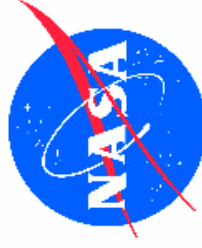


High Pressure Burner Rig Testing of Advanced Environmental Barrier Coatings for Si₃N₄ Turbine Components

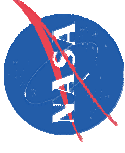
Dongming Zhu, Dennis S. Fox and Robert T. Pastel



Durability and Protective Coatings Branch
Materials and Structures Division
NASA John H. Glenn Research Center
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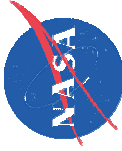
This work was supported by NASA UEET and Fundamental Aeronautics Programs

The 31st International Cocoa Beach Conference & Exposition on Advanced Ceramics & Composites
Daytona Beach, Florida, January 22-26, 2007



Abstract

Advanced thermal and environmental barrier coatings are being developed for Si_3N_4 components for turbine engine propulsion applications. High pressure burner rig testing was used to evaluate the coating system performance and durability. Test results demonstrated the feasibility and durability of the coating components under the simulated engine environments.

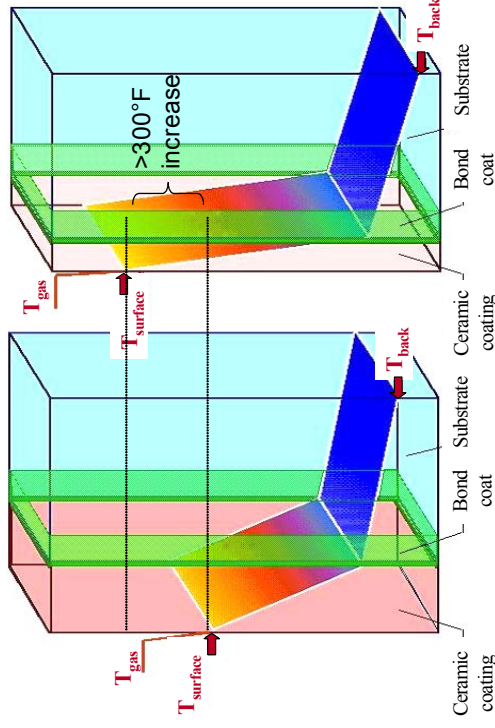


Revolutionary Ceramic Coatings Greatly Impact Turbine Engine Technology

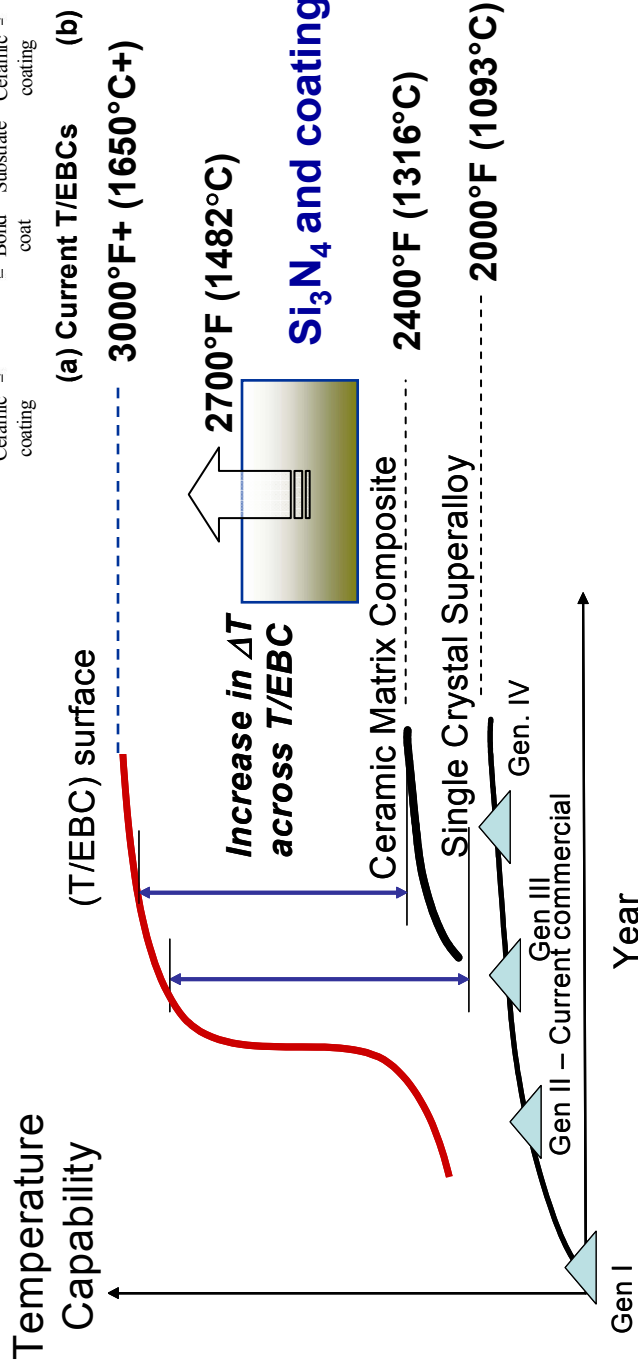
- **Ceramic barrier coating system development goals**
- Meet temperature and performance requirements
- Help fundamental scientific understanding
- Increase Technology Readiness Levels (TRL)

