NATIONAL ENERGY TECHNOLOGY LABORATORY

2011 UCR/HBCU Annual Review Meeting

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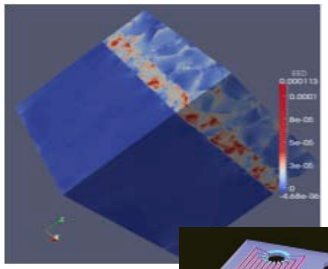
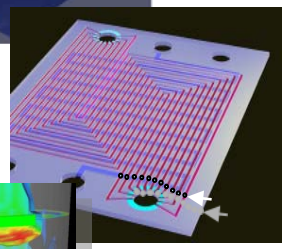
Advanced Research Program

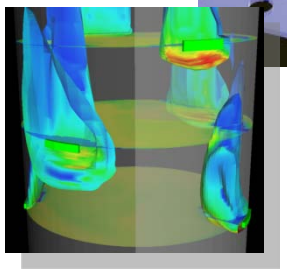
- Cross-cutting science, tools, and technology development program
- Has a 15-25 year horizon for technology that supports breakthrough concepts, addresses gaps, and has commercial application
- Innovation through fundamental and applied developments that benefit Coal-based Fossil Energy Systems

Bridge the gap between fundamental & applied technology

Reflective of industry needs and drives new technology







Advanced Materials

- *Ultrasupercritical Boilers & Turbines*
- *High-strength, oxidation & corrosion resistant metallic & intermetallic alloys*
- *High Performance Materials*

Sensors and Controls

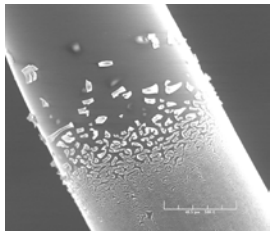
- *High Temperature Material & Sensor Designs*
- *Sensors Networks and Advanced Control*

Modeling and Simulations

- *High fidelity models of potential advanced power systems*
- *Advanced power systems using mathematical computational simulations*
- *Materials modeling tool development*

University Coal Research (UCR)

Historically Black Colleges & Universities (HBCU)



Advanced Research UCR/HBCU

Fiscal Year Activity

Program Funding ($K)

Program	FY08	FY09	FY10	FY11	FY12
UCR	2,434	2,413	2,400	2,400	2,400
HBCU	805	813	850	850	850

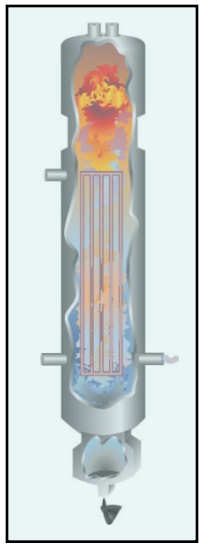
Projects Awarded

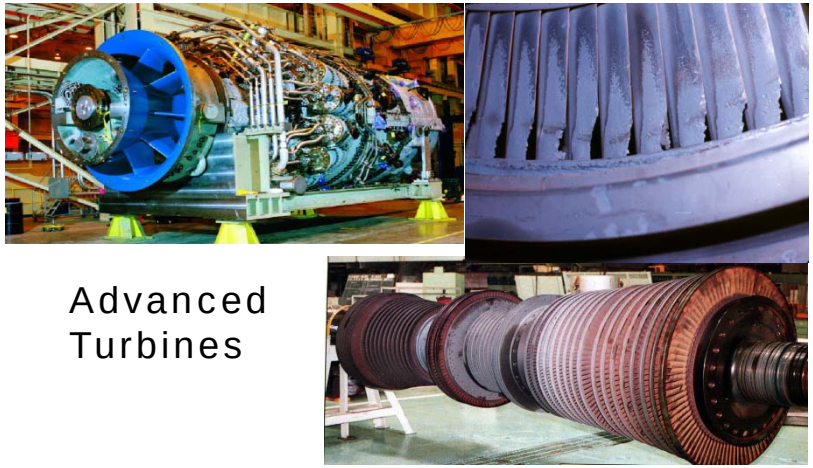
Projects	FY08	FY09	FY10	FY11	FY12
UCR	2	6	7	est 7-8	est 7
HBCU	4	4	4	est 4	est 4

