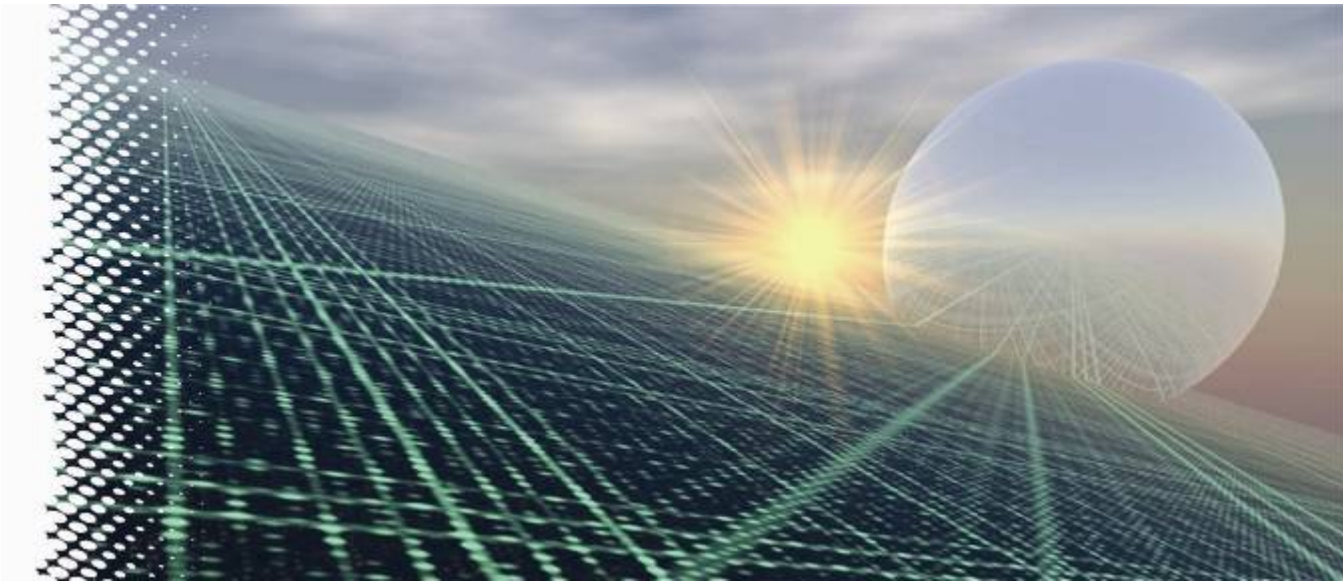
NATIONAL ENERGY TECHNOLOGY LABORATORY

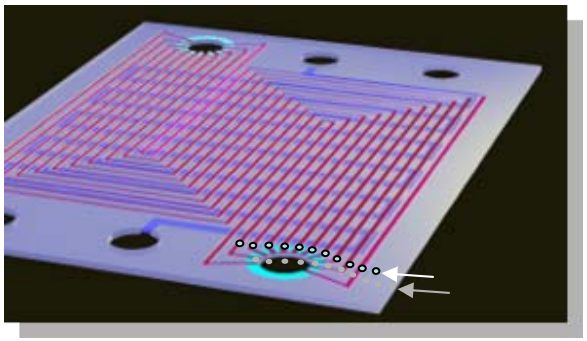


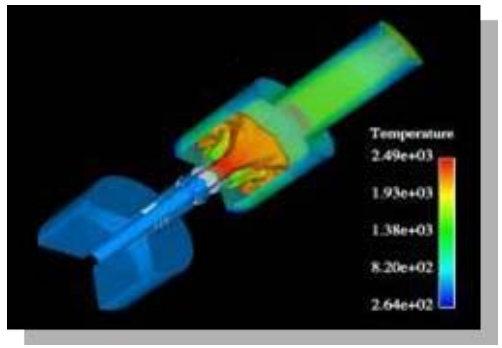
Advanced Research Program Overview

Robert R. Romanosky
Advanced Research Technology Manager

Advanced Research Program

Extend state of knowledge in fossil energy technology by supporting development and deployment of innovative systems capable of improving efficiency and environmental performance while reducing costs



