Cross Cutting Research
Innovative Process Technologies

David E. Alman

Innovative Process Technologies (IPT)

Develop innovative cost-effective technologies that promote efficiency, environmental performance and availability of advanced energy systems.

- ★ Grid technologies & electrochemical materials for grid scale energy storage
- ★ Advanced sensors & controls to improve efficiency, fuel flexibility, operational flexibility, and reduce emissions.
- ★ Validated simulations for accelerating the deployment of transformational energy technologies

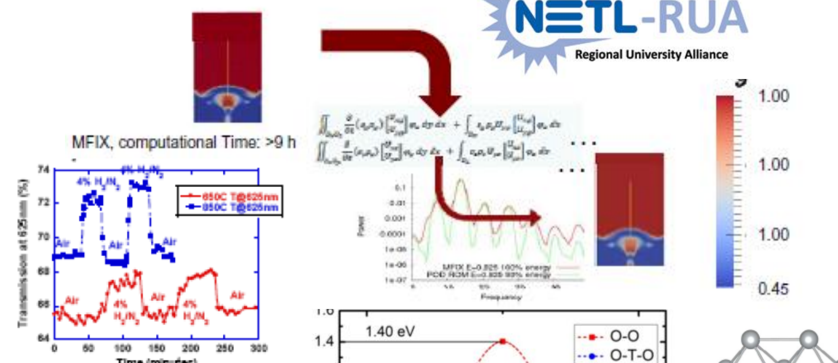
Develop computational tools that shorten development timelines of advanced energy systems.

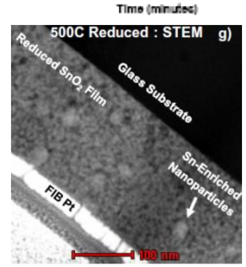
- ★ Predictive computational framework that will accelerate the development of materials

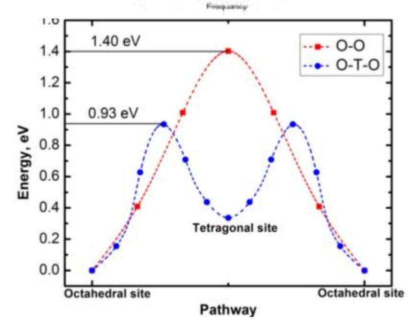
Develop physics-based CFD capability for simulating reacting multiphase flows

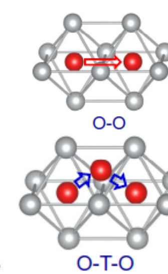
- ★ Reduce "time to solution" & improve the fidelity of multiphase CFD simulations
- ★ Make Uncertainty Quantification an integral part of simulations

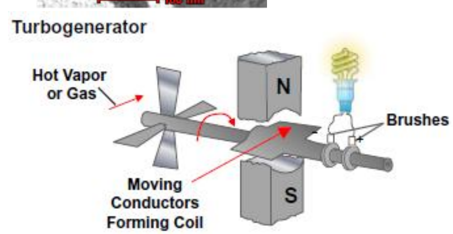
NETL Carnegie Mellon University University of Pittsburgh PENNSTATE VirginiaTech Invent the Future URS WestVirginiaUniversity NETL-RUA Regional University Alliance

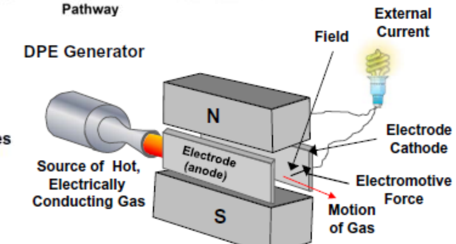












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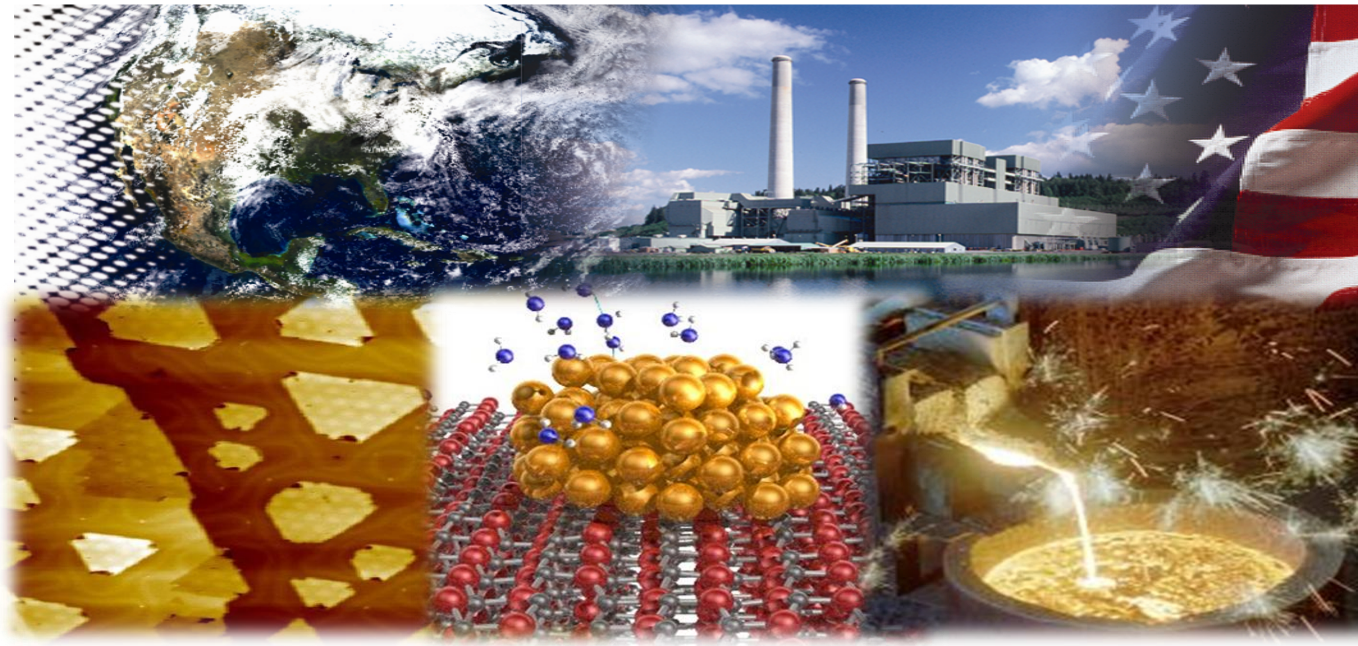


