Evaluation Of EBCs In ORNL's Keiser Rig

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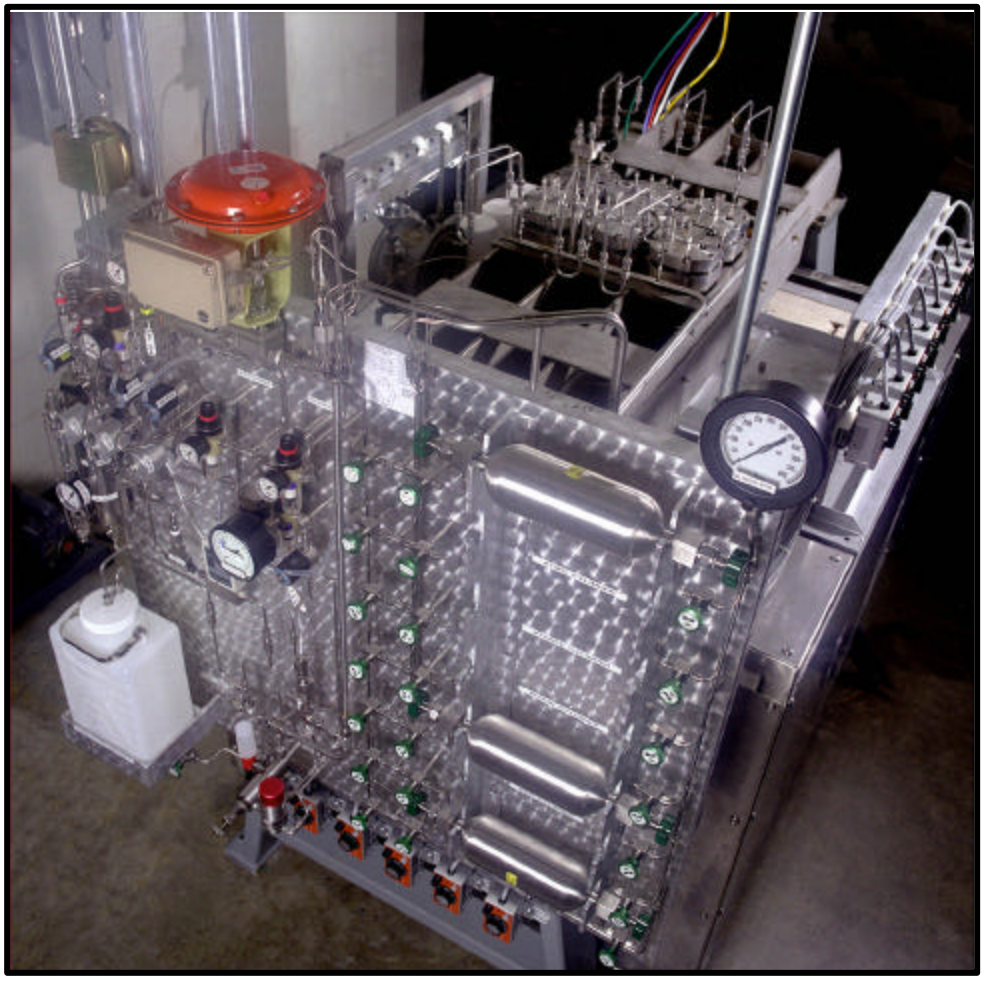
ORNL's Keiser Rig Is A High Temperature, High Pressure Exposure Facility



- Temperatures up to 1450°C
- pressures to 500 psi
- 0.05-0.3 cm/s
- two independent gas supply systems
- Combined stress and corrosion possible (Ferber-Keiser Rig)

How Is ORNL's Keiser Rig Relevant To Evaluating EBCs?