Ceramic barrier coating system development goals

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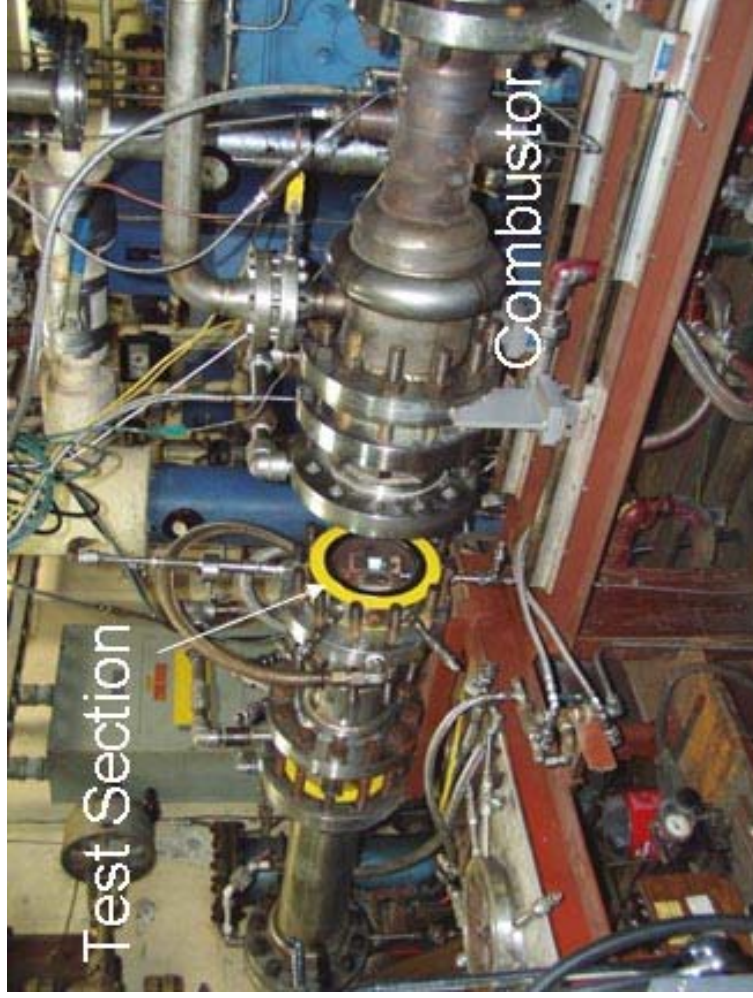


(a) Current T/EBCs (b) Advanced T/EBCs



High Pressure Burner Rig for Thermal and Environmental Barrier Coating Development

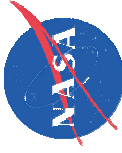
- Realistic engine combustion environments for specimen and component testing



High Pressure Burner rig (6 to 12 atm)