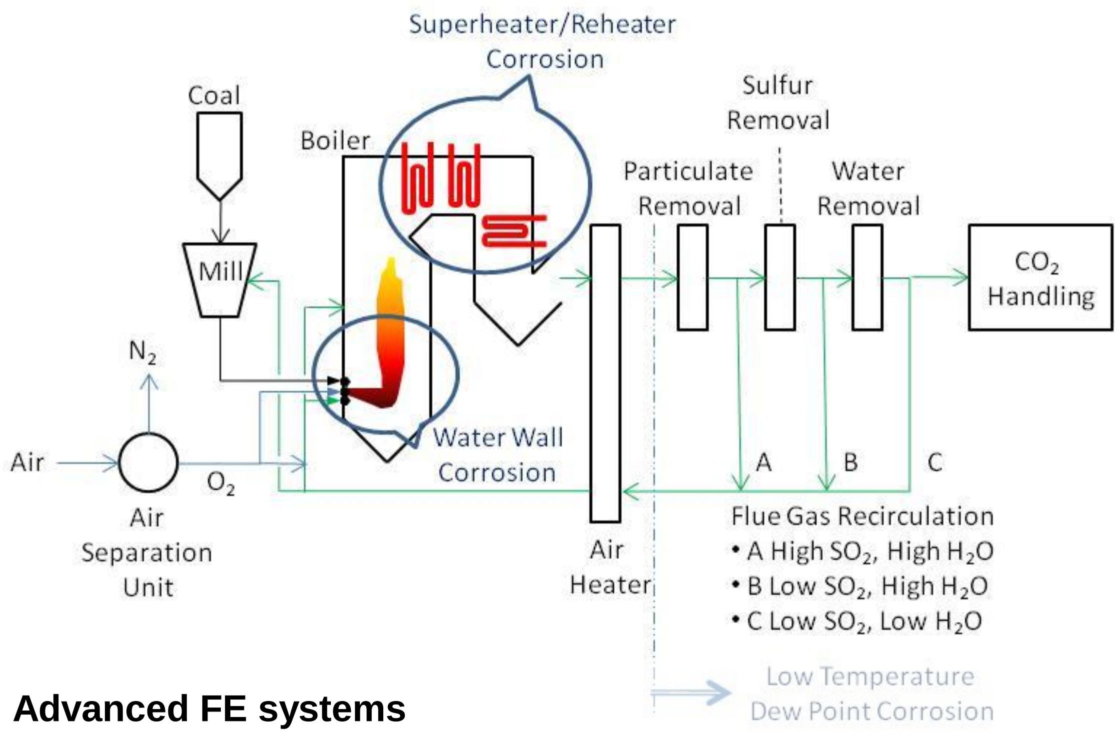
Innovative Process Technologies

Integrated Materials Initiative

Predictive computational framework that will accelerate the development of materials

U.S. DEPARTMENT OF ENERGY

Computational Materials: Integrated Materials Initiative



Advanced FE systems

– Extreme environment (corrosive,T,P)

– Components have to last 10,000's to 100,000's hours

➢ ***Lack of experience with alloy performance in these conditions***

Need for reliable and fast methods for predicting materials performance to accelerate materials design or identification – accelerate deployment and enable advanced technology

Develop a set of inter-related computational tools to predict performance of alloys in environments and time scales relevant to FE systems.

Computational Materials Team

Task Lead: D. Alman, NETL

Oxide Scale Tool Set Team

- ★ **Computational Simulations DFT, CALPHAD, MD, KMC:**

  A. van Duin (PSU), Z-K. Liu (PSU), G. Wang (Pitt), J.Kitchin (CMU), D. Alfonso (NETL), Y. Wen (NETL) M. Gao (URS), D. Tafen (URS)
- ★ **Targeted Experiments: B. Glesson (Pitt), A. Gellman (CMU).**

