Motivation and Objectives

Motivation:
- High energy Synchrotron X-ray Diffraction (XRD) provides high-resolution biaxial strain data in the coating that allows for accurate evaluation of residual strain in the coatings.

Objectives:
- Obtain strain state in TBC configurations with and without doped layer.
- Investigate the effects of doped layer on spatial residual strain distribution in the TBC top coat at room temperature and 1100°C.

Theory
- XRD can provide information about crystal structure, distribution of phases, and microstrains when the X-ray beam interacts with the material of interest.
- The angle of diffraction (θ) relates to the spacing (d) of the atomic planes through Bragg’s Law:
  \[ n \lambda = 2d \sin \theta \]
  where \( \lambda \) is wavelength of X-ray and \( d \) is spacing between layers of atoms, \( n \) an integer.

Methods and Materials

- A high-energy (71 keV) X-ray beam of size 30 x 30 μm² impinged on samples with a resolution of 30 μm
- Transmission XRD method was used
- The data was analyzed to quantify strain in the coatings

Reference sample
- YSZ
- NiCoCrAlY IN738

Doped layer placed at top
- YSZ+YSZ:Eu
- NiCoCrAlY IN738

Doped layer placed at bottom
- YSZ+YSZ:Eu
- NiCoCrAlY IN738

XRD results

- Fit to determine biaxial strain state
- The coating is found to be under tensile in-plane strain (ε₁₁) and compressive out-of-plane strain (ε₃₃).
- Introducing the dopant layer at top increases the strains in YSZ layer closer to bond coat compared to regular configuration.
- At high temperature, more thermal expansion is observed away from the doped layer, and less thermal expansion close to doped layer, in both cases.

Summary

- High-resolution Synchrotron XRD experiments were performed using three TBC configurations at Argonne National Laboratory.
- Introduction of doped layer at top increases the residual strain in YSZ layer.
- At high temperature, larger thermal expansion is observed away from the doped layers.

Future Work

Determination of coefficient of thermal expansion (CTE) and inter-layer mismatch at high temperature
- Coefficient of thermal expansion can be determined from high temperature XRD data.
- Mismatch in thermal strain in different layers will provide insight into the interfacial mechanics of the TBC at service conditions.

Phosphor Thermometry by time decay method
- The intensity of photoluminescent light from RE elements decays over time with a characteristic time constant, called decay time.
- The decay time is temperature sensitive. Therefore, measurement of decay time traces the temperature of the doped layer.
- Measurement of photoluminescence will elucidate the viability of the above configurations to develop temperature sensing TBCs.

Background and Introduction

- Introducing Rare Earth (RE) dopants into Thermal Barrier Coating (TBCs) can enable temperature sensing coatings.
- The temperature measurement is achieved by the photoluminescence property of RE elements.
- However, maintaining mechanical integrity in service environments is of utmost importance while achieving temperature sensing TBCs.
- Introducing the new layer with RE elements may alter the mechanics of the topcoat depending on TBC configurations.
- In this work, TBC configurations are probed using synchrotron X-ray Diffraction (XRD) to determine spatial strain distribution.

References/Acknowledgements


Synchrotron X-Ray Diffraction Measurements of Thermal Barrier Coating Configurations with Rare Earth Elements for Phosphor Thermometry

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