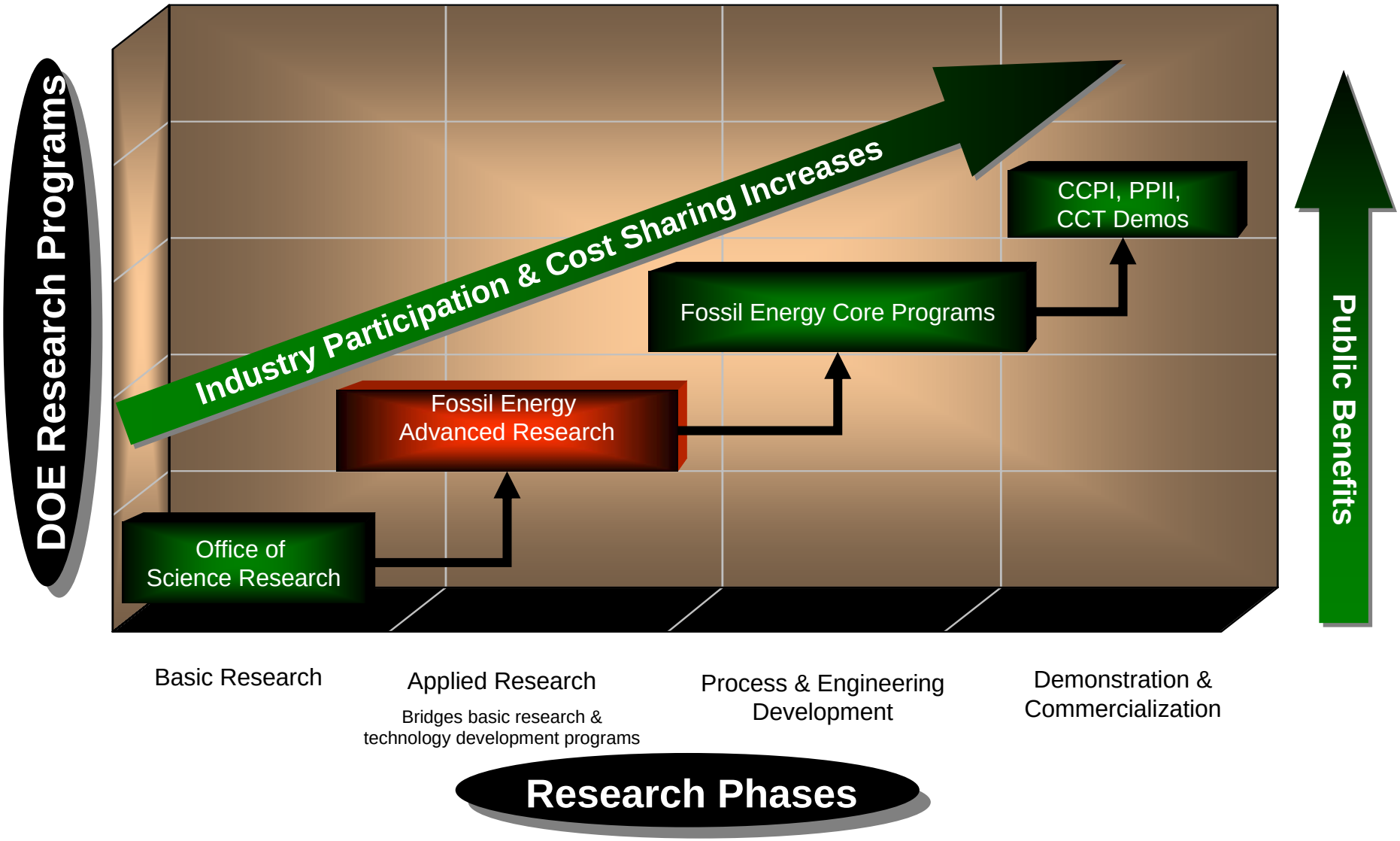


Bridge the gap between fundamental and applied technologies

Reflective of industry needs and responsible for driving new technologies

Develop technologies that address critical needs for Fossil Energy

Stages of Energy RD&D

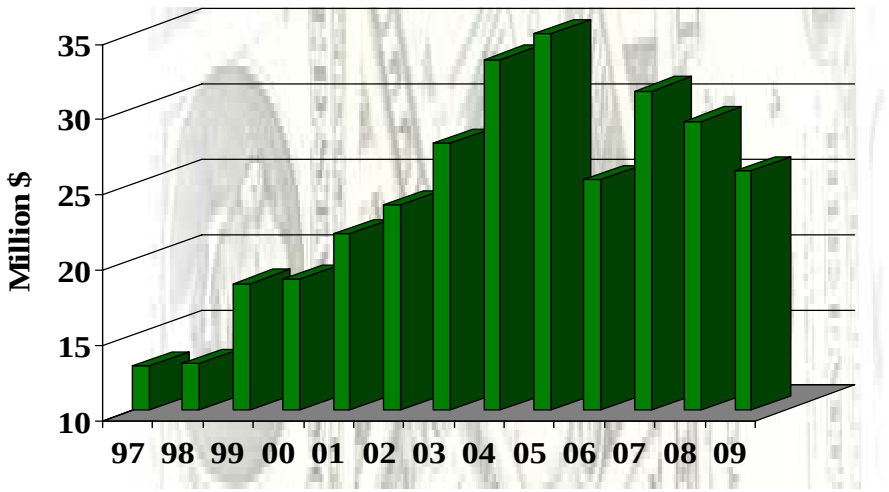


Advanced Research Program

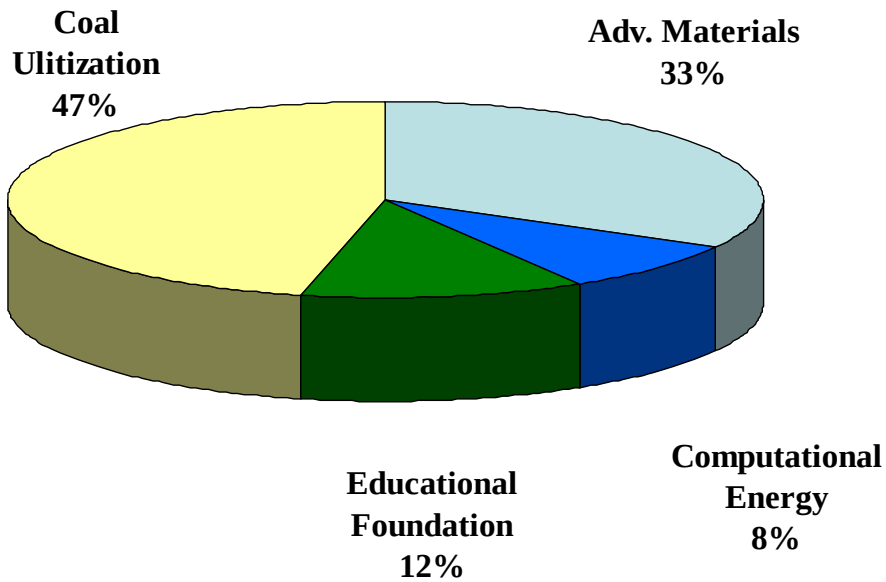
Projects by Organization Type

• Industry	21
• University	80
• National Laboratories	33
• Non-Profit	6
• Other	3
Total	143