Oxide Scale Growth Kinetics & Microstructural Stability Tool Set Team

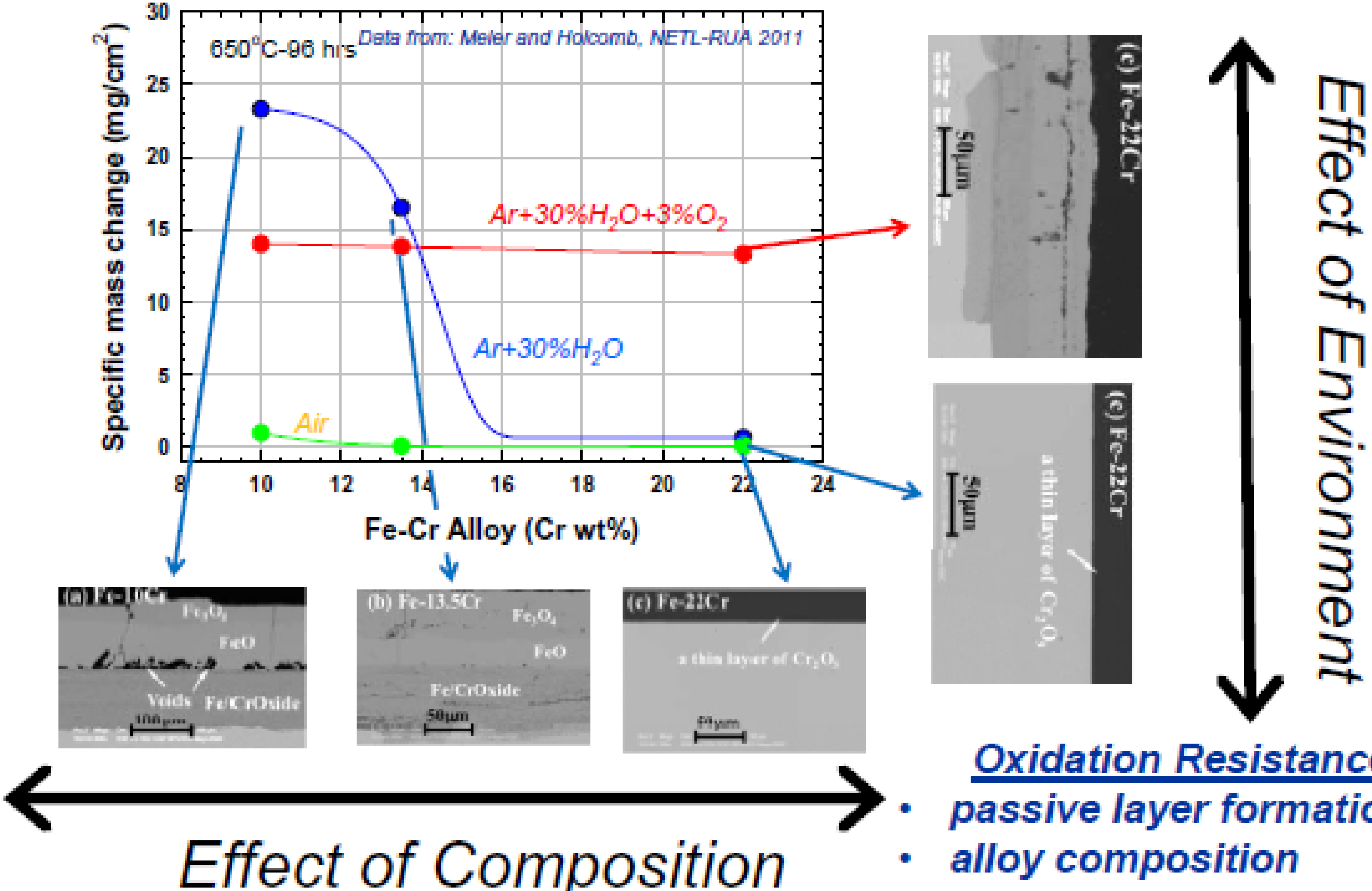
- ★ **Computational Simulations Mean and Phase Field:**

  Y. Wen (NETL), L-Q Chen (PSU), T. Cheng (ORISE)
- ★ **Targeted Experiments: J. Hawk (NETL), M. Muryarma (VT)**
- ★ **Close coordination with Advanced Combustion FWP**

ESR Slag Modeling Tool Set Team

- ★ **Slag Database: Z-K. Lui (PSU),P. Jablonski (NETL)**
- ★ **Close coordination with Advanced Combustion FWP**

Computational Tool for Predicting External (Protective) Oxide Scales



Oxidation Resistance

- *passive layer formation.*
- *alloy composition*
- *environment*

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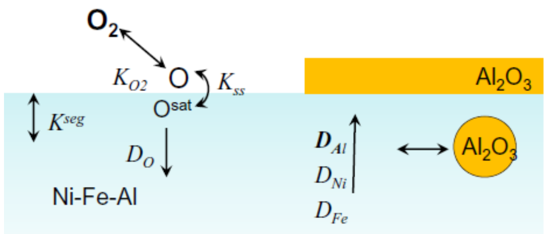
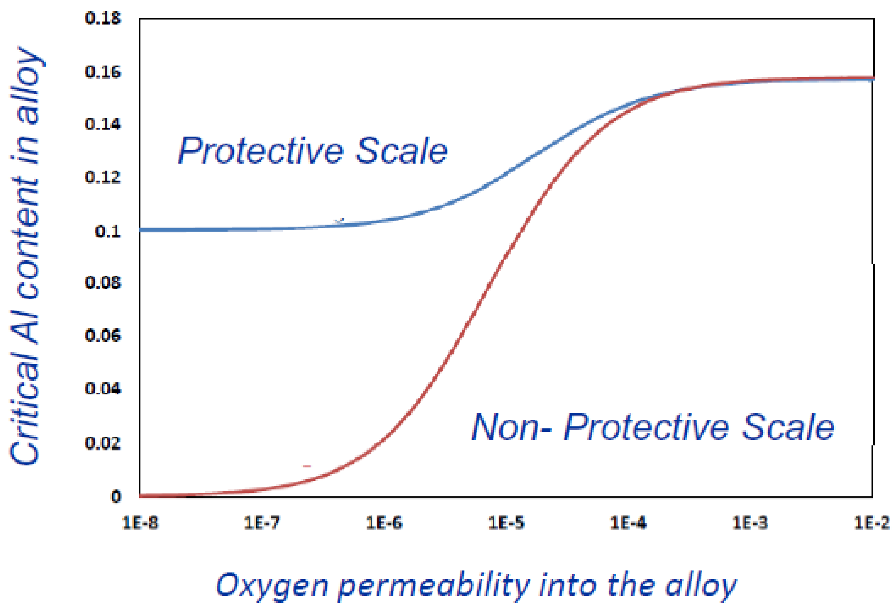
Computational Tool for Predicting External (Protective) Oxide Scales

