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Materials Science

Processing-Microstructure-Properties studies of thermal barrier coatings via high-resolution X-ray microtomography

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Introduction

Thermal barrier coatings (TBCs) are being increasingly used to enhance the performance and reliability of gas turbine engines. The expansion of TBC applications is very much dependent on fuller understanding of the microstructures of these ceramic coatings. The Stony Brook – NIST Argonne program has led to an improved basis upon which to design these coatings.

Method and materials

A multidisciplinary approach towards 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 Ultra Small Angle X-ray Scattering (USAXS) are being explored for the first time to establish these correlations. Experiments were focused on quantitative characterization of porosity (pore size distribution, orientation and morphology) in these coatings and relative changes in microstructural features upon thermal cycling, thus the resulting lifetime of the coatings.

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

Studies were focused on the correlation of sintering behavior to thermal cycling life of the coatings. Thermal cycling at high temperatures results in increased diffusion, thus eliminating pores and cracks in the microstructure. This densification results in increased modulus and thermal conductivity, therefore reducing strain tolerance and thermal barrier effect. This sintering response differs in plasma sprayed and EBPVD coatings due to differences in the pore morphology. In EBPVD coatings, bridging of columns upon high temperature exposure of the coating has been demonstrated, thus reducing the intercolumnar spacing. Quantifying the effects of increasing temperature and time duration on microstructural changes in the coatings is underway. In case of plasma spraying, resolution limits revealing microstructural changes with respect to the intrasplat cracks and interlamellar pores but sintering effects were observed with respect to change in number of globular pores.

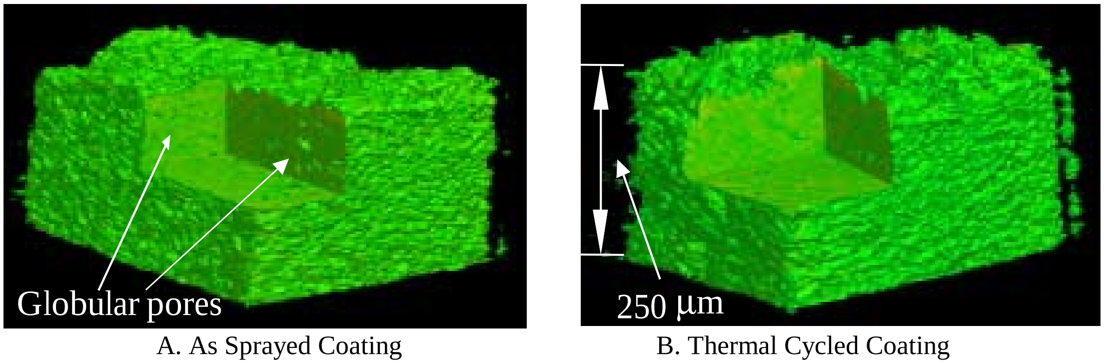

FIG. 1. Computed Microtomography results show microstructural features observed in plasma-sprayed partially stabilized zirconia coating, A shows the globular pore structure in an as-sprayed coating. B shows the sintering effect during thermal cycling (1150 C, 10 cycles).

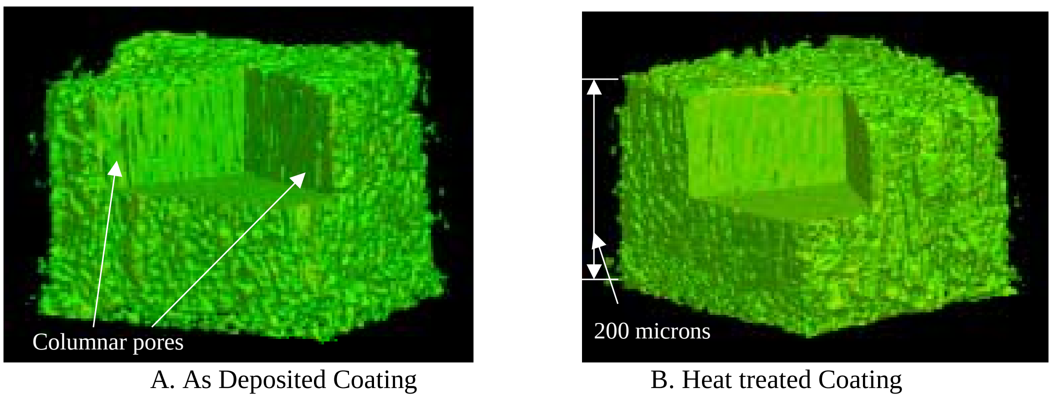

FIG. 2. Computed Microtomography results show columns bridging in EB PVD partially stabilized zirconia coating, A shows the columnar pore structure in an as-deposited coating. B shows the sintering effect during isothermal exposure (1300 C, 100 hours).

The tomography data combined with results from other experimental techniques, such as small-angle X-ray scattering (see another abstract in this book) provide unparalleled insight into the microstructural features of the coating and allow a deeper understanding among various features of the microstructure and resulting engineering properties.

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