Annual Budget

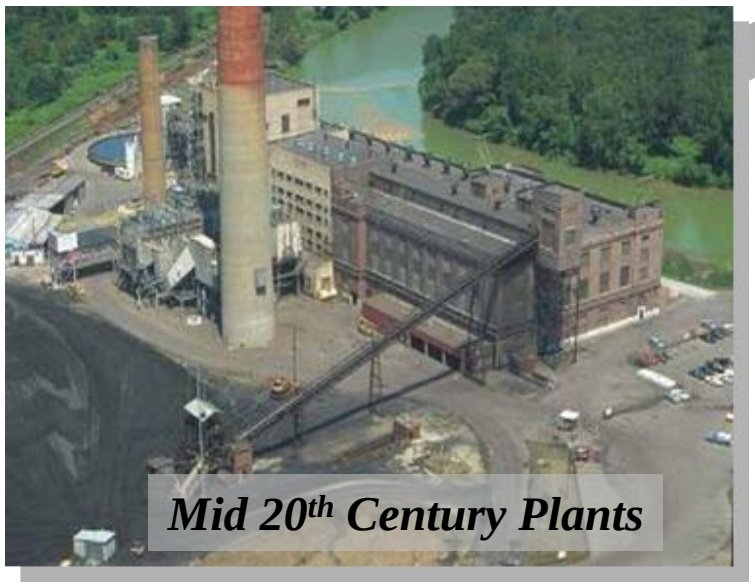


FY08 Budget Allocation



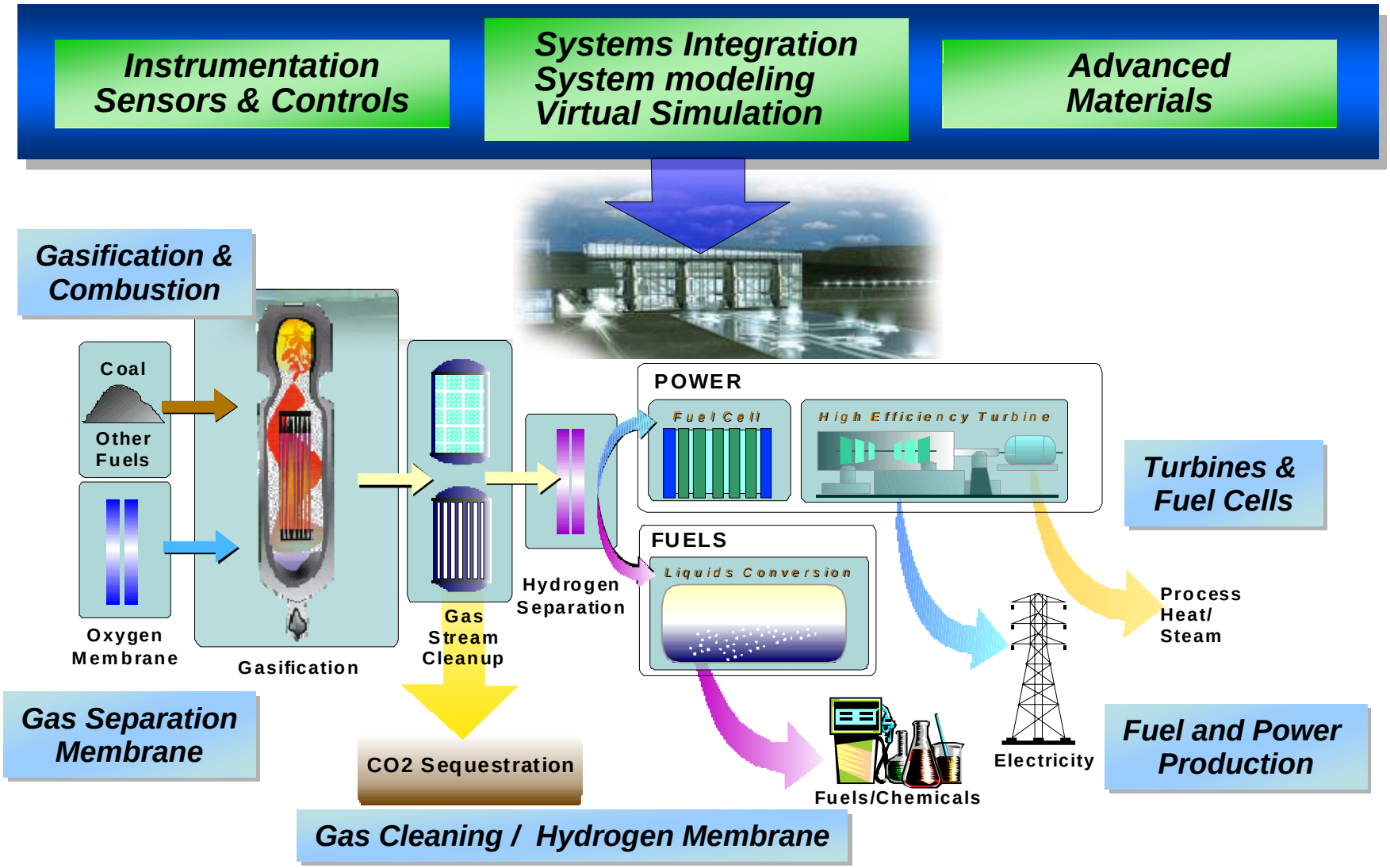
Technology Challenges

- Zero emissions
- Integrated systems
- Controllable and reliable designs
- Tight tolerances & operating margins
- High temperatures & pressures