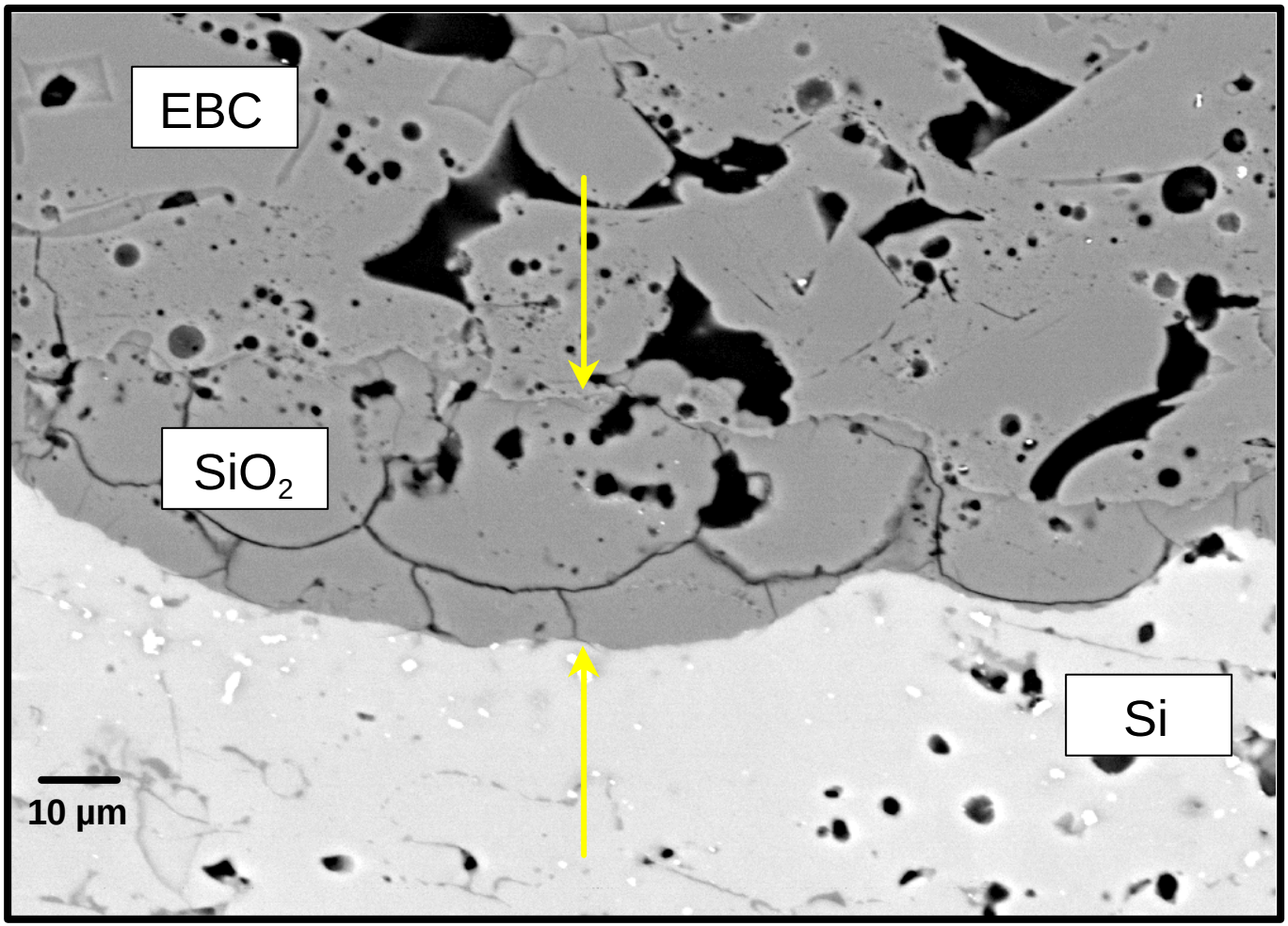
While the Keiser Rig CAN'T directly reproduce microturbine operating conditions...

- Keiser Rig exposures (high H_2O pressures, low gas-flow velocities) reproduce the microstructural damage at an accelerated rate comparable to that observed during engine testing of SiC and SiC/SiC composites
  More, et.al., *J. of Engineering for Gas Turbines and Power*, **122** [2000]
  More and Tortorelli, *J. Amer. Cer. Soc.*, **83** [2000]

- High sample throughput for first stage screening of prospective Si_3N_4 materials for very long exposure times (>6000 h)

- Test is ideally suited for evaluating damage created below an EBC since gas velocity is not a factor (provided volatilization of EBC is not a factor)

Keiser Rig Is Quite Effective In Evaluating EBCs Since Slow-Flow Conditions Exist At Coating-Substrate Interface



SiC/SiC, 1500 h, 1200°C, 1.5 atm H_2O

To Effectively Protect A Ceramic Substrate, EBCs Must:

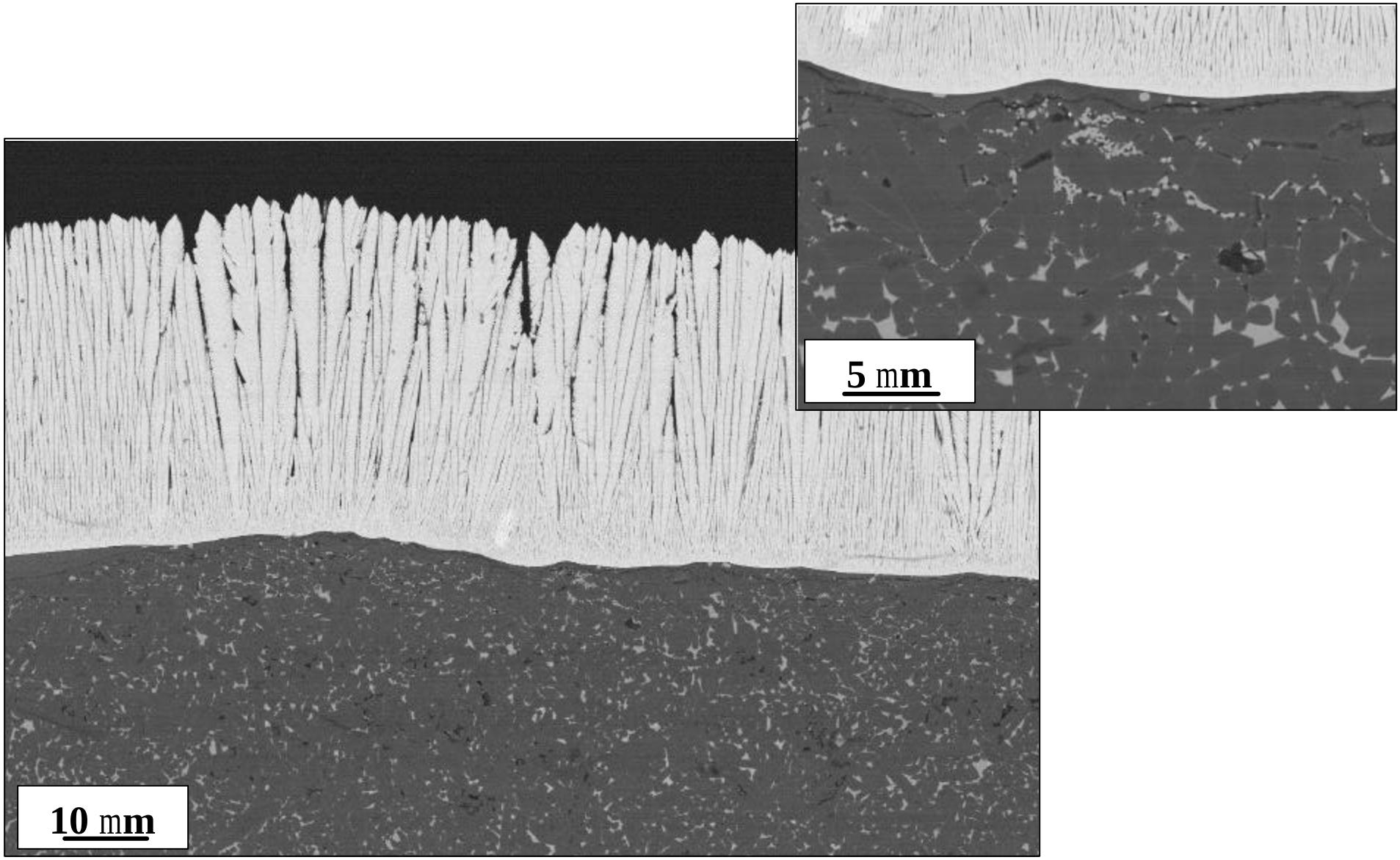
(1) Not interact with underlying substrate

(2) Be thermally stable at temperatures >>1100°C