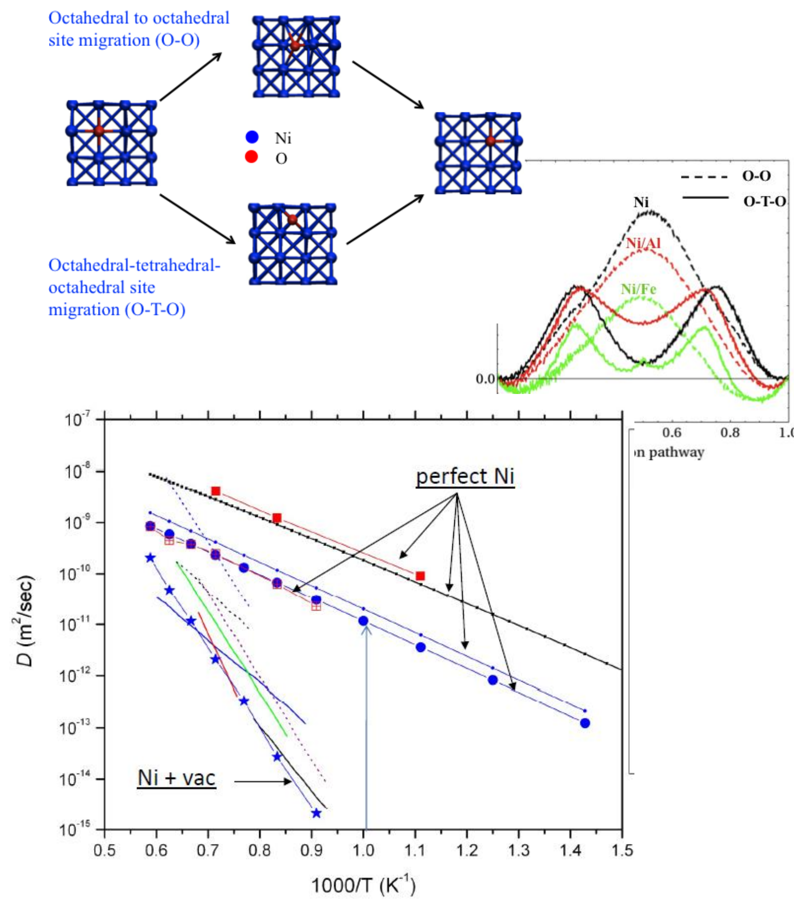
- ★ ***Development of a microkinetic model for $Al_xFe_yNi_{1-x-y}$ oxidation using the critical parameters estimated by atomistic simulation to predict N_{Al}* in O_2, H_2O and CO_2.***
- ★ ***The equilibrium and kinetic constants will determined from multi-scale atomistic computational methods with targeted validation experiments.***



$$N^{o}_{B^*} \geq \left[f^* \left(\frac{V_m}{V_{ox}} \right) \pi \frac{N^s_o D_o}{2\nu D_B} \right]^{1/2}$$



Simulation of Oxygen Diffusion in Nickel



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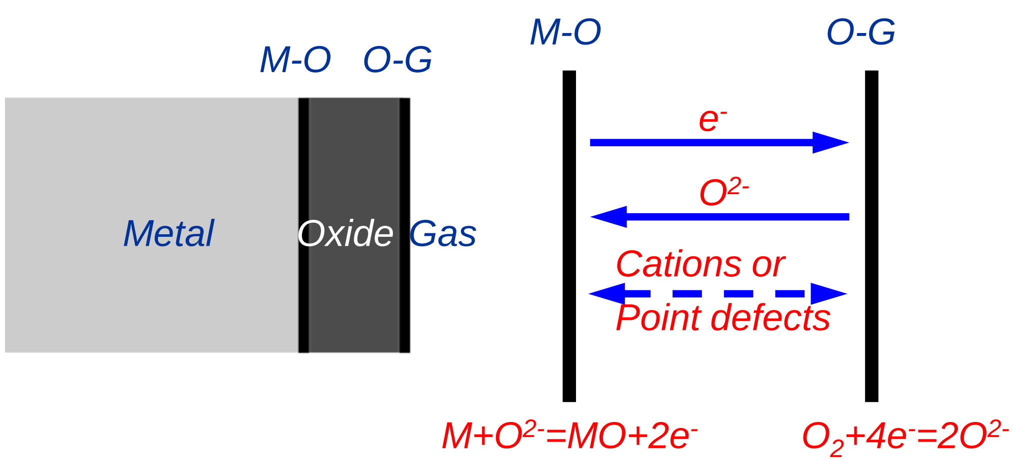
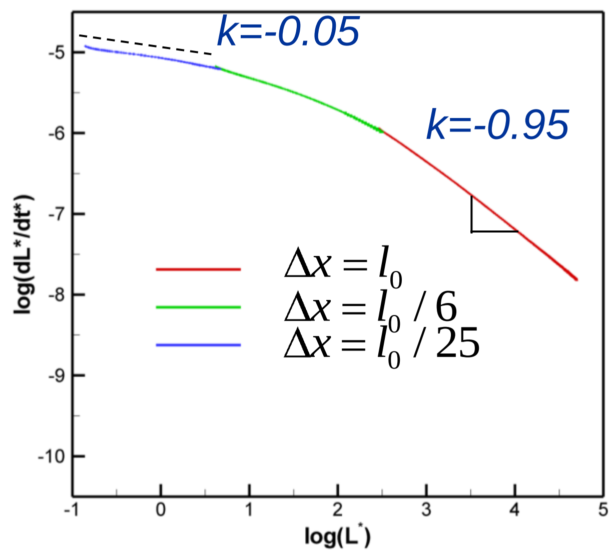
Computational Tool for Predicting Oxidation Kinetics

- ★ *Quantitative oxidation kinetics is essential to the life prediction of high temperature materials for FE applications.*
- ★ *Existing theoretical models can handle extreme cases with either very thin oxide film or very thick films by simplifying the space charge effects.*
- ★ ***Physics-based modeling tool that can bridge this length scale gap for more accurate oxidation kinetics prediction***

