

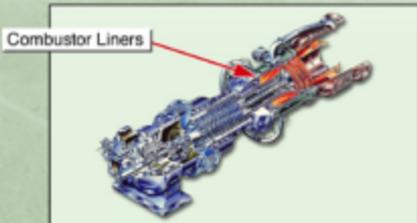
# Ceramic Matrix Composites for Industrial Gas Turbines

Solar Turbines, Inc. has been investigating the use of ceramics in industrial gas turbines to improve fuel efficiency and to reduce exhaust emissions of  $\text{NO}_x$  and CO. Large air-cooled metallic combustor liners have been successfully replaced with uncooled continuous-fiber-reinforced ceramic-matrix composite (CFCC) liners. Field tests in Bakersfield, CA and Lawrence, MA have verified that ceramic composites can survive for extended periods and significantly reduce exhaust emissions ( $<15$  ppm  $\text{NO}_x$ ,  $<10$  ppm CO).

## Combustor Field Testing



## Industrial Gas Turbine



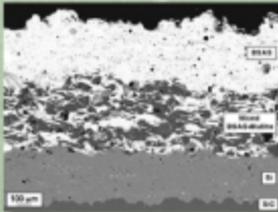
### Development and Characterization of CFCC Combustor Liners is a Collaborative Effort:



- Solar Turbines, Inc. – engine manufacturer
  - Chevron, Bakersfield, CA – engine test site
  - Malden Mills, Lawrence, MA – co-generation facility
- CFCC liner manufacturers
  - GE Power Systems Composites, Inc.
  - Goodrich, Inc.
  - ATK-COI Ceramics, Inc.
- United Technologies Research Center
  - Environmental Barrier Coating (EBC) Development
- Oak Ridge National Laboratory
  - Lab-scale simulated engine exposures in Keiser Rig
  - Microstructural and mechanical evaluation of engine-exposed liners
- Argonne National Laboratory
  - Nondestructive evaluation of liners

## Environmental Barrier Coatings (EBCs) Will Be Required on Gas-Path Surfaces of Si-Based CFCC Liners

State-of-the-art EBCs consist of BSAS-based layers on a Si bond coat and CVD SiC seal coat



## Summary

- >63,000 hours of total accumulated field testing proved that CFCC liners reduce exhaust emissions to  $<15$  ppm  $\text{NO}_x$  and  $<10$  ppm CO.
- A single CFCC liner set with EBCs survived 13,937 hours in a Chevron field test in Bakersfield, CA.
- A second industrial gas turbine operated for 15,144 hours and 150 starts at the Malden Mills facility in Lawrence, MA.

Contact: Karren More, Phone: (865) 574-7788, E-mail: [morek1@ornl.gov](mailto:morek1@ornl.gov)  
Oak Ridge National Laboratory, Oak Ridge, TN 37831-6064

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