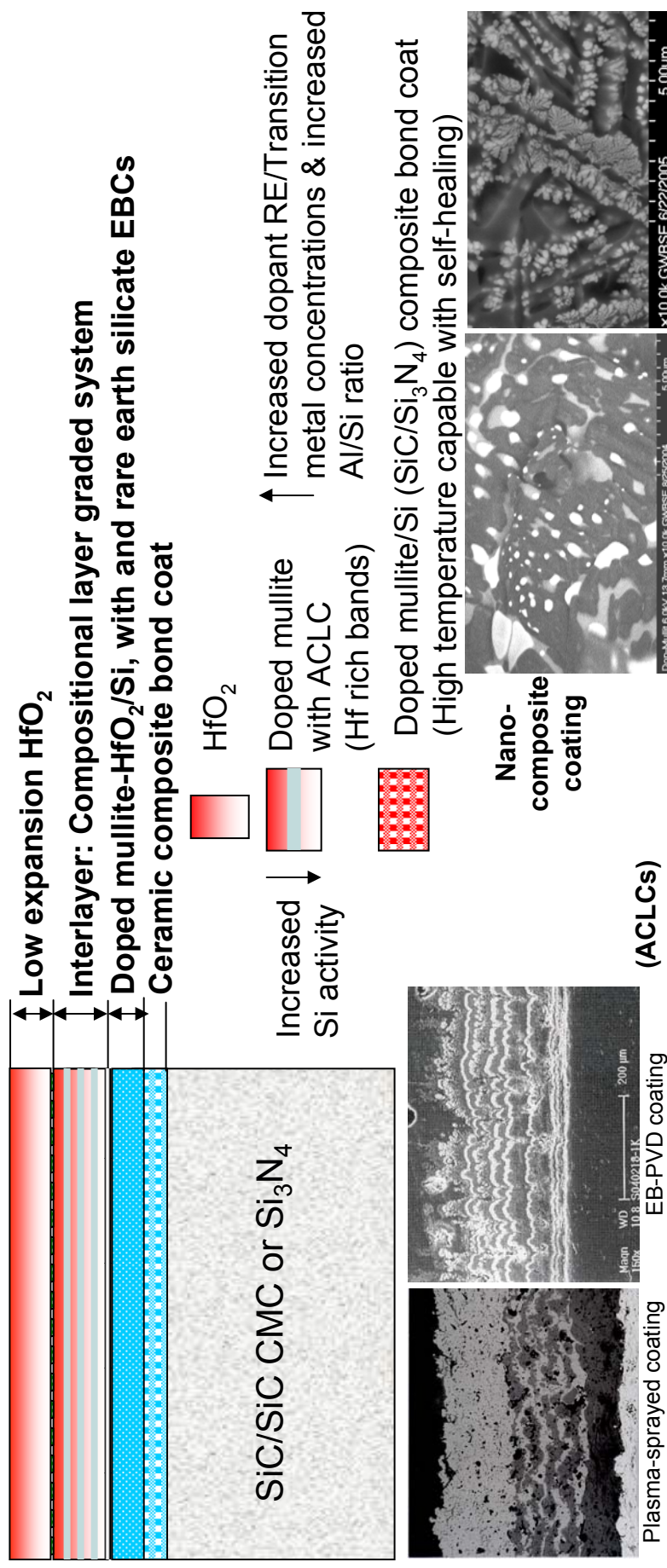


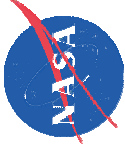
Coated turbine vane test fixtures



Multi-functionally Graded Environmental Barrier Coatings for Si-based Ceramic Components

