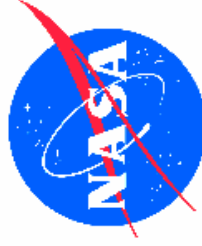


# High Pressure Burner Rig Testing of Advanced Environmental Barrier Coatings for Si<sub>3</sub>N<sub>4</sub> Turbine Components

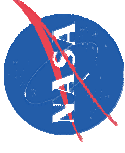
Dongming Zhu, Dennis S. Fox and Robert T. Pastel



Durability and Protective Coatings Branch  
Materials and Structures Division  
**NASA John H. Glenn Research Center**  
**Cleveland, Ohio 44135, USA**

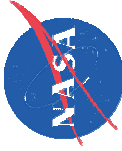
**This work was supported by NASA UEET and Fundamental Aeronautics Programs**

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



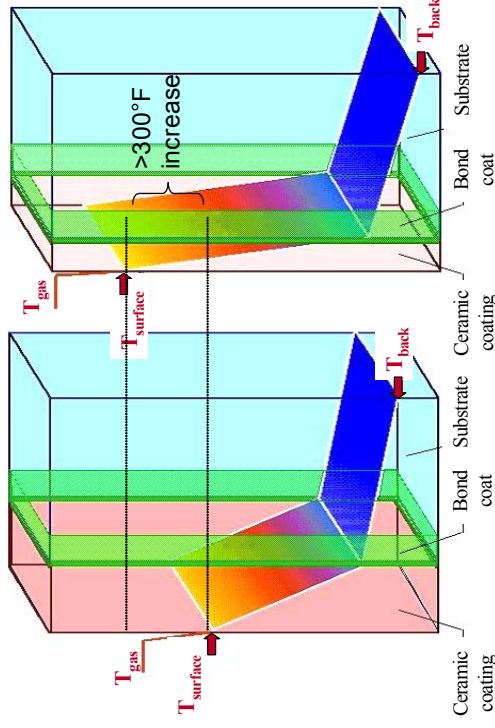
## **Abstract**

**Advanced thermal and environmental barrier coatings are being developed for  $\text{Si}_3\text{N}_4$  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.**

