Air Systems Command (Grant No. N00421-05-1-0001)

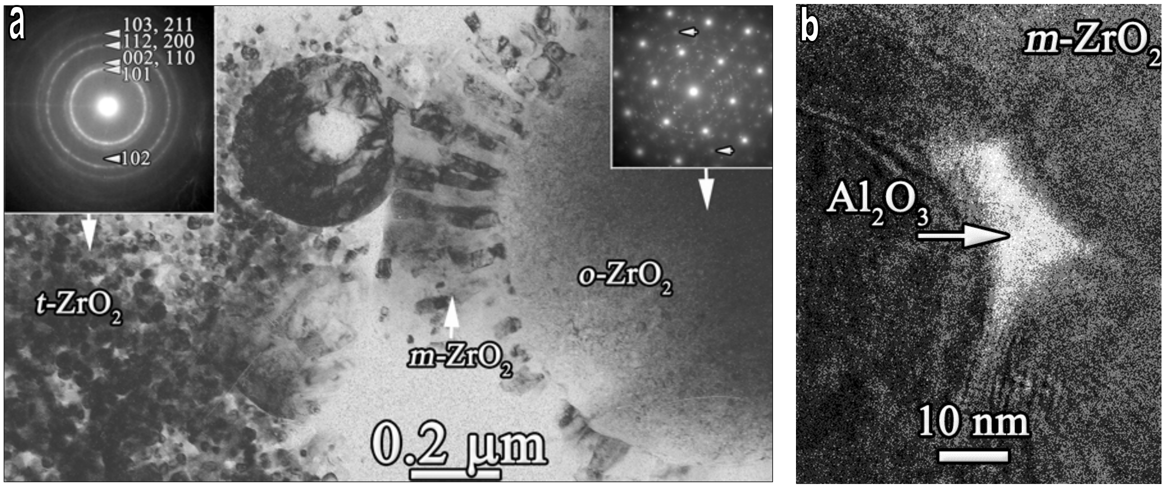

Fig.1. (a) TEM image of as-sprayed ZrO_2-10 mol%Al_2O_3 coating with correspondent SADP from *t*- and *o*-ZrO_2 and (b) Al EELS map from the quaternary *m*-ZrO_2 grain boundary area.

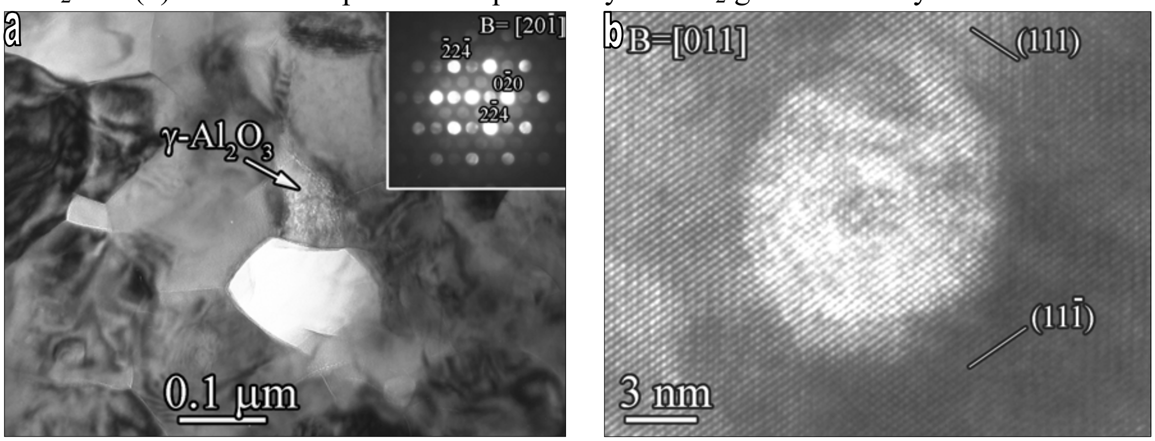

Fig. 2. TEM images of: (a) As-sprayed ZrO_2-3.6mol%Y_2O_3-10mol%Al_2O_3 with tetragonal γ-Al_2O_3 grain, and corresponding μ-diffraction pattern, surrounded by *t*-ZrO_2 grains, and (b) amorphous alumina particle inside *t*-ZrO_2 grain.

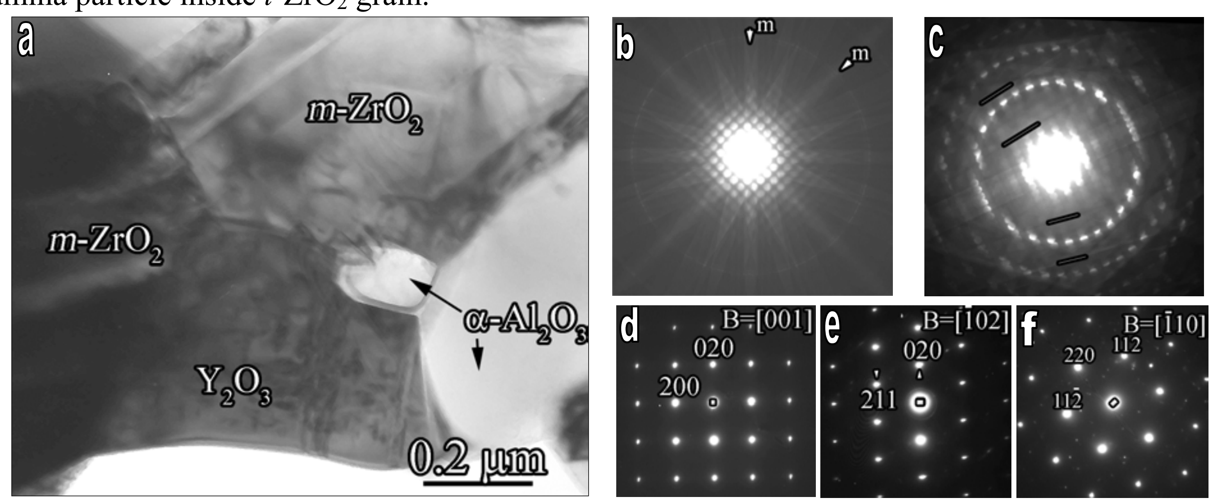

Fig.3. (a) TEM image of heat-treated (1500^{0}C 30 hours) ZrO_2-3.6mol%Y_2O_3-10 mol%Al_2O_3, together with CBED patterns in [001]-(b), [133] –(c) zone axes and CBED patterns (d-f).

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