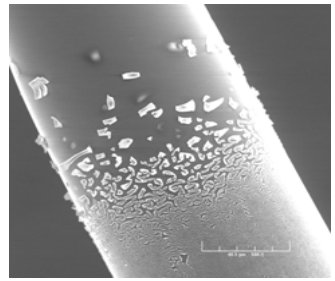
- Plant design
- Process modeling and control
- Operations monitoring
  (efficiency, emission, equipment)
- Dynamic & transient mode management
- Materials for harsh environments

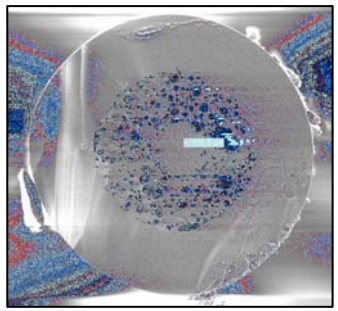
Ultra-Clean Energy Plant



Technology Development Program

- **Sensors and Controls**
  - High Temperature Material and Sensor Designs
  - Sensors Networks and Advanced Control
- **Advanced Materials**
  - Ultrasupercritical Boilers and Turbines
  - High-strength, oxidation and corrosion resistant metallic and intermetallic alloys
  - High Performance Materials
- **Modeling and Simulations**
  - High fidelity models of potential FutureGen systems
  - Advanced power systems using mathematical computational simulations and computer-based models
  - Fuel-cell and gas turbine hybrid models

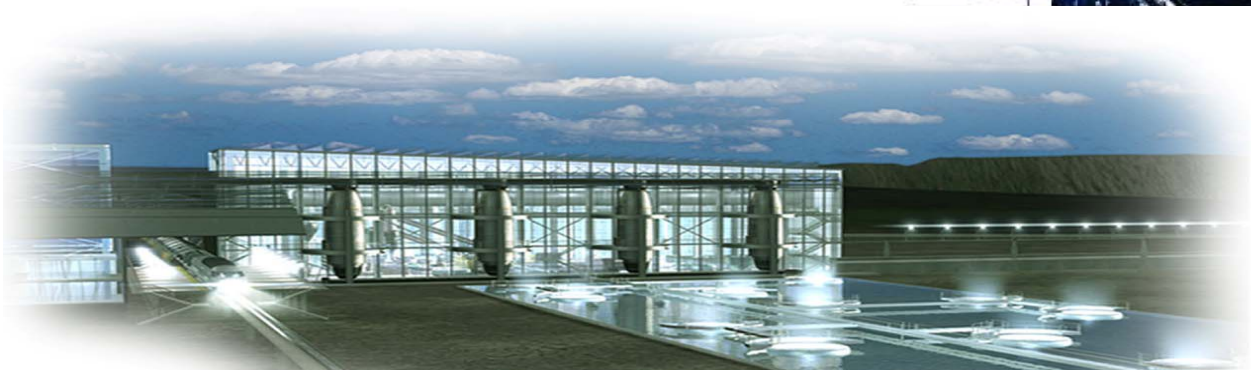




Target for Sensor and Controls

Seamless, integrated, automated, optimized, intelligent power and fuel production facilities

Identify and execute research and development for sensing and advanced process control to help ensure that key technologies will be available to meet the needs of future near zero emission power systems



Driver for New Sensing Technology

- **Advanced Power Generation:**
  - Harsh sensing conditions throughout plant
  - Monitoring needed with advanced instrumentation and sensor technology.
  - Existing instrumentation and sensing technology are inadequate

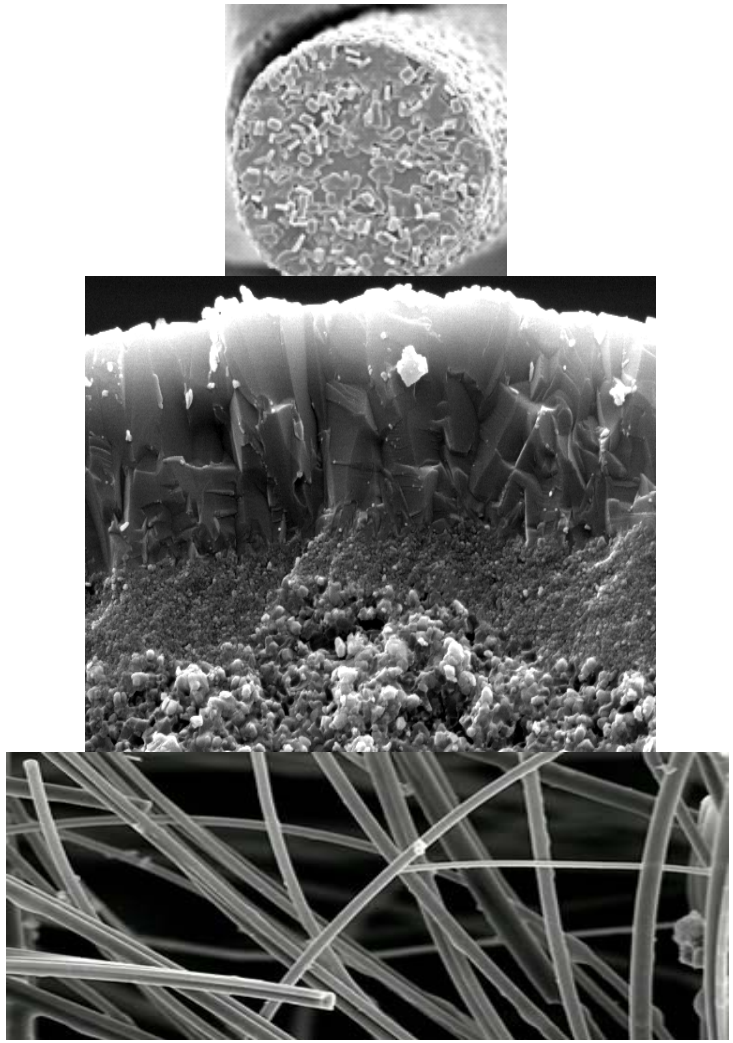
- **Coal Gasifiers and Combustions Turbines:**
  - have the most extreme conditions
    - Gasifier temperatures may extend to 1600 °C and pressures above 800 psi. Slagging coal gasifiers are highly reducing, highly erosive and corrosive.
    - Combustion turbines have a highly oxidizing combustion atmosphere.