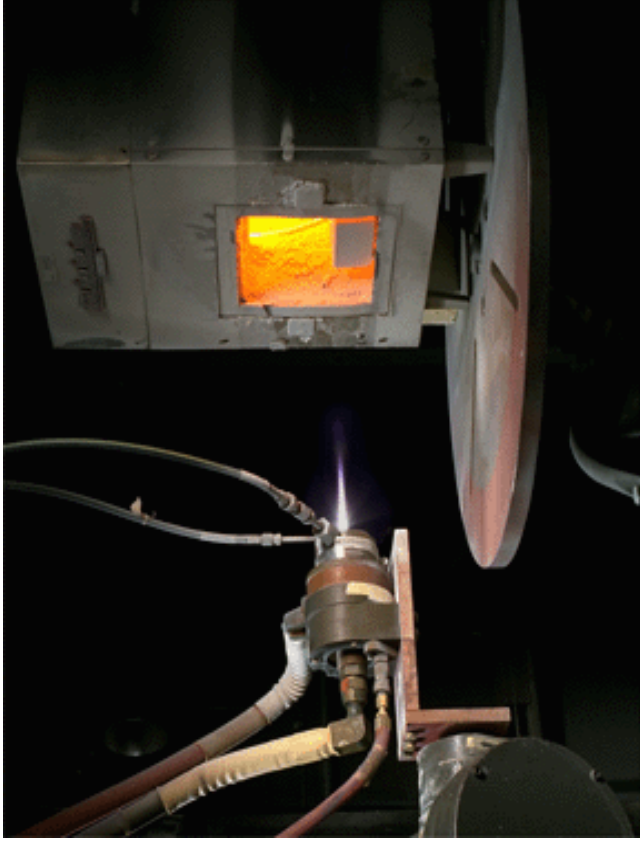
- **Advanced TEBC System**
Multifunctionally Graded Materials for SiC/SiC CMC and Si₃N₄ applications
- High stability HfO₂ layer with graded interlayer, environmental barrier and advanced bond coats
- Alternating composition layered coatings (ACLCS) and nano-composite coatings





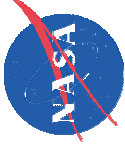
Environmental Barrier Coatings Processed on Complex-Shaped Specimens

- **The coating processing technologies developed for complex shaped components**



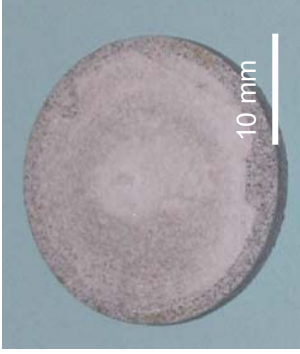
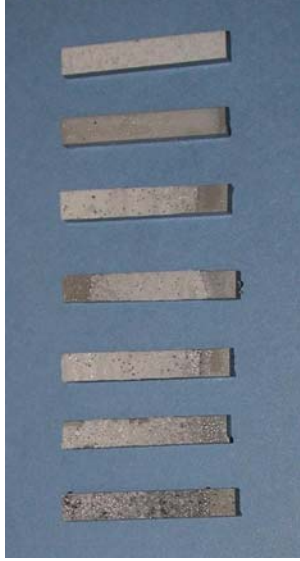
Plasma-spray processing of Environmental barrier coatings for various components





Advanced Environmental Barrier Coatings Development for Si₃N₄ components

- The coatings tested using cyclic furnaces, laser rig and the high pressure burner rig at the temperatures up to 2650°F (1450°C)
- Coating temperature capability, water vapor stability and durability emphasized

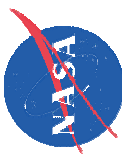


Furnace/laser heat flux/high pressure burner rig testing

Fracture strength and high temperature rupture testing



High Pressure Burner Rig Sub-Component Testing

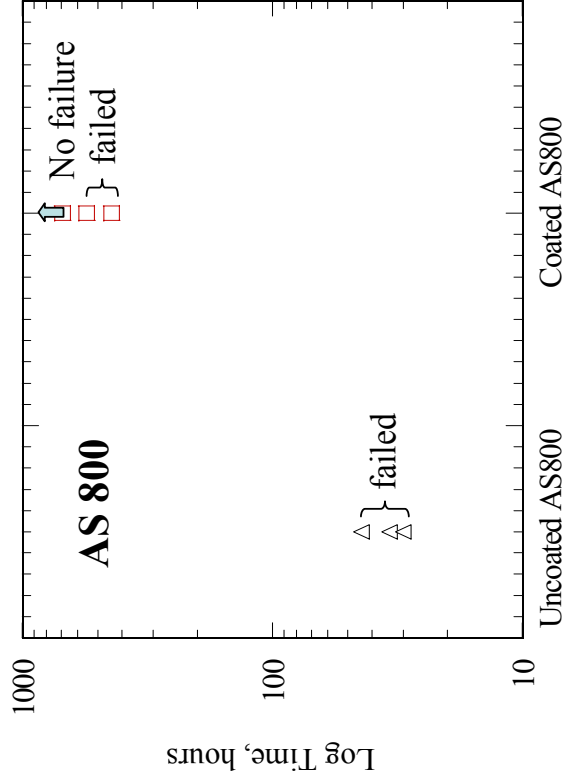


Dynamic Fatigue Testing of Advanced Environmental Barrier Coatings Coated Si₃N₄ Materials

