Processing/Microstructure/Properties Studies of Thermal Barrier Coatings via High-resolution X-ray Microtomography

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Introduction

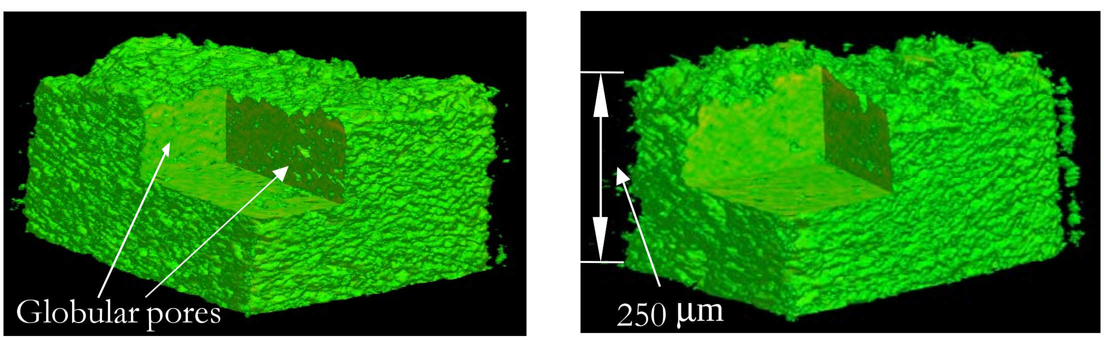
Thermal barrier coatings (TBCs) are increasingly used to improve the performance and reliability of gas turbine engines. The application of TBCs in this area and the expansion of TBC applications into new industrial areas depend on our ability to tailor the microstructure of these (usually ceramic) coatings to the properties required. The strong SUNY/NIST/ANL program in TBCs has played an important role in improving our ability to design and fabricate quality material.

Methods and Materials

A multidisciplinary approach toward materials characterization is being undertaken for processing/microstructure/property correlations in plasma-sprayed and electron-beam physical-vapor-deposited (EB-PVD) ceramic coatings. High-resolution x-ray microtomography and ultrasmall-angle x-ray scattering (USAXS) are being explored for the first time to establish these correlations. Experiments focused on the quantitative characterization of porosity (pore size distribution, orientation, and morphology) in these coatings and relative changes in microstructural features upon thermal cycling and thus the resulting lifetime of the coatings.

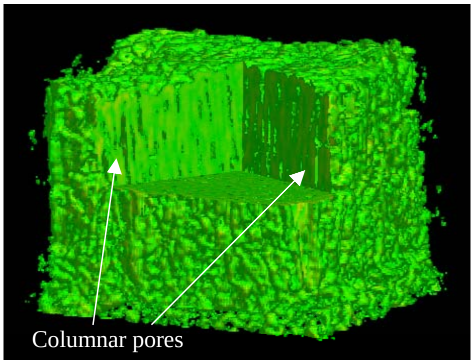
Computed microtomography permits visualization of these microstructural features, mainly porosity distribution, in 3-D, thus providing a better insight at 1- to 1.5-µm resolution. This work was carried out under a strong industrial collaboration, in which ceramic coatings were obtained from General Electric in Nishiyama, NY; Chromalloy Gas Turbine Corp. in Orangeburg, NY; Siemens Westinghouse Power Corporation in Orlando, FL; and ONERA in France. Studies focused on understanding the microstructural behavior of these ceramic coatings, an issue of considerable scientific and industrial interest.

Studies focused on the correlation between the sintering behavior and thermal cycling life of the coatings. Thermal cycling at high temperatures results in increased diffusion, which eliminates pores and cracks in the microstructure. This densification results in increased modulus and thermal conductivity, thereby reducing strain tolerance and the thermal barrier effect. This sintering response differs in plasma-sprayed and EB-PVD coatings because of differences in pore morphology. In EB-PVD coatings, bridging of columns upon high-temperature exposure has been demonstrated; this reduces the intercolumnar spacing. A quantification of the effects of increasing temperature and time duration on microstructural changes in the coatings is underway. In plasma-sprayed coatings, resolution limits revealed microstructural changes with respect to the intrasplat cracks and interlamellar pores, but sintering effects were observed with respect to changes in the number of globular pores. (See Figs. 1 and 2.)

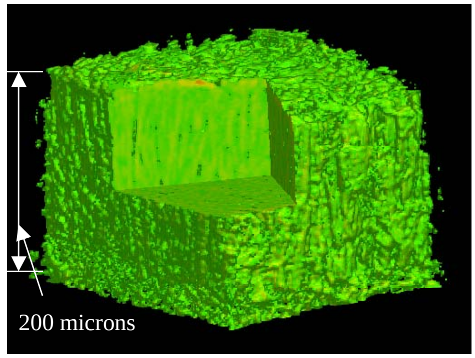


(A) As-sprayed coating (B) Thermal-cycled coating

FIG. 1. Computed microtomography results show microstructural features observed in plasma-sprayed partially stabilized zirconia coating, (A) shows the globular pore structure in an as-sprayed coating. (B) shows the sintering effect during thermal cycling (1150ºC, 10 cycles).



(A) As-deposited coating



(B) Heat-treated coating

FIG. 2. Computed microtomography results show columns bridging in EB-PVD partially stabilized zirconia coating. (A) shows the columnar pore structure in an as-deposited coating. (B) shows the sintering effect during isothermal exposure (1300ºC, 100 h).

Quantitative analysis is underway to obtain various porosity parameters. The tomography data combined with results from other experimental techniques, such as small-angle x-ray scattering (SAXS), provide unparalleled insight into the microstructural features of the coating and allow a deeper understanding of various features of the microstructure and resulting engineering properties.

Acknowledgments

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