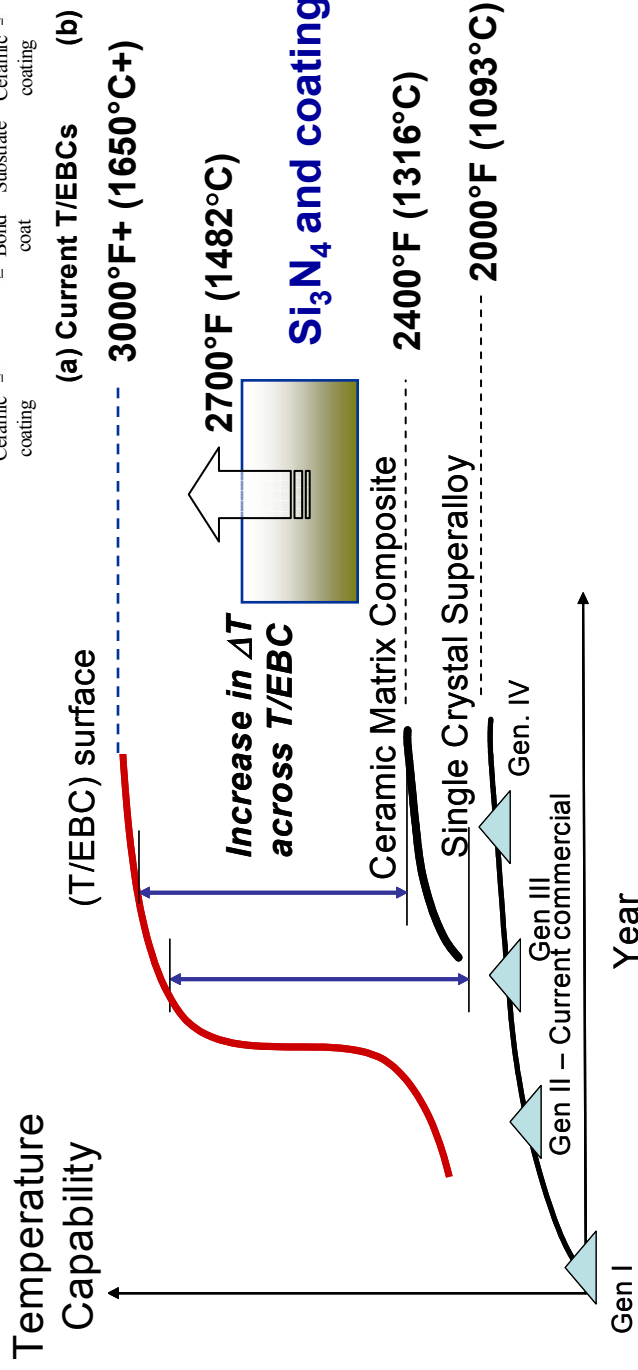


# Revolutionary Ceramic Coatings Greatly Impact Turbine Engine Technology

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

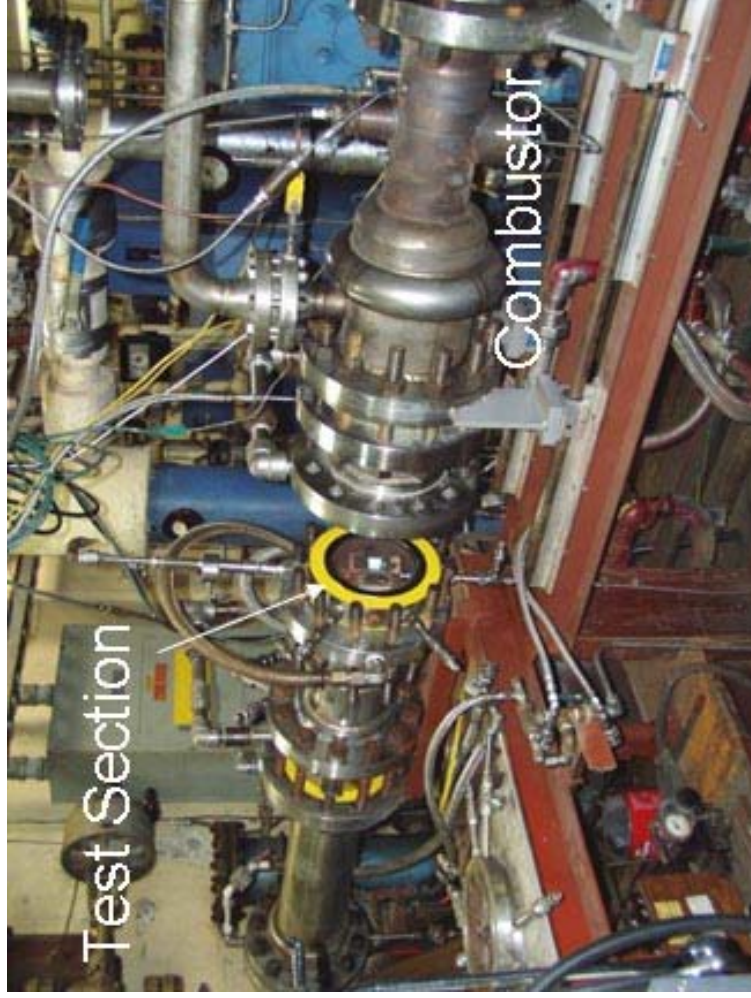


(a) Current T/EBCs (b) Advanced T/EBCs



## 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)

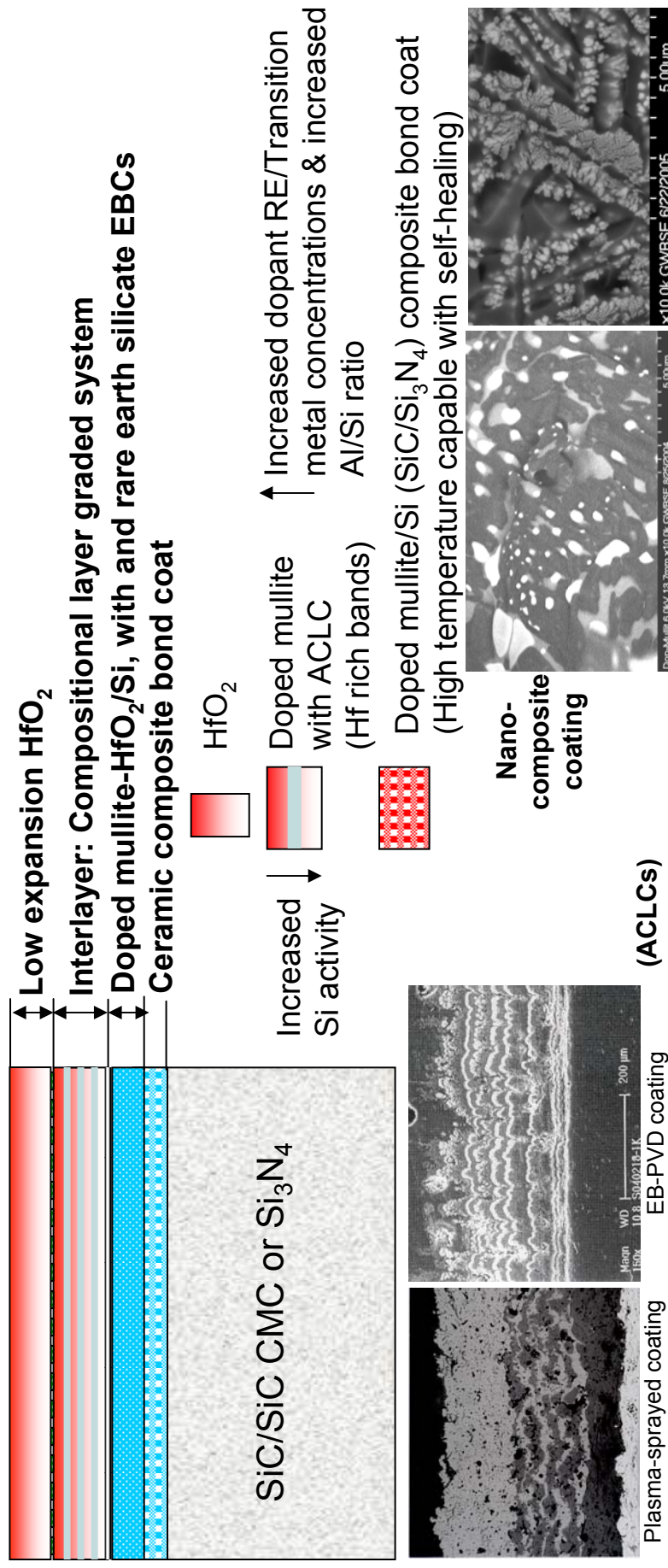


Coated turbine vane test fixtures



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

- **Advanced TEBC System**  