Fossil Energy Key Material Research Areas

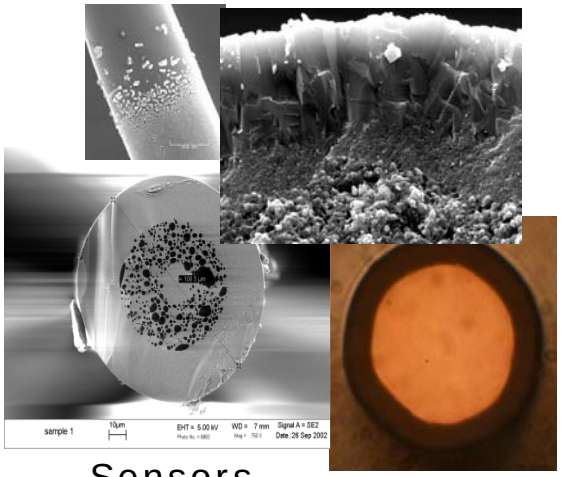
USC Boilers/Turbines

Gasifier

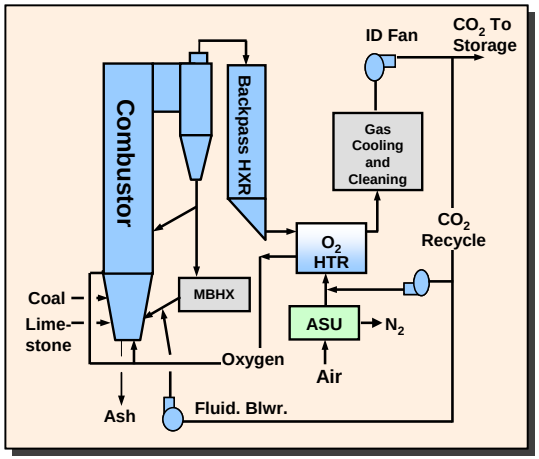




Advanced Turbines



Sensors



Oxy-Firing

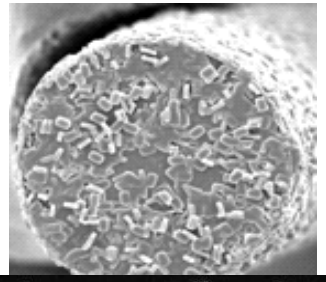
Driver for New Sensing Technology

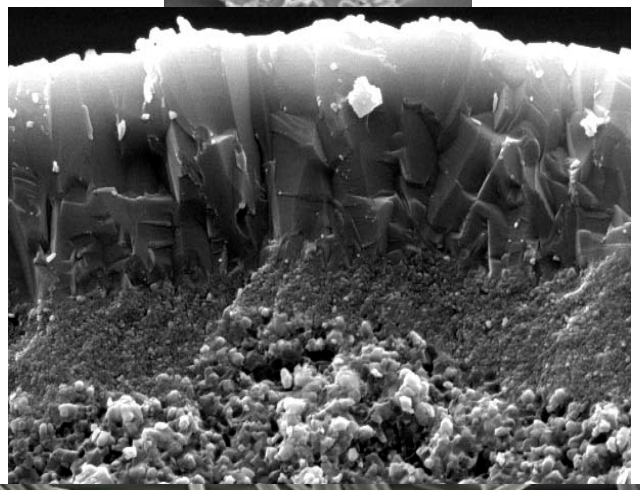
- **Advanced Power Generation:**
  - Harsh sensing conditions throughout plant
  - Monitoring needed with advanced instrumentation and sensor technology.
  - Existing instrumentation and sensing technology are inadequate
- **Coal Gasifiers and Combustions Turbines:**
  - have the most extreme conditions
    - 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.

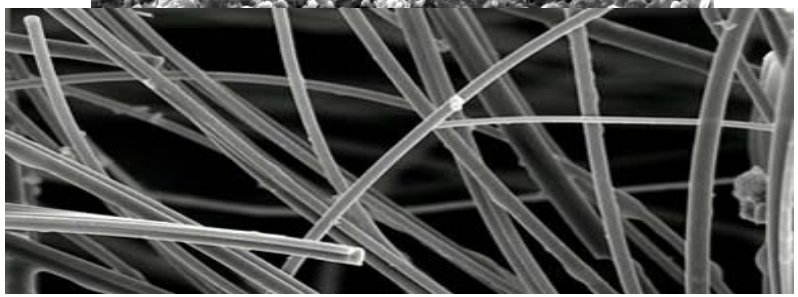
Materials for Sensing in Harsh Environments

Optical and Micro Sensors

- **Sapphire**
- **Alumina**
- **Silicon Carbide**
- **Doped Silicon Carbide Nitride**
- **Yttria stabilized zirconia**
- **Fused/doped silica for certain process conditions**
- **Active/doped coatings**
- **Nano derived high temperature materials and structures**
- **Novel materials for high temperatures (1000 °C)**







Advanced Research Materials Program

HIGH TEMPERATURE APPLICATIONS

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.