- The coated specimens demonstrated significantly improved slow crack growth resistance at high temperatures



Composite EBC coated AS 800 Si₃N₄ rupture testing (completed 691 hrs 2500°F 1371°C, 250 MPa without failure)

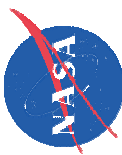


(a)



(b)

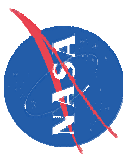
EBC coated SN 282 rupture testing
(completed 815 hr testing at 2500°F (1371°C) at 200MPa without failure)



Advanced Environmental Barrier Coatings for Si₃N₄ Demonstrated High Temperature Capability

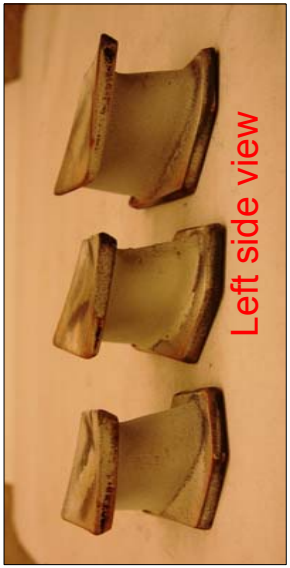
— The coated SN 282 bend bar specimens demonstrated 50hr durability at 2500°F in the high pressure burner rig

The figure illustrates the durability testing of coated SN 282 bend bar specimens. It includes a central diagram of the burner rig with a flame and pyro coating, and a series of photographs showing the specimens at various stages of testing. The specimens are labeled #1 through #6. The photographs show the specimens at 14 hrs., 27.8 hrs. (new setup), 41.6 hrs., and at the end of the test. Red arrows indicate the leading edges and the total time spent on specimens #6 and #3. A central diagram shows the specimens in a burner rig with a flame and pyro coating. Labels include '8 micron pyro / .90 emmissivity focused on coated side (#5)', 'view thru pyrometer', and 'back side/ 2-color pyro'. Red arrows point to 'leading edges' and 'total of .40.6 hrs. on #6 & #3'.



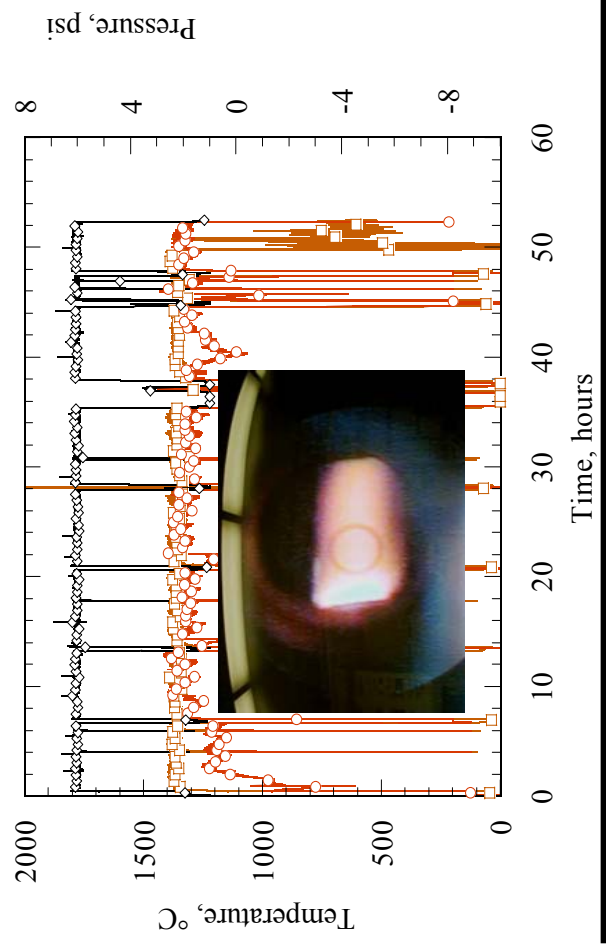
Advanced Environmental Barrier Coatings for Si₃N₄ Demonstrated in High Pressure Burner Rig

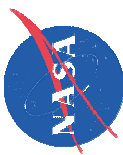
- The coated miniature Si₃N₄ vanes demonstrated 50hr durability in the high pressure burner rig test at up to 2500°F