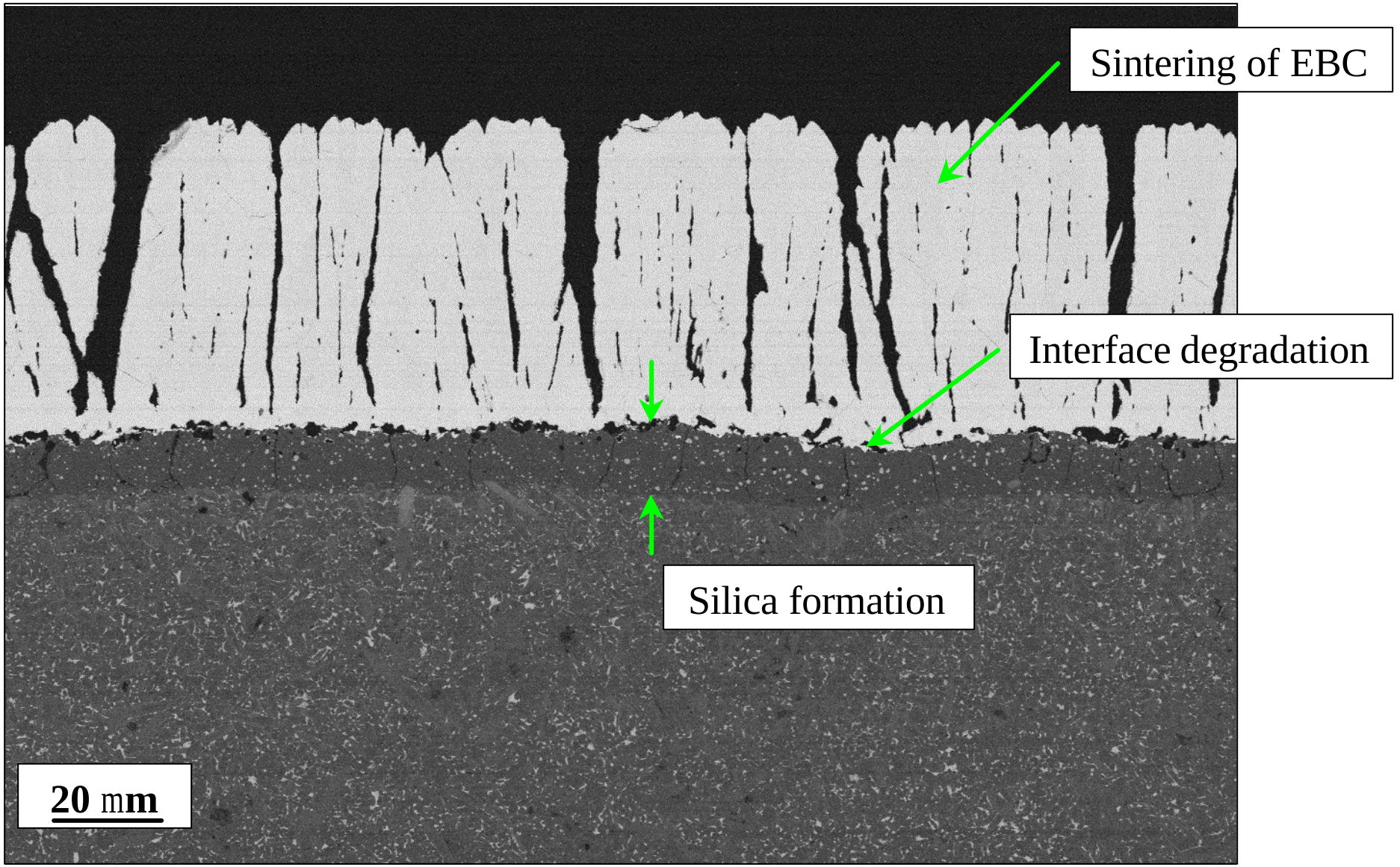
(3) Provide a sufficient permeation barrier to oxidizing species