**Multifunctionally Graded Materials for SiC/SiC CMC and Si<sub>3</sub>N<sub>4</sub> applications**
- High stability HfO<sub>2</sub> layer with graded interlayer, environmental barrier and advanced bond coats
- Alternating composition layered coatings (ACLs) and nano-composite coatings



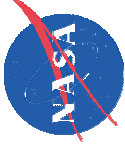
## **Environmental Barrier Coatings Processed on Complex-Shaped Specimens**

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



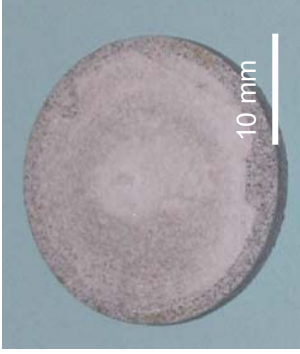
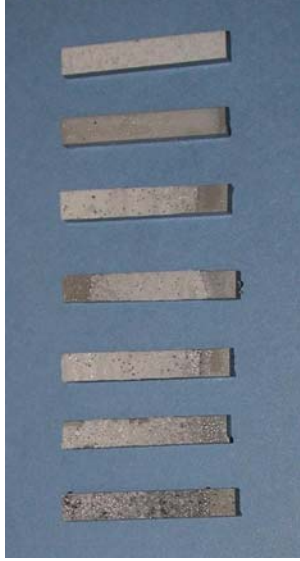
**Plasma-spray processing of Environmental barrier coatings for various components**