- **Targeting development of critical on line measurements**
  - Sensor materials and designs are aimed at up to 1600 °C for temperature measurement and near 500 °C for micro gas sensors.
  - Goal is to enable the coordinated control of advanced power plants followed by improvement of a system's reliability and availability and on line optimization of plant performance.

Materials for Sensing in Harsh Environments

Optical and Micro Sensors

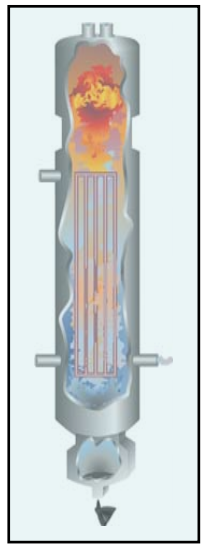
- **Sapphire**
- **Alumina**
- **Silicon Carbide**
- **Doped Silicon Carbide Nitride**
- **Yttria stabilized zirconia**
- **Fused/doped silica for certain conditions**
- **Interest in**
  - Active / doped coatings
  - 3D porous or “mesh” nano-derived ceramics / metal oxides

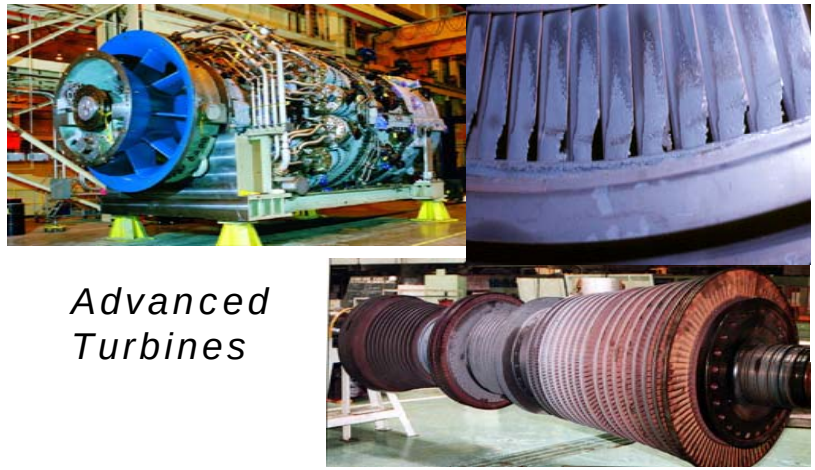


Fossil Energy Key Material Research Areas

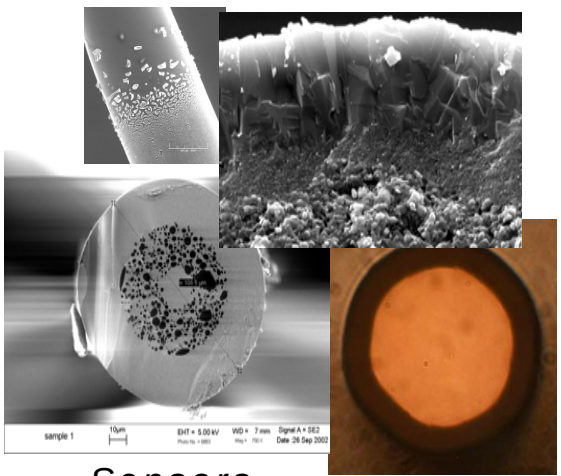
USC Boilers/Turbines

Gasifier

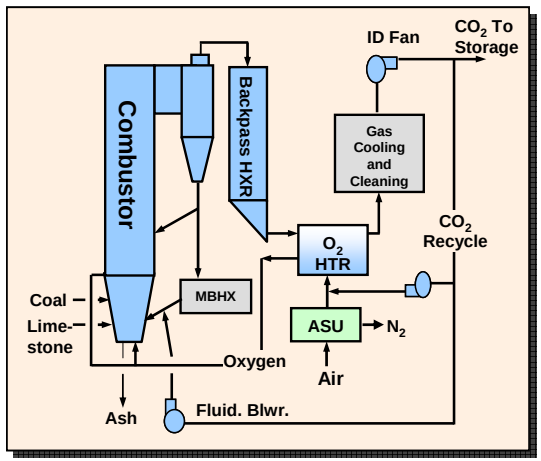




Advanced Turbines



Sensors



Oxy-Firing

Fuel Cells

AR Materials Research Areas

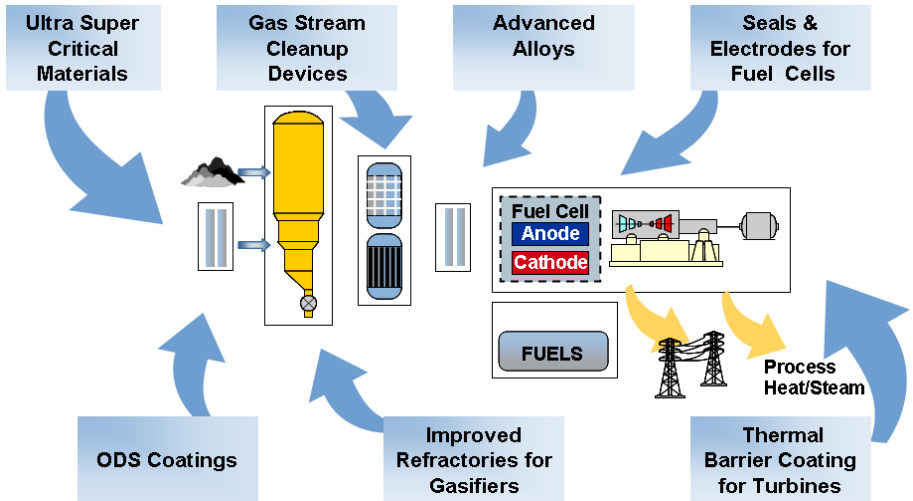
- **New Alloys** - To increase the temperature capability of alloys for use in specific components required for advanced power plants by understanding the relationships among composition, microstructure, and properties.