(4) Be volatilization-resistant - volatility cannot be evaluated

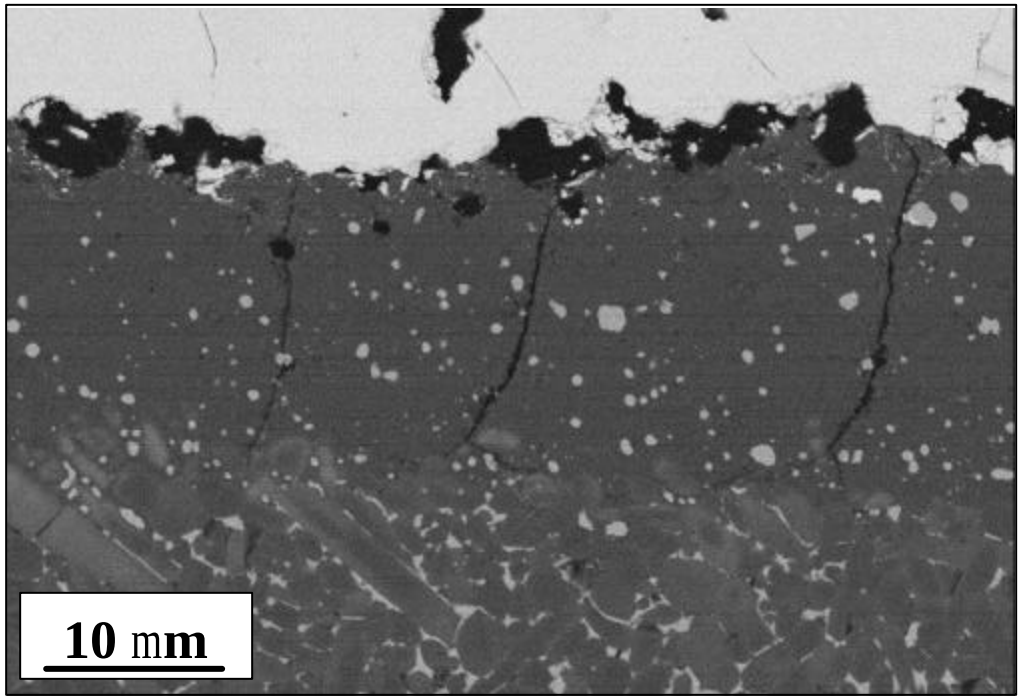
Typical As-Processed PVD EBC on Si_3N_4



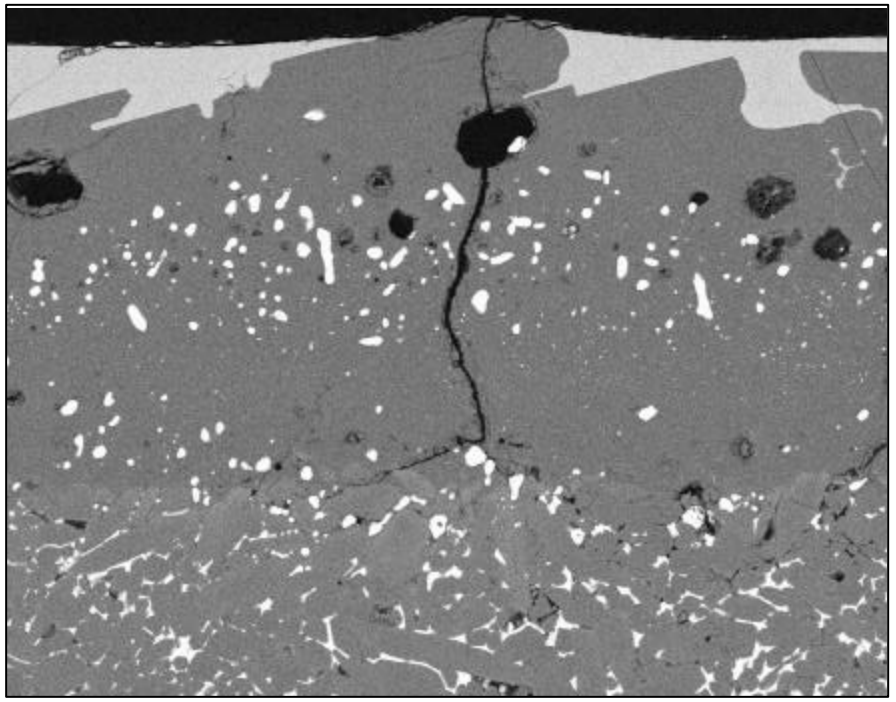
Same EBC After 500 h In Keiser Rig
1315°C and 0.3 atm H_2O