## Advanced Environmental Barrier Coatings Development for $\text{Si}_3\text{N}_4$ components

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

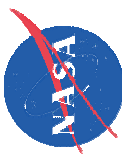


Furnace/laser heat flux/high pressure burner rig testing

Fracture strength and high temperature rupture testing



High Pressure Burner Rig Sub-Component Testing

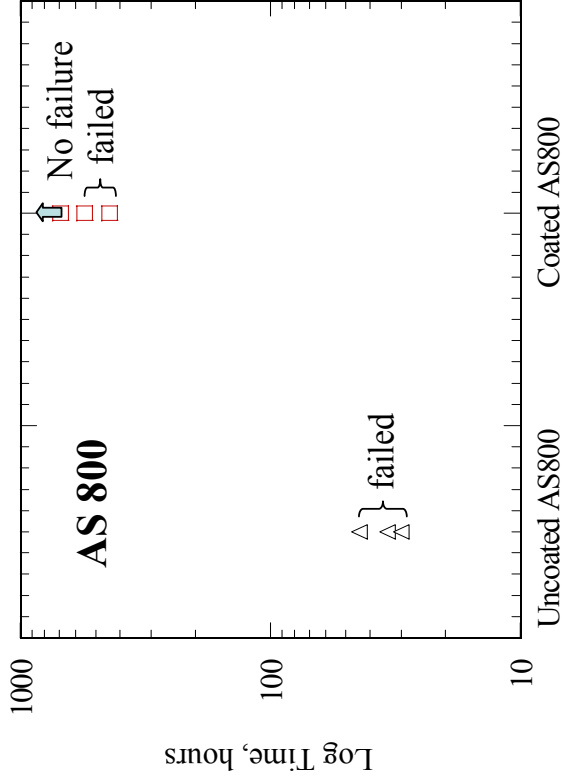


# Dynamic Fatigue Testing of Advanced Environmental Barrier Coatings Coated Si<sub>3</sub>N<sub>4</sub> Materials

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



**Composite EBC coated AS 800 Si<sub>3</sub>N<sub>4</sub> rupture testing** (completed 691 hrs 2500°F 1371°C, 250 MPa without failure)



(a)

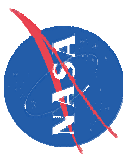


(b)

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

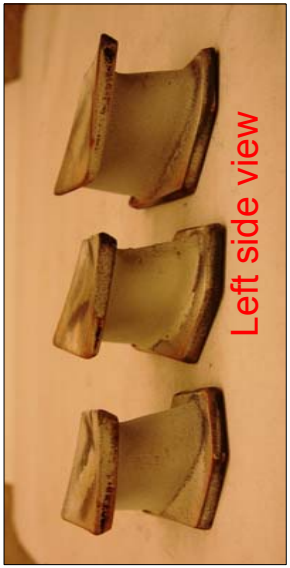






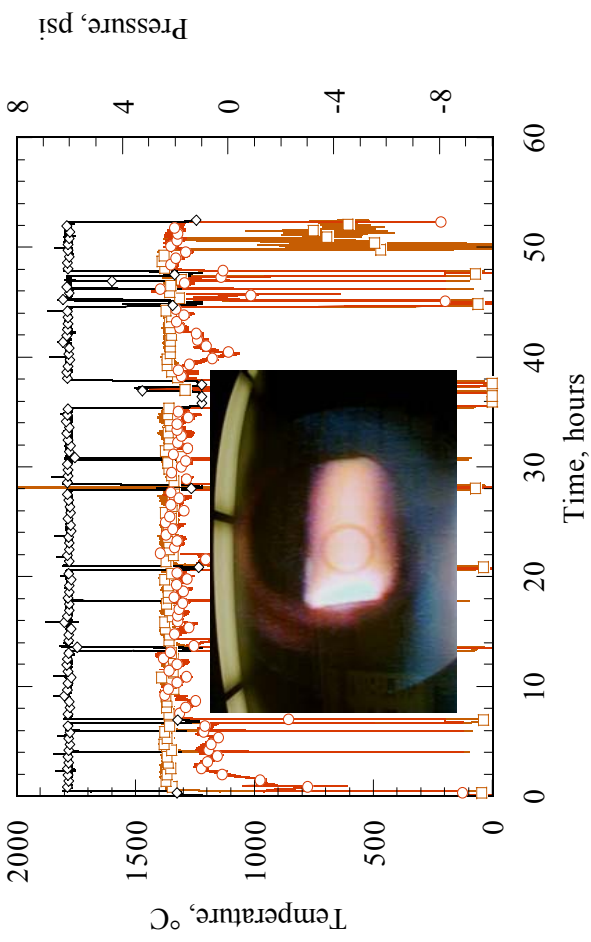
# Advanced Environmental Barrier Coatings for Si<sub>3</sub>N<sub>4</sub> Demonstrated in High Pressure Burner Rig

- The coated miniature Si<sub>3</sub>N<sub>4</sub> vanes demonstrated 50hr durability in the high pressure burner rig test at up to 2500°F

