NOVEL THERMALLY-SPRAYED ARCHITECTURES FOR HIGH TEMPERATURE THERMAL BARRIER COATING SYSTEMS

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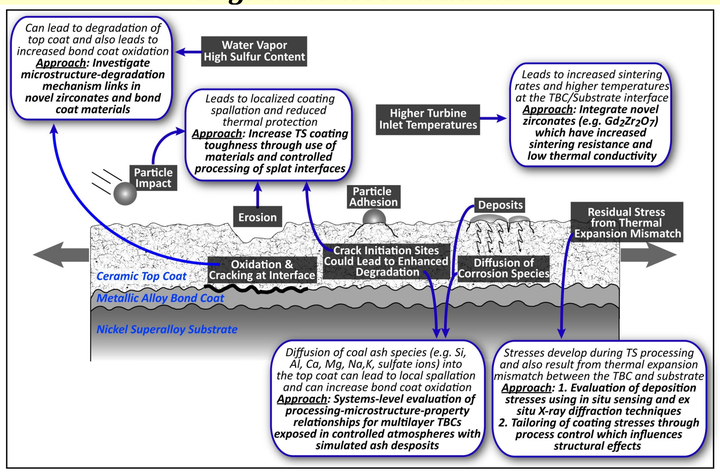
Thermal Barrier Coating Challenges for High Temperature Systems

- Thermal spray processing is widely used for the application of thermal barrier coatings (TBC) and bond coats (BC) to components in both propulsion and land-based gas turbines.
- A multilayer coating architecture was designed to address several issues in the IGCC turbine:
  - Higher turbine inlet temperatures
  - Particle erosion
  - Environmental degradation of the bond coat
  - Thermal and residual stresses
- Two sets of novel TBC materials were investigated:
  - Pyrochlore-type zirconates
  - Co-doped materials with rare earth oxides.
- Powders were procured that were suitable for plasma spray processing. (Acknowledgement: Dr. Rober Vassen, Prof. Carlos Levi, Dr. Dongming Zhu, Mr. Howard Wallar)

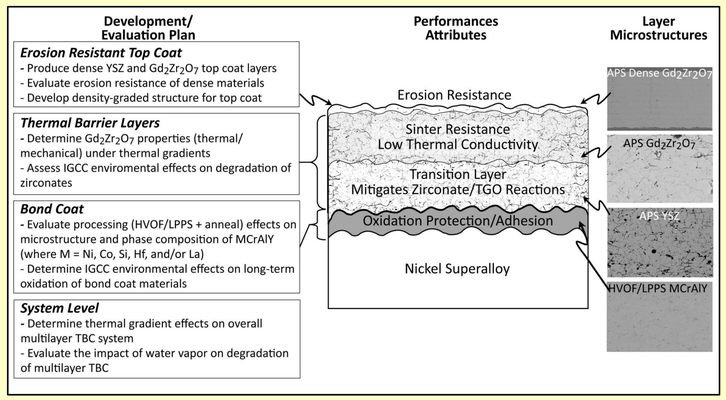
Top: Schematic of TBC degradation issues for high temperature applications including approaches to addressing the issues.

Bottom: Schematic of a multilayer coating architecture to address the requirements for IGCC gas turbines including high temperature thermal barrier , sinter resistance, erosion resistance and environmental degradation protection of the bond coat.

Degradation Mechanisms



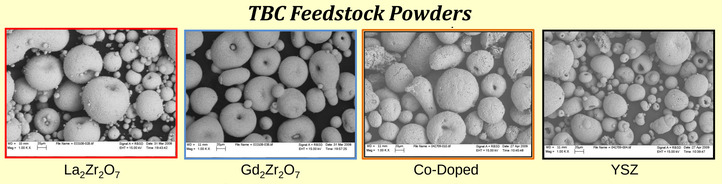
Multilayer Coating Architecture



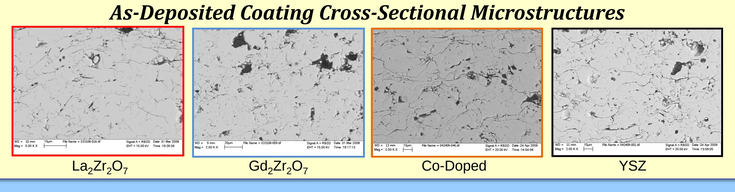
Plasma Spray Processing Optimization

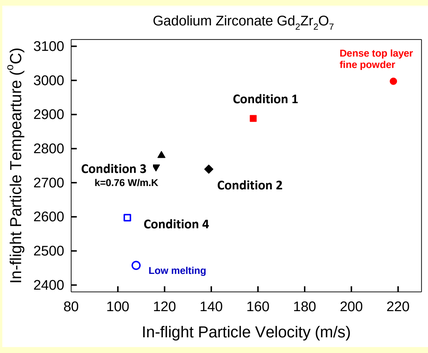
- Plasma processing conditions were optimized using in-flight particle sensors.
- Similar microstructures were achieved in the various materials to allow for material property comparisons

TBC Feedstock Powders



As-Deposited Coating Cross-Sectional Microstructures



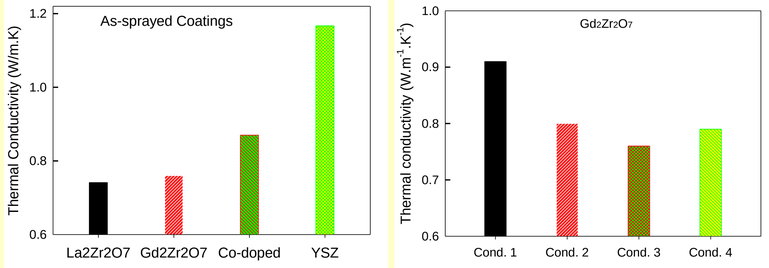


Process optimization and mapping of plasma sprayed $Gd_2Zr_2O_7$.