Schematic Oxidation Process in Metals





Linear-Parabolic kinetics transition captured without any a prior assumptions

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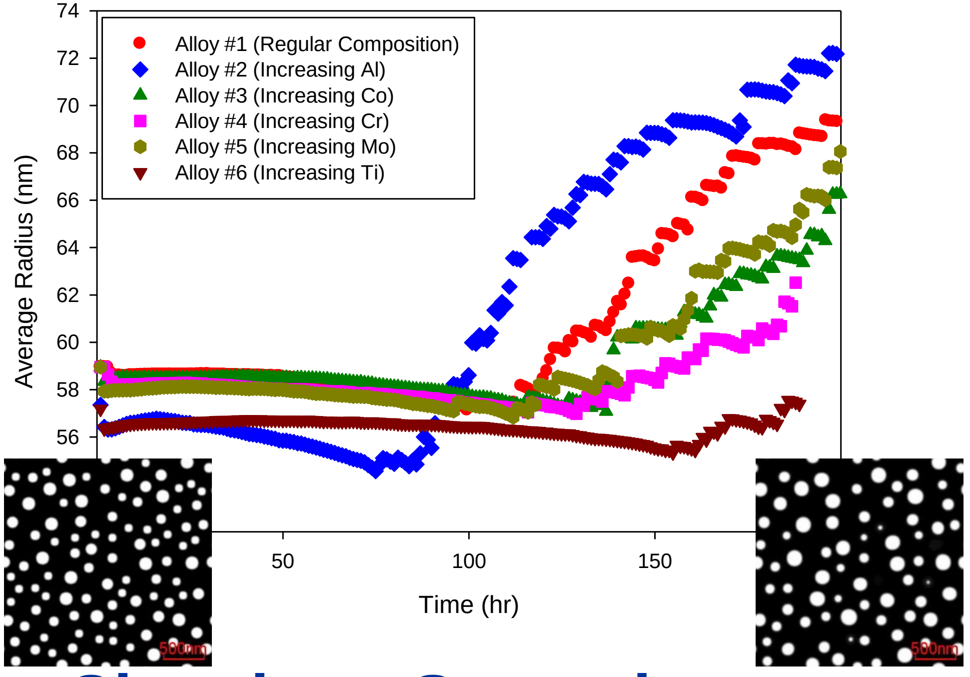
Computational Tool for Predicting Microstuctural Stability.

- ★*Microstructural stability is a critical issue for FE applications, which requires a computer model that can simulate its evolution.*
- ★ *Existing models for gamma prime precipitation in Ni-base superalloys are for simple systems, binary or ternary, which are not really relevant for FE applications.*
- ★***Multi-component model that can simulate the underlying microstructural stability of industrial alloys.***

	Al	Co	Cr	Fe	Mo	Ti	Ni	Vol.%
1	1.5	10.0	20.0	1.5	8.5	2.1	Bal	18.86
2	**1.8**	10.0	20.0	1.5	8.5	2.1	Bal	21.08
3	1.5	**11.0**	20.0	1.5	8.5	2.1	Bal	18.91
4	1.5	10.0	**21.0**	1.5	8.5	2.1	Bal	18.97
5	1.5	10.0	20.0	1.5	**9.5**	2.1	Bal	19.05
6	1.5	10.0	20.0	1.5	8.5	**2.5**	Bal	21.62

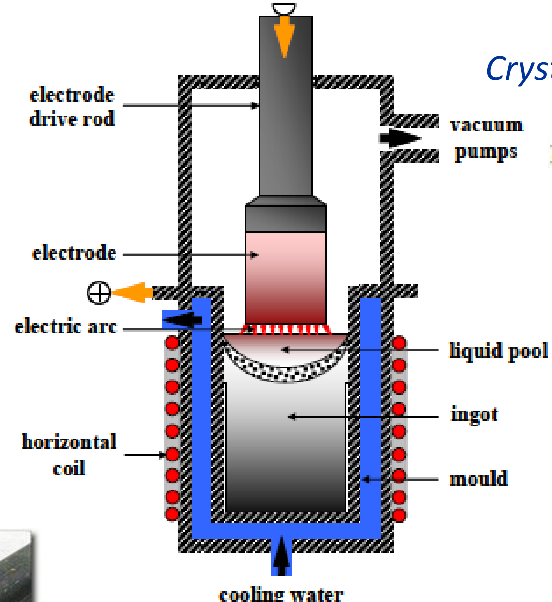
A multi-component phase-field model is developed that links directly with commercial CALPHAD thermodynamic and kinetics databases. Here we test the effect of alloy chemistry on the coarsening kinetics of γ' in Haynes 282. It is found that Alloy 6 with higher Ti content shows the slowest kinetics and therefore good for structural stability.



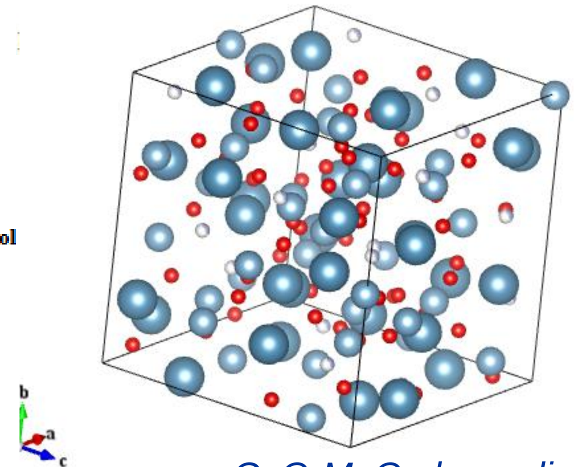
A Virtual Tool for Alloy Chemistry Screening

★***Close coordination with Advanced Combustion FWP***

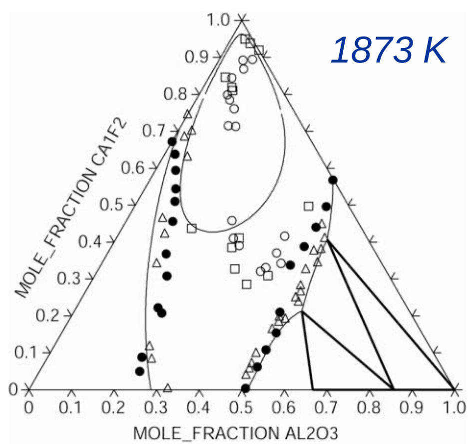
Processing Tool: ESR Slags Design



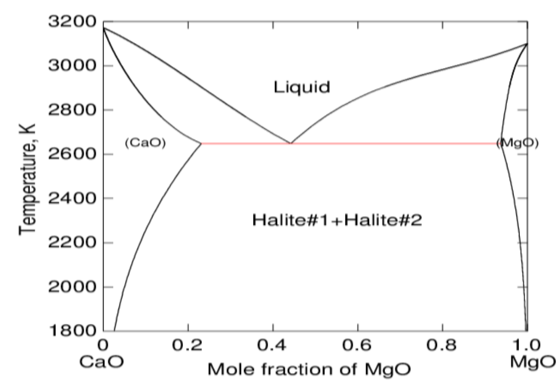
Crystal Structure of C11A7F1--$(CaO)_{11}(Al_2O_3)_7(CaF_2)$