- **Functional Materials** - To understand the special requirements of materials intended to function in specific conditions such as those encountered in hot gas filtration, gas separation, and fuel cell systems.

- **Breakthrough Materials** - To explore routes for the development of materials with temperature/strength capabilities beyond those currently available.

- **Coatings & Protection of Materials** - To develop the design, application, and performance criteria for coatings intended to protect materials from the high-temperature corrosive environments encountered in advanced fossil energy plants.

- **Ultra Supercritical Materials** – To evaluate and develop materials technologies that allow the use of advanced steam cycles in coal-based power plants to operate at steam conditions of up to 760°C (1400°F) and 5,000 psi .



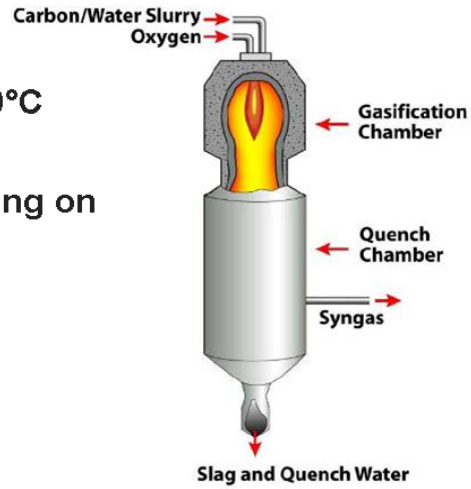
Materials R&D Key to Energy Options

Key Research Projects

- USC Boilers and Turbines
- High Temperature Alloys
- Modeling and Material Performance in Low N_2 Environments
- Refractory Material for Slagging Gasifier
- Computational Capability to Protect Corrosion Wastage of Boiler Tubes

Development of Advanced Refractory Materials for Slagging Gasifiers

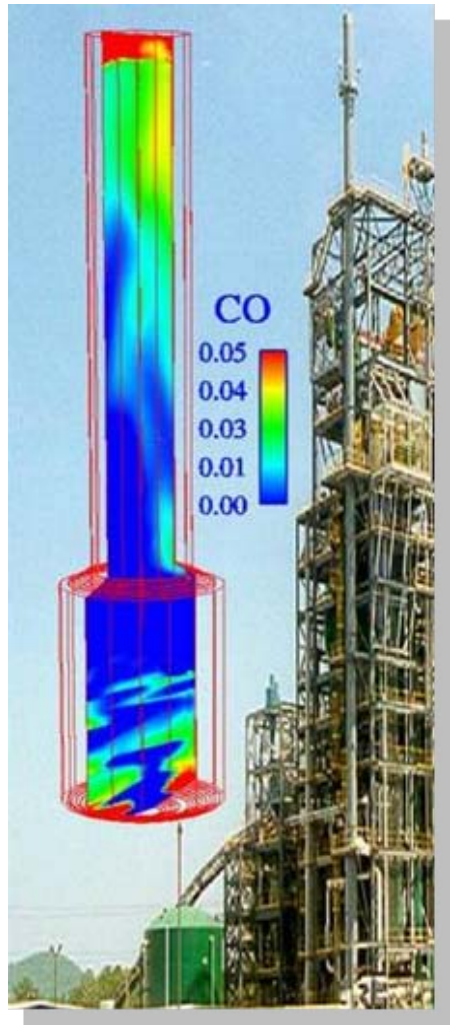
- Temperatures of 1325 to 1600°C
- Thermal Cycling
- Variable Environment (oxidizing on start-up; reducing in service)
- Corrosive Slags of Variable Chemistry
- Corrosive Gases
- Pressures ≥ 400 psi