After 50 hot hr testing

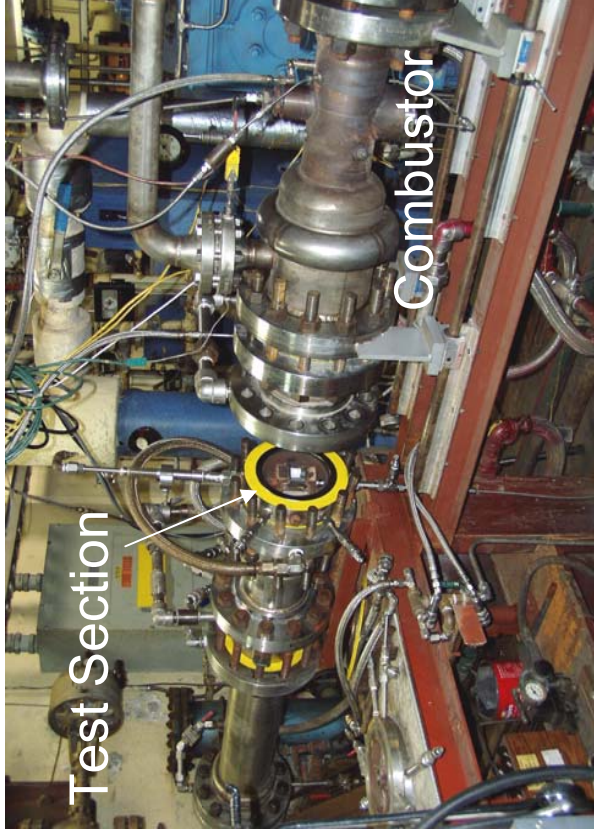
—□— T_{gas} —◇— Pressure, psi
—○— T_{surface}



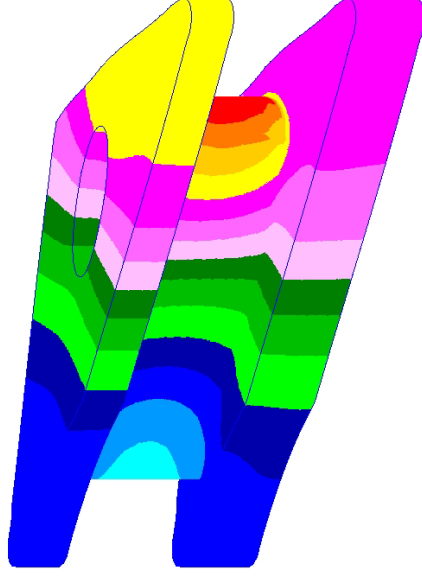
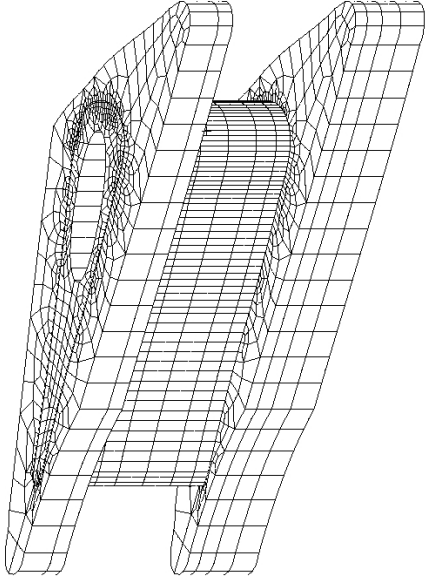


Advanced Environmental Barrier Coatings for Si₃N₄ Demonstrated in High Pressure Burner Rig

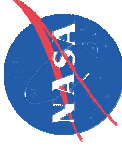
- A coated Si₃N₄ vane also demonstrated 50hr durability in the high pressure burner rig test at up to 2700°F



Tested coated Si₃N₄ vane



Modeled temperature distributions



Summary

- **Advanced multi-functionally graded thermal and environmental barrier coatings developed and processed on complex-shaped components**
- **The coated specimens showed significantly improved high temperature strength and slow crack growth resistance**
- **Coated Si_3N_4 vanes have been successfully demonstrated in the high pressure burner rig**
- **The coating systems showed promising performance in the burner rig simulated engine environments**