Aubert & Duval



CaO-MgO phase diagram



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★*Close coordination with Advanced Combustion FWP*

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Innovative Process Technologies

Innovative Energy Concepts

Validated simulations for accelerating the deployment of transformational energy technologies

U.S. DEPARTMENT OF ENERGY

Innovative Energy Concepts

Validated simulations for accelerating the deployment of transformational energy technologies

University of Pittsburgh

WestVirginiaUniversity

VirginiaTech Invent the Future

PENNSTATE

NETL

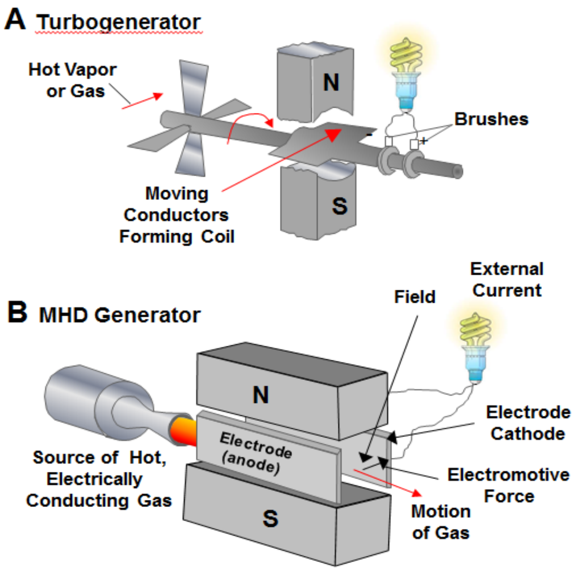
IEC TEAM

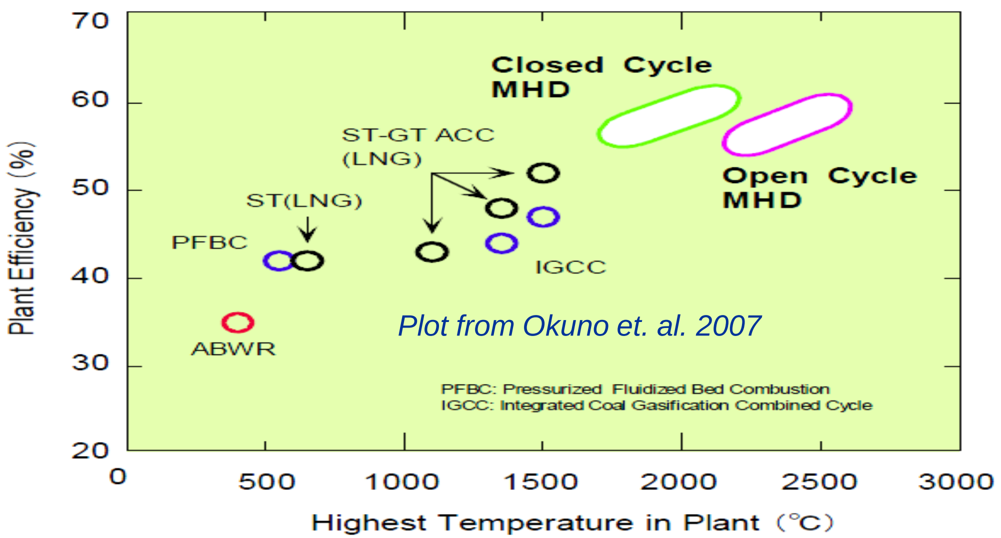
P. Givi (Pitt)
D. Haworth (PSU)
D. Santavicca (PSU)
I. Celik (WVU
N. Weiland (WVU)
U. Vandsburger (VT)
K. Casleton (NETL)
D. Ferguson (NETL), pGain Lead
E.D. Huckaby (NETL)
T.Ochs (NETL)
D. Oryschchyn (NETL)
T. Sidwell, (NETL)
P. Strakey (NETL), Task Lead
C. Woodside (NETL), DPE Lead

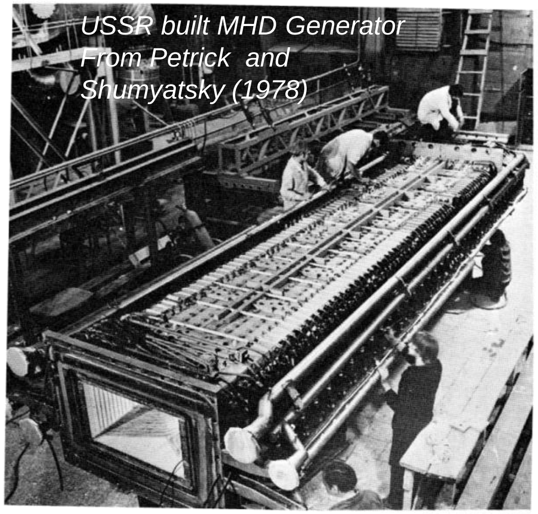
Direct Power Extraction (via MHD)

- **Magnetohydrodynamic (MHD) Power Generator:**
  - Use a strong magnet and convert kinetic energy of conductive gases directly to electric power.
  - ***Generates power directly from the moving gases.***
- **Higher plant T.E. – works at higher T so higher Carnot**
  - Synergy w/ oxy-fuel for CCUS
    - Oxy-coal COE much higher than baseline COE primarily due to ASU
    - Oxy-combustion flames ~ 3000K → in conventional systems no benefit
    - Oxy-combustion flames ~ 3000K → gives ionization needed for MHD cycle
  - Need to use in combined cycle
    - exhaust → conventional steam generator ("bottoming cycle").

MHD cycle turns having an ASU from efficiency disadvantage to efficiency advantage & promotes CCUS!