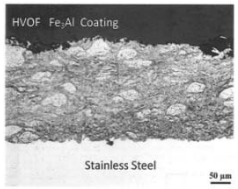
Breakthrough Materials

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

UltraSupercritical 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

Coatings and 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.

Functional Materials

To understand the special requirements of materials intended to perform specific functions, such as energy storage systems.

AR Materials Program

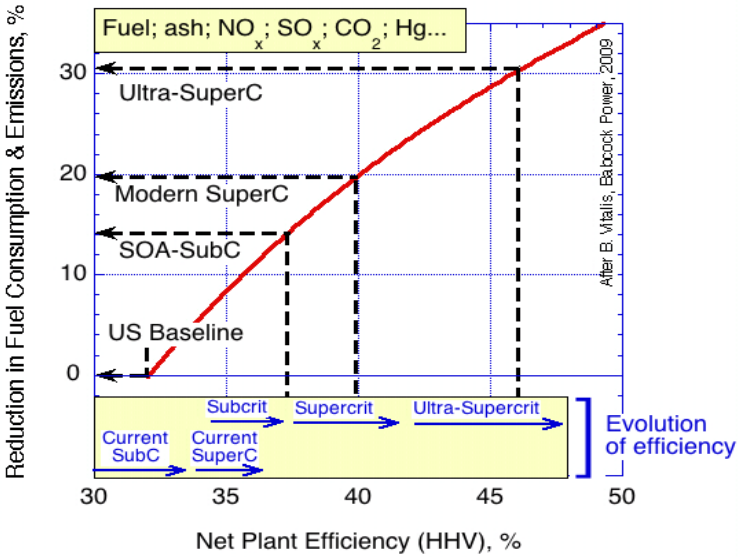
- **Development of a technology base in the synthesis, processing, life-cycle analysis, and performance characterization of advanced materials.**
- **Development of new materials that have the potential to improve the performance and/or reduce the cost of existing fossil fuel technologies.**
- **Development of materials for new systems and capabilities**.

Current Key Research Areas

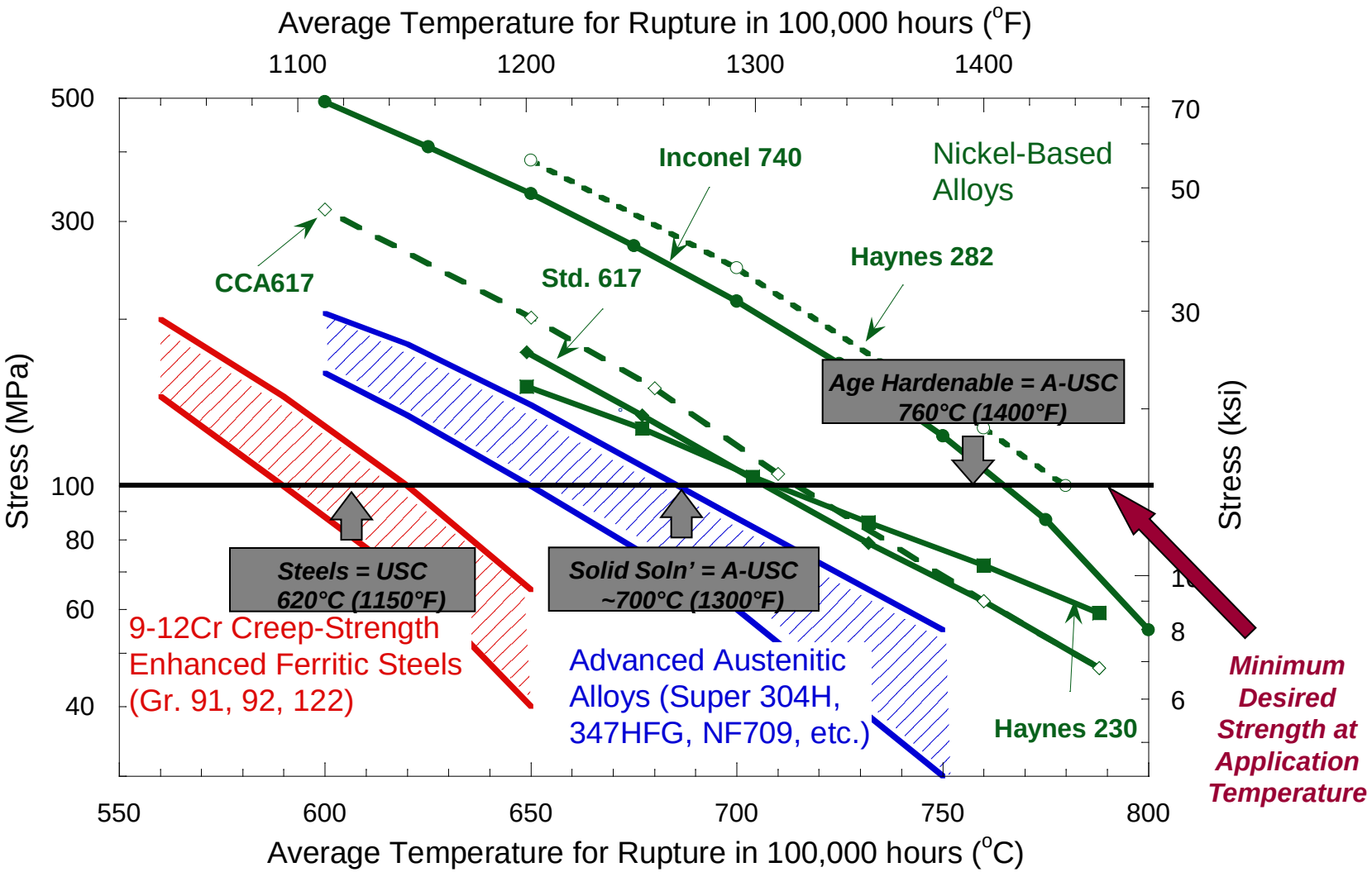
- A-USC Boilers and Turbines
- *High* Temperature Alloys
- Modeling and Material Performance in *Oxy Combustion* Environments
- Coatings for *Materials in Advanced Power Plants*
- *Computational Design of Materials*
- *Advanced Functional Materials for Electrical Power Storage*