The result is frequent gasifier shutdowns for refractory replacement

NETL Uses Simulation-Based Engineering to Support Clean Coal Approach

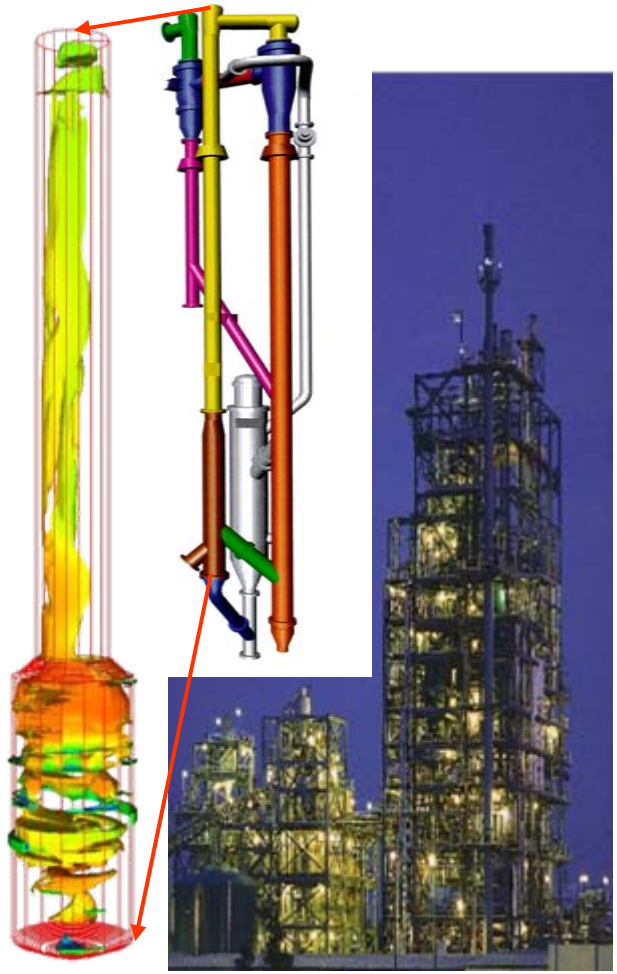
- ***Goal***
  - *Develop and apply simulation and visualization tools for designing/analyzing zero-emission, fossil energy plants of the future*
- ***Approach***
  - *Integrate experimental and computational sciences at multiple scales, to generate information beyond the reach of experiments alone*
- ***Benefits***
  - *Speeds design, reduces risk, and saves money*
  - *Barrier issues to FE program can be addressed in a cost effective manner*



Device Scale Modeling

Model development and application to advanced fossil power generation devices

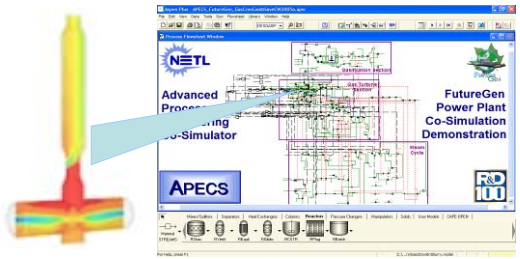
- Gasifier design and analysis
- Gas turbine combustion
- Gas mixing
- LNG vapor dispersion



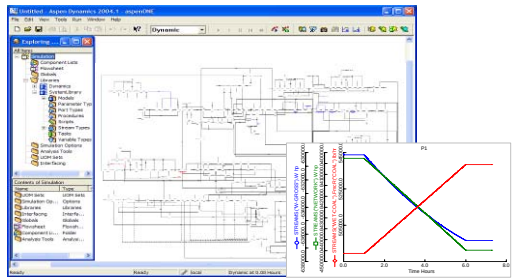
MFIX simulation of pilot scale
KBR/Southern transport gasifier

Process & Dynamic Systems Research
Focus Areas

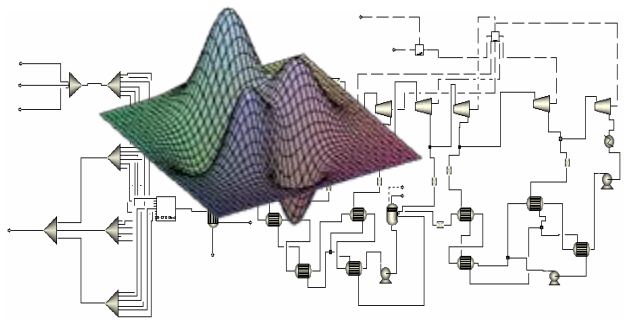
- **High-Fidelity Systems**
  - Advanced process engineering co-simulation (APECS)
  - Virtual power plant simulation
- **Dynamic Systems**
  - Dynamic simulation
  - Process control
  - Real-time applications
- **Systems Optimization**
  - Plant-wide optimization
  - Stochastic simulation for uncertainty/risk analysis
  - Cost estimation