The Silica Thickness Is Nearly Identical



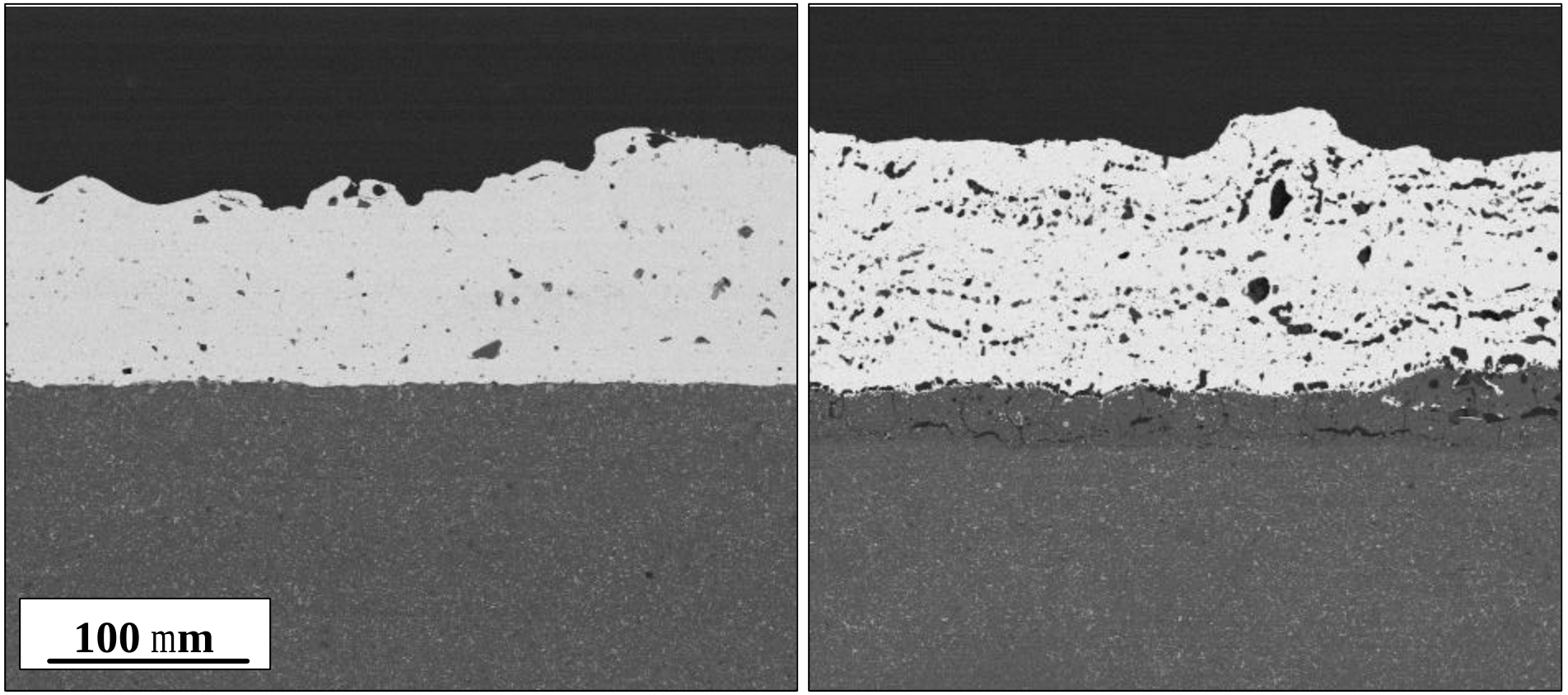
PVD EBC/AS800



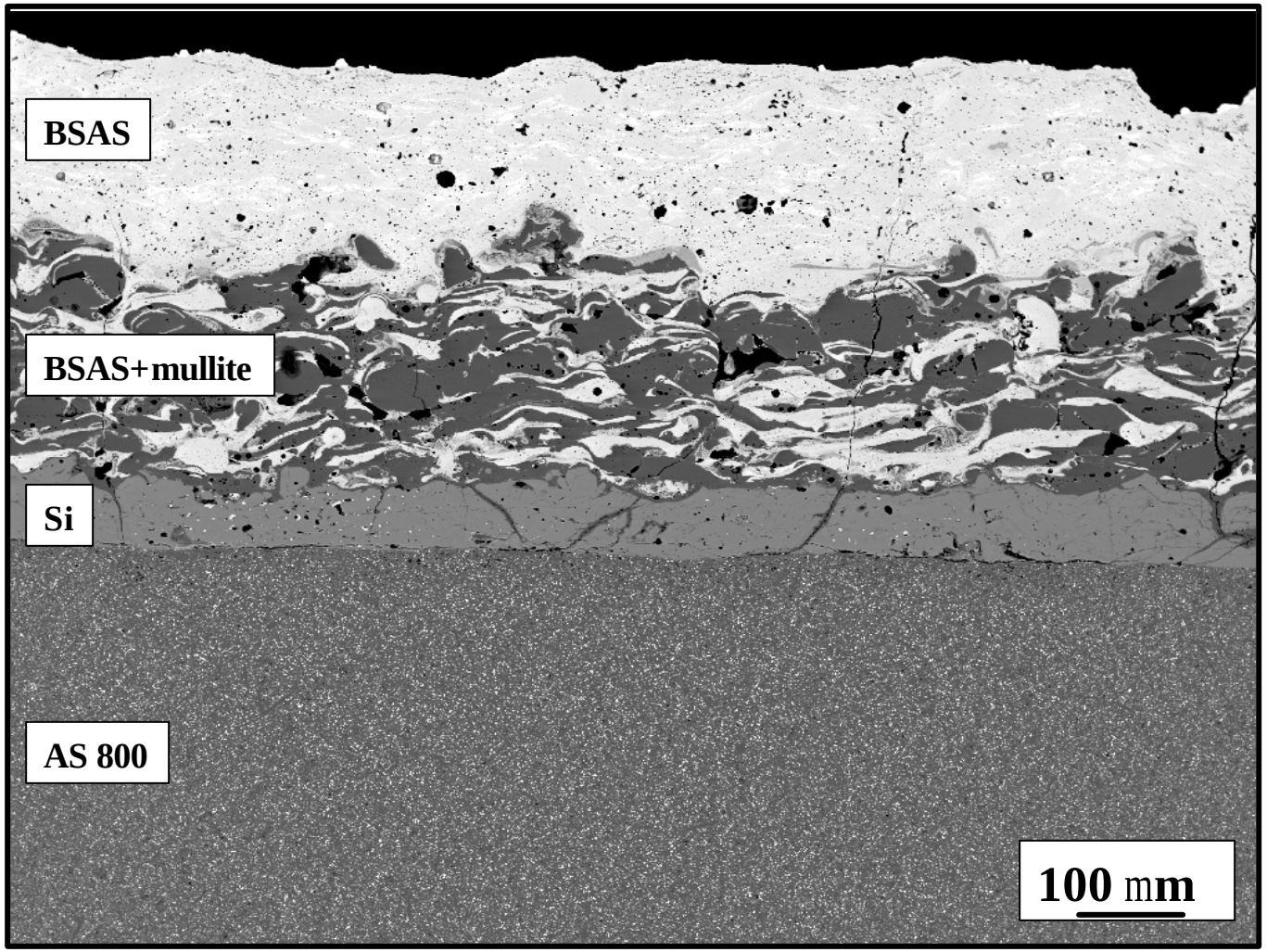
Uncoated AS800

In this case, EBC offered no protection
Accompanied by a ~10% drop in mechanical strength