Current USC R&D Efforts

- Current technology for U.S. Boilers
  - Typical subcritical = 540 °C
  - Typical supercritical = 593 °C
  - Most advanced supercritical = ~610 °C
- Advanced ultrasupercritical (USC) DOE goal for boiler and turbine materials capable of:
  - 760 °C (1400 °F)
  - 5,000 psi (35 MPa)
  - Oxygen firing
- Ultrasupercritical plant advantages:
  - Higher efficiency - 45 to 47% HHV
  - Decreased emissions - ~ 20%
  - CO_2 capture ready with oxy-firing
  - Smaller coal handling and pollution controls for the same net plant output
- Meeting these targets requires:
  - The use of new materials
  - Novel uses of existing materials



Materials Limit the Current Technology



US A-USC Materials Programs

- Identify and evaluate **advanced materials** that help achieve highly efficient, cost competitive, and environmentally acceptable pulverized coal combustion based electric power generation (A-USC)
  - Steam conditions of 760 ° C (1400 ° F) and 5000 psi
  - Plant efficiency increases to 45 -47%
- Primarily a Materials Technology Evaluation Program
  - Focus on **nickel-based alloys** including gamma prime (age-hardenable) strengthened alloys for highest temperature regions of the boiler and steam turbine
  - Develop fabrication and joining technology for new alloys
  - Continue research on stainless and ferritic steels for economy of new plant
- Unique Conditions for US Program
  - Higher-temperatures than European Program (760°C versus 700°C) means **different alloys** are being evaluated
  - High Cr Alloys and extensive testing of coatings and surface modification for **US coals**
  - Data for **ASME code** acceptance of new materials
  - Phase II Boiler work includes focus on **Oxycombustion**

Materials Modeling Program

- Develop modeling methodology tools that can provide a scientific understanding of high-performance materials
- Must be compatible with the hostile environments associated with advanced Fossil Energy (FE) power generation technologies
- Thereby enabling faster development and/or improved processing of these materials.

- Included are structural materials, including processing and fabrication methods, and functional materials necessary for all FE systems
- Including materials for coal fuels technologies and for advanced power generation technologies such as coal gasification, gas turbines, coal combustion systems (i.e. advanced ultra supercritical and oxygen fired), and fuel cells.

Conclusions

- **The USA and the world will face great energy challenges with ever increasing environmental constraints**
- **Advanced fossil energy power systems will be needed**
- **The Advanced Research Program is poised to have even greater impacts on future energy systems**
  - New/novel harsh environment sensors and sensor materials
  - Advanced self-organizing control systems for complex advance fossil energy power systems
  - New alloys for high temperature, high pressure applications with higher strength and better oxidation resistance under extreme environments
  - Advanced coatings to extend temperature range of current materials
  - University Research to generate novel concepts
  - Advanced modeling activities to reduce cost and time to deploy innovative clean coal technologies

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