MHD generator concept proven in 1980s w/ grid transferred power in both U.S. and USSR

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MHDTechnological Barrier Then and Now

- **Then: commercialization not realized ---> high costs**
  - Higher maintenance costs then expected
    - Unsteady combustor slag retention
    - Electrode durability problems
    - Seed Recovery and Re-use Cost
  - IGCC emerged as more cost favorable coal tech route

- **Now: new economics & improved technology**
  - Different pollution control baseline economics (e.g. Sulfur) and potential for CO_2 regulation
  - MHD gen: $P_{out} \propto \sigma u^2 B^2$
    - » σ is gas-plasma conductivity…~2x better (before enhanced air, now oxy-fuel T)
    - » u is gas-plasma velocity…possibly better if CFD can lead to steady flow design
    - » B is applied magnetic flux...~2x better (before 6T now 9T)

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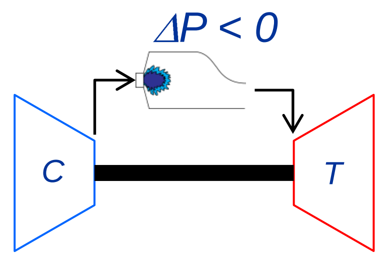
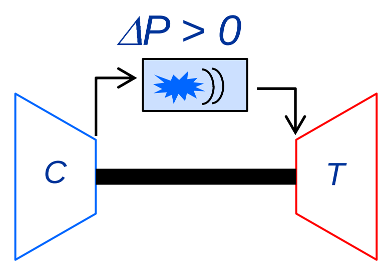
Pressure Gain Combustion

Convention gas turbines combustion results in a pressure loss across the combustor (Brayton cycle)

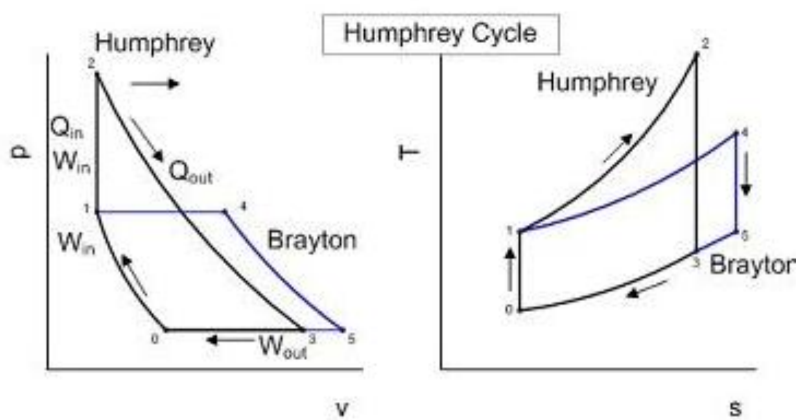
Pressure gain with *constant volume combustion (Humphrey cycle). Deflagration or detonation pressure* *wave* increases pressure and peak temperatures at turbine inlet reducing entropy. Reduced fuel consumption and increased efficiency (less CO_2).

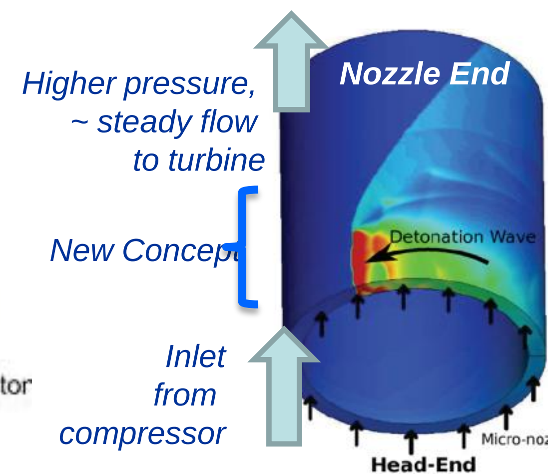


$$S_T - S_C = c_p \ln\left(\frac{T_T}{T_C}\right)$$



$$S_T - S_C = c_p \ln\left[M_{cj}^2\left(\frac{\gamma+1}{1+\gamma M_{cj}^2}\right)^{(\gamma+1)/\gamma}\right]$$





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Why is pressure-gain appealing *now*?

Pressure-Gain Combustion for Power Generation

Michael Idelchik, Vice President of Advanced Technologies at GE Research… ***Research…Sept 2009 interview on Pulse Detonation for Technology Review published by MIT.***

“An existing turbine burns at constant pressure. With detonation, pressure is rising, and the total energy available for the turbine increases. We see the potential of ***30 percent fuel-efficiency improvement***. Of course realization, including all the hardware around this process, would reduce this.

I think it (efficiency gains) will be anywhere from 5 percent to 10 percent. That's percentage points--say from ***59 to 60 percent efficient to 65 percent efficient***. We have other technology that will get us close [to that] but **no other technology that can get so much at once.** It's very revolutionary technology.

The first application will definitely be land-based--it will be power generation at a natural-gas power plant. “

“If we can turn 5% pressure loss in a turbine into 5% pressure gain, it has the same impact as doubling the compression ratio” – Dr. Sam Mason, Rolls-Royce (2008)*

** Quotation courtesy Fred Schauer AFRL*

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Developing Codes for High Temperature and High Pressure Combustion and Validating Against Existing Data Sets

Technology Assessment

Use commercial CFD codes to assess sensitivities and develop capabilities (NETL, PSU, WVU and Pitt).

DPE combustor simulations of oxy-coal combustion (PSU).

Simulations of rotating detonation wave experiment (NETL and WVU).

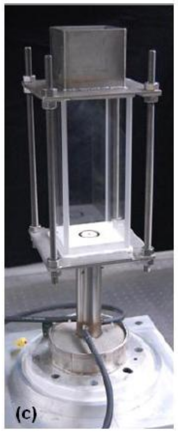
Studies of wall functions for MHD channels (WVU).