Typical Plasma Sprayed EBC Showed Similar Behavior Although Much Denser Coating

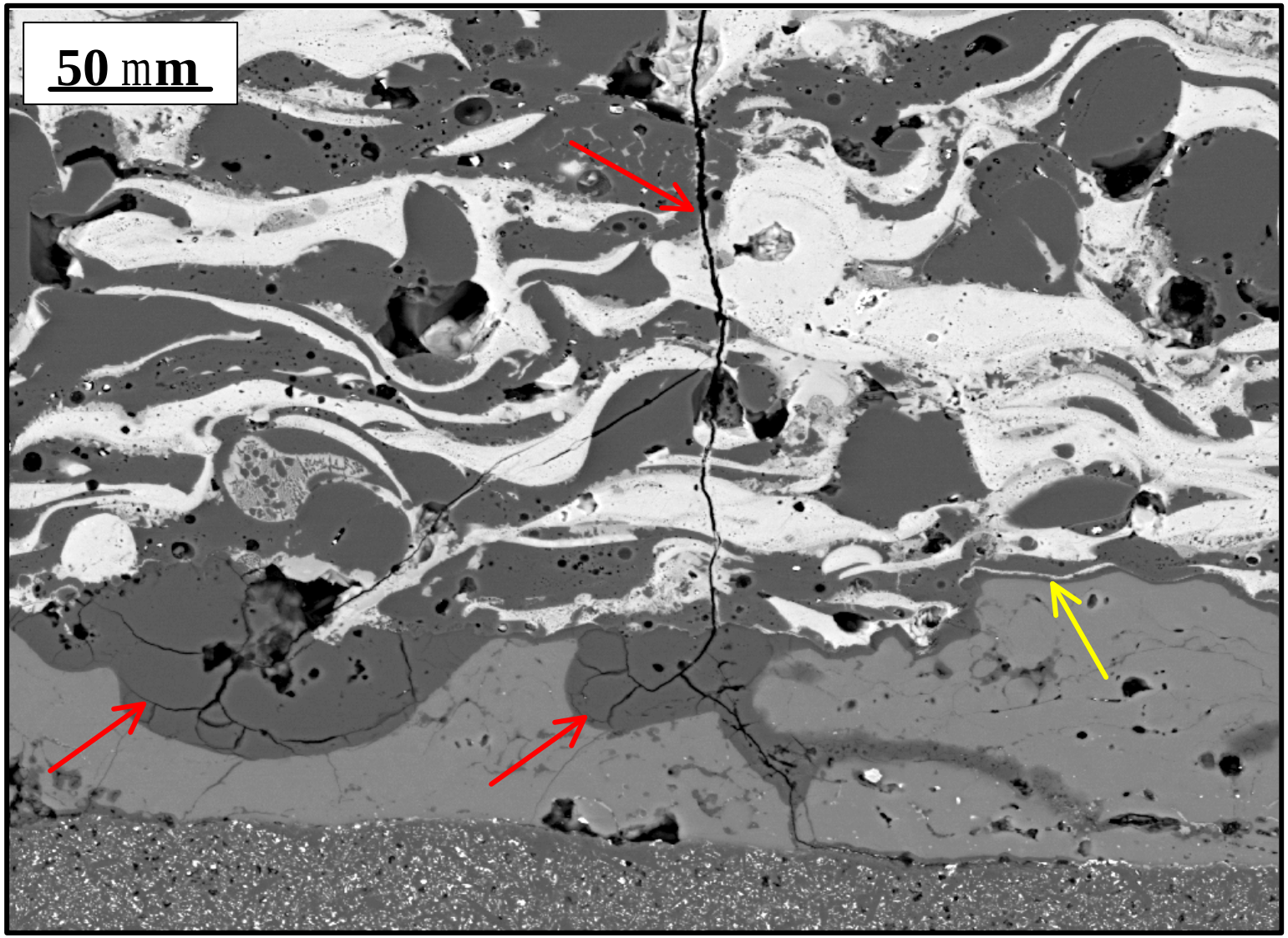


UTRC's First Attempt To Put A Standard EBC On AS800 Silicon Nitride



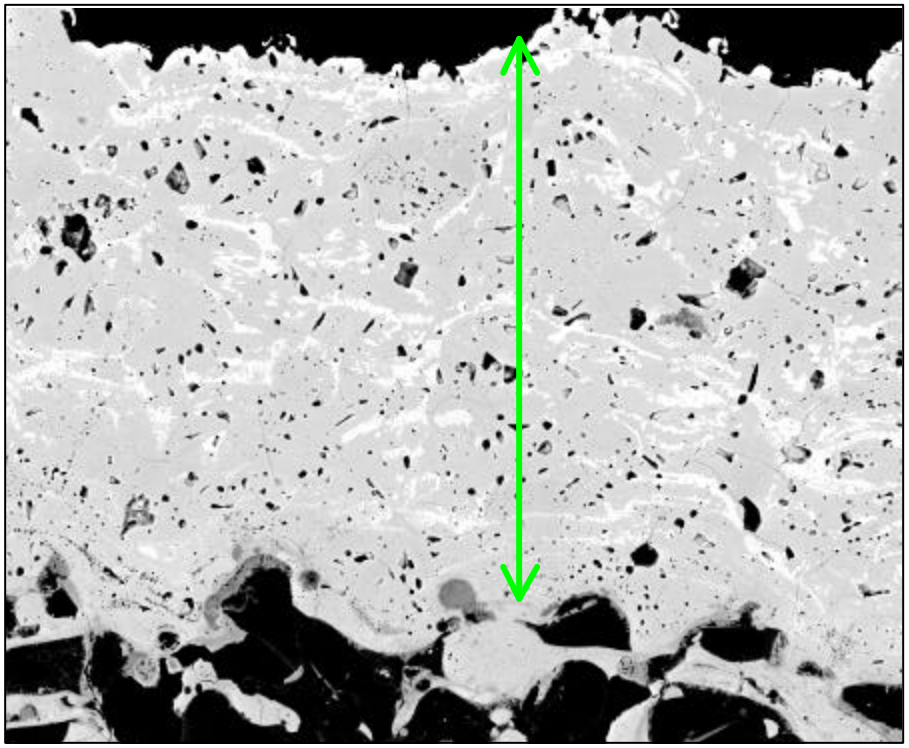
Specimen thermally cycled 100X1h cycles (UTRC) then exposed in Keiser Rig @ 1200°C and 1.5atm H_2O