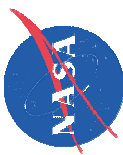


After 50 hot hr testing

—□— T<sub>gas</sub>     —◇— Pressure, psi  
—○— T<sub>surface</sub>

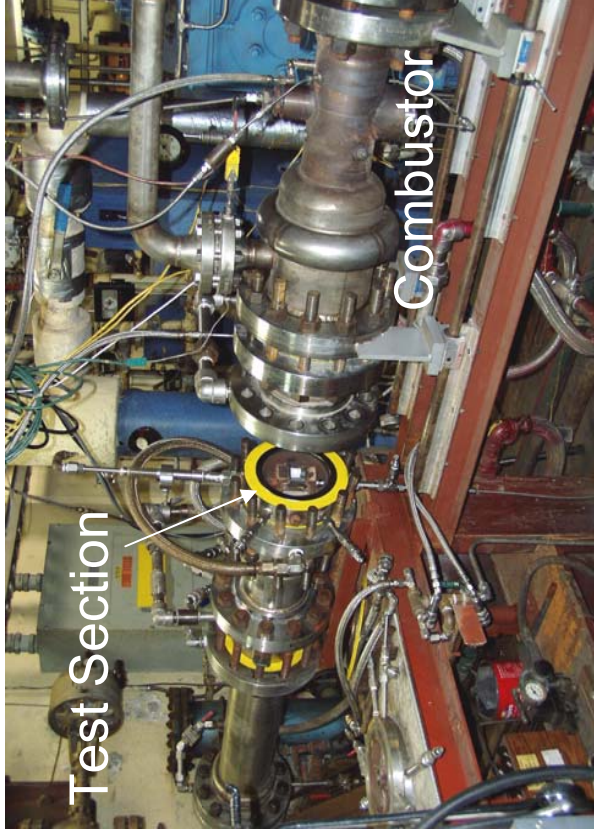




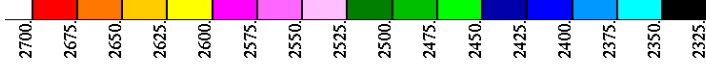
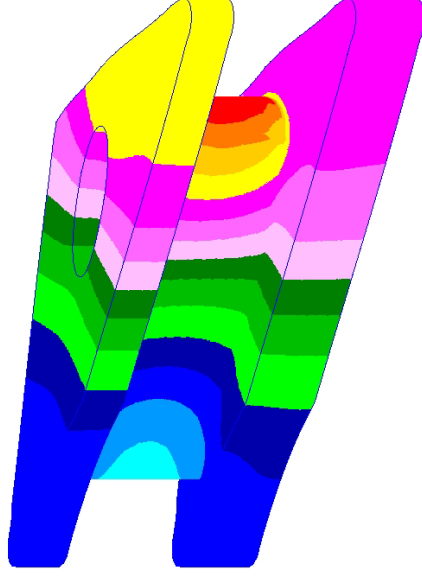
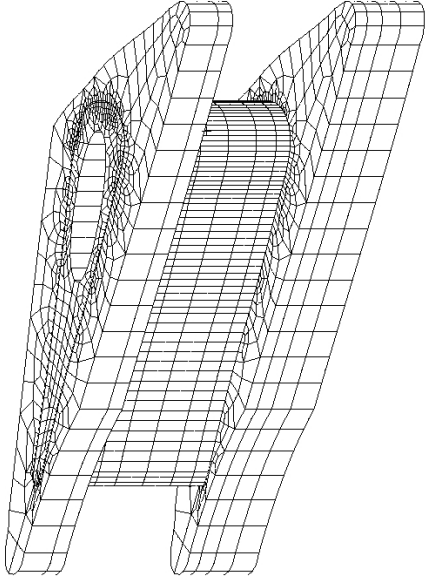


# Advanced Environmental Barrier Coatings for Si<sub>3</sub>N<sub>4</sub> Demonstrated in High Pressure Burner Rig

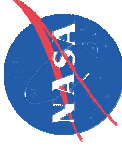
- A coated Si<sub>3</sub>N<sub>4</sub> vane also demonstrated 50hr durability in the high pressure burner rig test at up to 2700°F



**Tested coated Si<sub>3</sub>N<sub>4</sub> 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  $\text{Si}_3\text{N}_4$  vanes have been successfully demonstrated in the high pressure burner rig**
- **The coating systems showed promising performance in the burner rig simulated engine environments**