APECS Advanced Power Systems

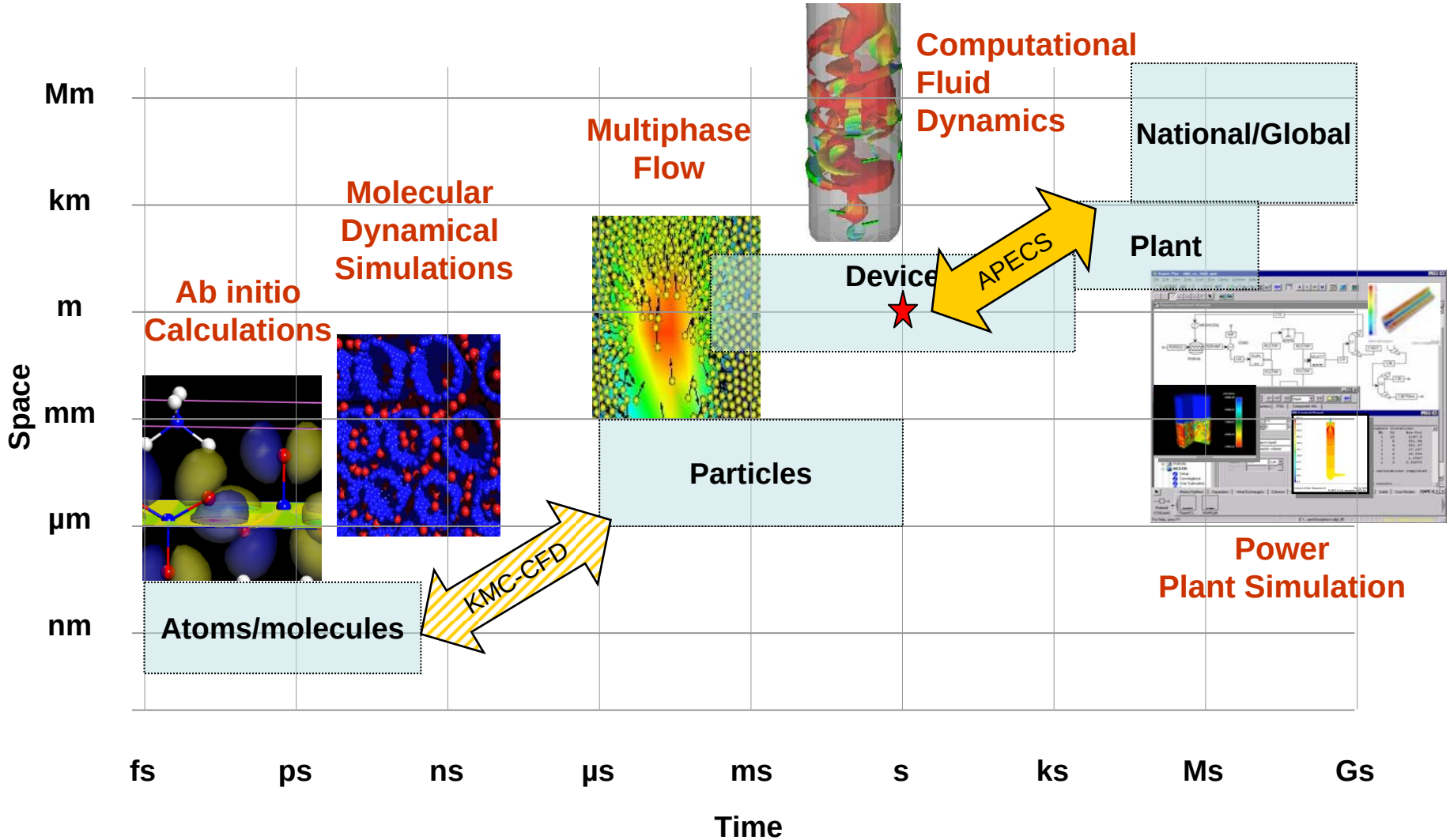


IGCC Dynamic Simulation



Process Optimization

Computational Science at NETL



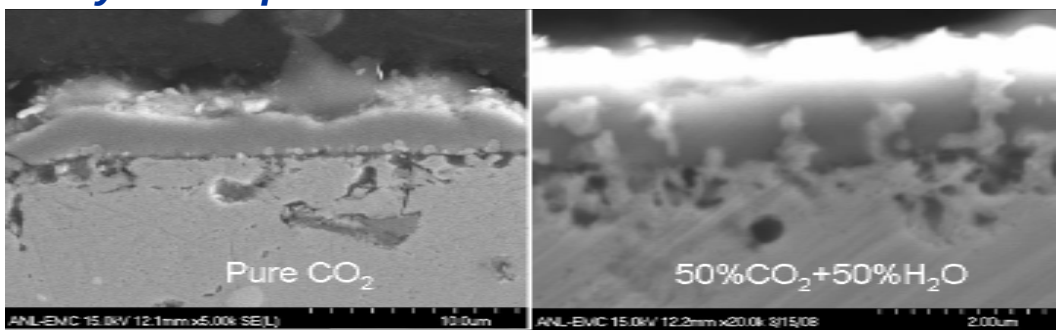
Materials Performance in CO2 and in CO2-Steam Environments

Program Objectives

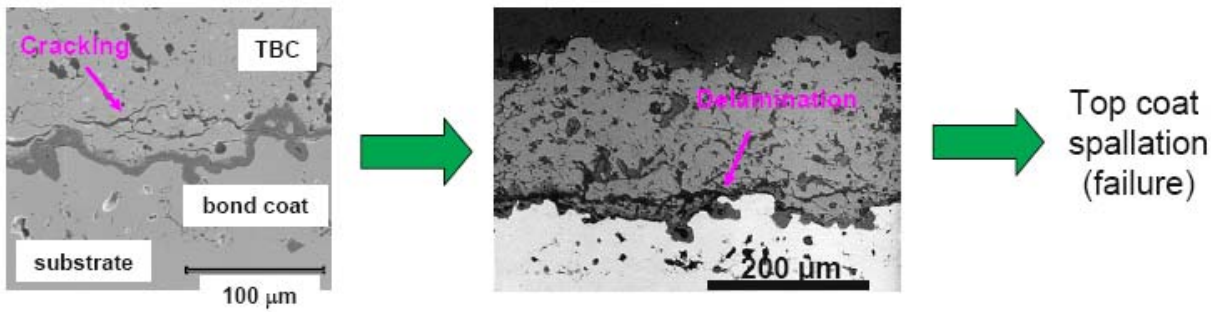
- Evaluate oxidation/corrosion performance of metallic structural alloys in pure CO2and in CO2-steam environments over a wide temperature range
- Establish the kinetics of scaling and internal penetration, if any, and develop correlations for long term performance•
- Identify viable alloys for structural and gas turbine applications
- Evaluate the influence of exposure environment on the mechanical properties (especially creep, fatigue, and creep-fatigue) of the candidate alloys

K. Natesan, Z. Zeng, and D. L. Rink
Argonne National Laboratory

Alloy 617 exposed to 50%CO2-50% Steam at 750°C



Development Of Nondestructive Evaluation Methods For Thermal Barrier Coatings

- Nondestructive evaluation (NDE) methods are being developed at Argonne National Laboratory for thermal barrier coatings (TBCs) applied to components in the hot-gas path of :
  - Advanced high-efficiency and low-emission gas turbines
  - Syngas fired turbines
- Work is focused on developing several quantitative NDE methods for direct measurement and imaging of TBC thickness and thermal conductivity
- These NDE methods can be used to assess the reliability of new coating processes, identify defective components that could cause unscheduled outages, monitor degradation rates during engine service, and provide data for reaching rational decisions on replace/repair/re-use of components.

J. G. Sun
Argonne National Laboratory