EBC On AS800 After 2000 h - Defects In Coating Lead To Enhanced Localized Oxidation Of Si Bond Coat

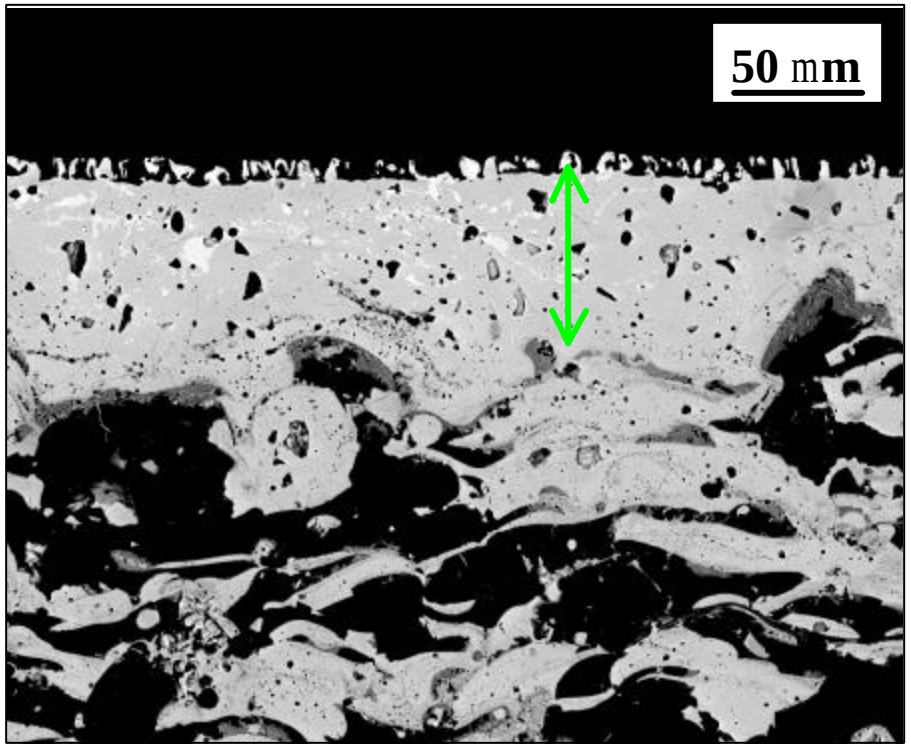


BSAS Coating Surface Recession Was Observed Following A ~14,000 h Engine Test

Definite volatility issue associated with the BSAS which can only be assessed under true engine operating conditions



Aft (cool)



Middle (hot)

The DOE Environmental Test Center (ETC) Will Provide Characterization As Well As Exposure Capabilities

- Exposures
  - High-temperature, high-pressure (Keiser) rigs
  - High-Velocity Rig (Honeywell Engines and Systems)
- Microstructural characterization (ORNL)
- Corrosion analyses (ORNL)
- Mechanical Testing (ORNL)

Coordination/Steering Committee Will Process Requests For Use Of ETC Capabilities And Serve As Conduit For Specimen Submittal/Routing And Results/Analysis Reporting

Approach Can Address Many Of The Material Issues Associated With Gas-Turbine Environmental Effects

- ✓ High temperatures
- ✓ High pressures
- ✓ Reactive species
- ✓ High gas velocities
- ✓ Mechanical Loading

- ✓ Mechanical failure
- ✓ Oxidation
- ✓ Hot corrosion
- ✓ Erosion

- ✓ Monolithic ceramics
- ✓ Ceramic composites
- ✓ Environmental Barrier Coatings

Summary

- ORNL's Keiser Rig can be used for the first-stage evaluation of the protective capability of EBCs in simulated (high H_2O pressure) gas turbine and microturbine environments

- DOE's Environmental Test Center provides a means for ceramic materials and EBCs to be evaluated under simulated (slow-flow) and actual (high gas velocity) engine operating conditions