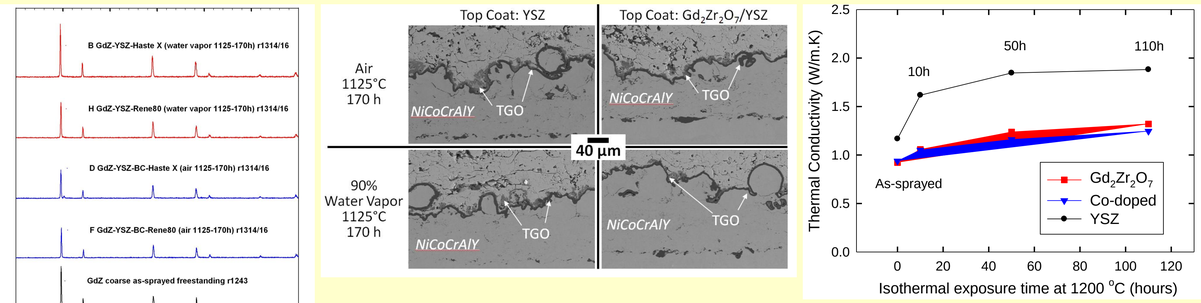
Thermal & Mechanical Properties

- Thermal properties were evaluated in as-sprayed and heat treated coatings.
- Heat treatments were conducted at 1200°C in air and 90% water vapor.
- Thermal conductivity was measured at room temperature using laser flash.
- $Gd_2Zr_2O_7$ coatings were phase-stable.
- TGO growth on the bond coat consisted of both alumina and spinel
- Co-doped and $Gd_2Zr_2O_7$ coatings had improved sintering resistance.

As-Sprayed Coating Thermal Conductivity



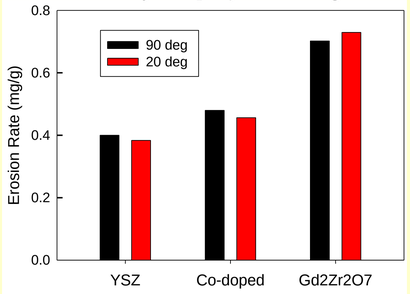
Effect of Heat Treatment on Phase Composition, Oxidation and Thermal Conductivity



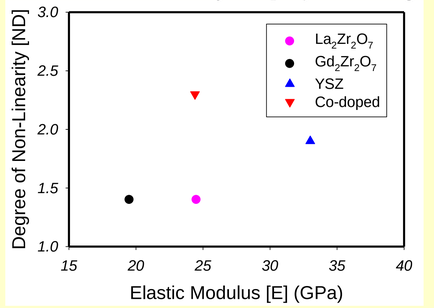
Left: X-ray diffraction on as-sprayed and heat treated $Gd_2Zr_2O_7$-based coatings.
Center: TGO formation on BCs after heat treatments in air and water vapor.
Right: Thermal conductivity changes due to heat treatment-induced sintering

- Erosion rates were evaluated at 90°and 20°for new and traditional TBC materials.
- $Gd_2Zr_2O_7$ showed higher erosion rates than traditional YSZ.
- Coatings elastic modulus and degree of non-linearity were obtained from bi-layer curvature analysis.
- The new materials exhibited lower elastic modulus, and which suggests higher compliance in them.

Erosion of As-Sprayed Coatings

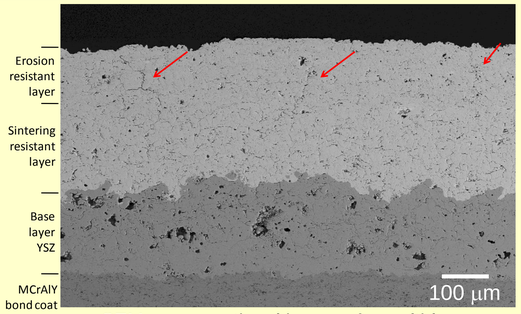


Mechanical Behavior of As-Sprayed Coatings



Architecture Fabrication

- Material property data served as the basis for a layered TBC coating designed to provide the necessary multi-functionality:
  - A CoNiCrAlY bond coat was deposited via HVOF on nickel-superalloy substrates.
  - The multi-layer TBC architecture system was applied via plasma spray as the top coat.
- The goals for this coating architecture included:
  - Decreasing the coating thermal conductivity
  - Increasing the top layer erosion resistance
  - Reduction of the overall fabrication cost



SEM cross-sectional image of a multi-layer TBC architecture