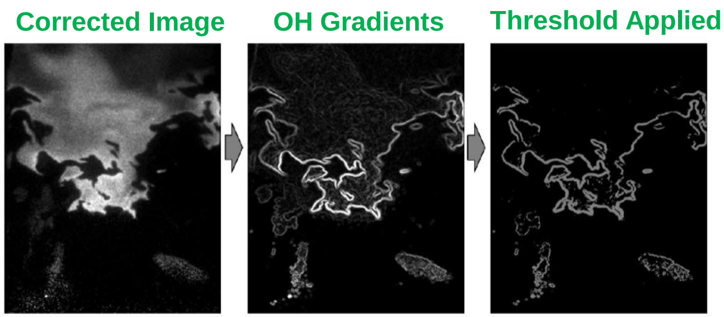
Model Validation

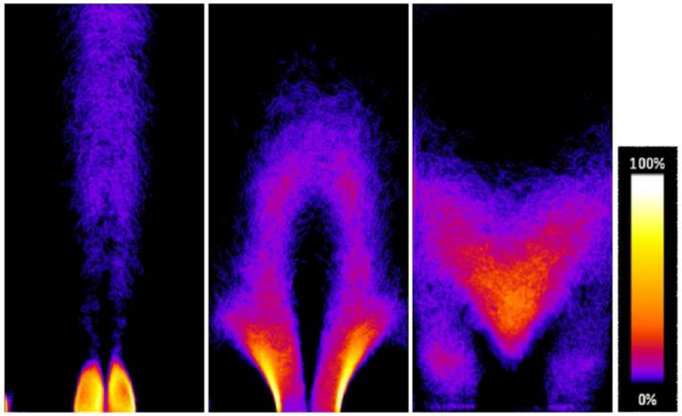
High-pressure experiments in SimVal as well as atmospheric pressure experiments (NETL).

Expansion of current database in gas-phase combustion rigs (NETL, PSU and VT).

Diffusion flame experiments and LES-FDF simulations (WVU and Pitt).







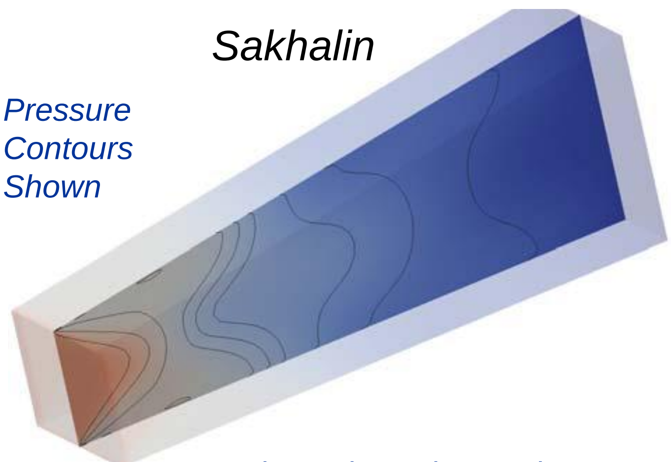
MHD Generator Simulation Summary

We are currently working on validation of solvers for MHD power generation.

Table I – Governing Equations	
Mass	$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho u) = 0$
Momentum	$\frac{\partial \rho u}{\partial t} + \nabla \cdot (\rho u u) + \nabla p = \nabla \cdot (\tau) + \underbrace{\vec{J} \times \vec{B}}$
Energy	$\frac{\partial \rho H}{\partial t} + \nabla \cdot (\rho u H) = \frac{\partial p}{\partial t} - \nabla \cdot (q) + \underbrace{\nabla \cdot (u \cdot \tau)} + \underbrace{\vec{J} \cdot \vec{E}}$
Charge (Ohm's Law)	$\nabla \cdot \vec{J} = 0$
Current	$\vec{J} = \sigma(\vec{E} + \vec{u} \times \vec{B}) - \frac{\beta}{\lvert\vec{B}\rvert} \vec{J} \times \vec{B}$
Generalized Ohm's Law	$\nabla \cdot (\sigma_{eff} \nabla \phi) = \nabla \cdot (\sigma_{eff} (\vec{u} \times \vec{B}))$

Sakhalin

Pressure Contours Shown

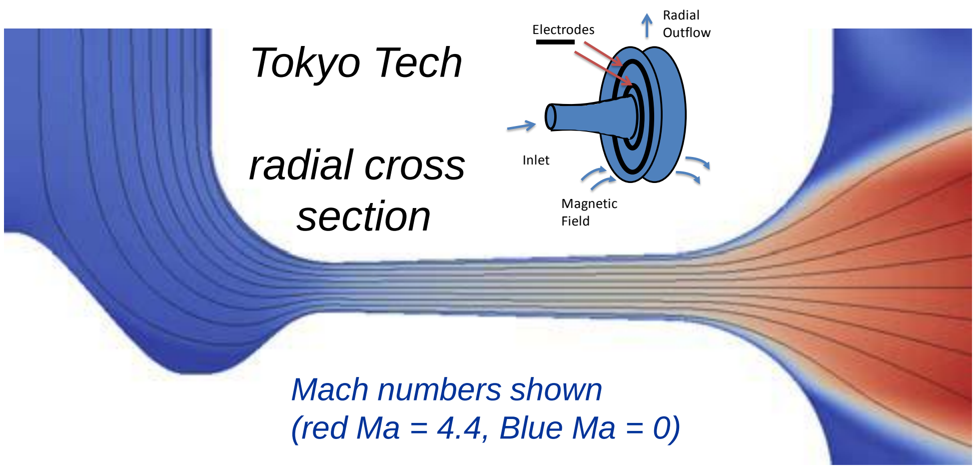


Red ~3.3 bar, Blue 1.4 bar

Faraday generator

Tokyo Tech

radial cross section



Mach numbers shown (red Ma = 4.4, Blue Ma = 0)

Hall generator

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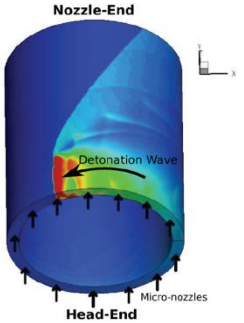
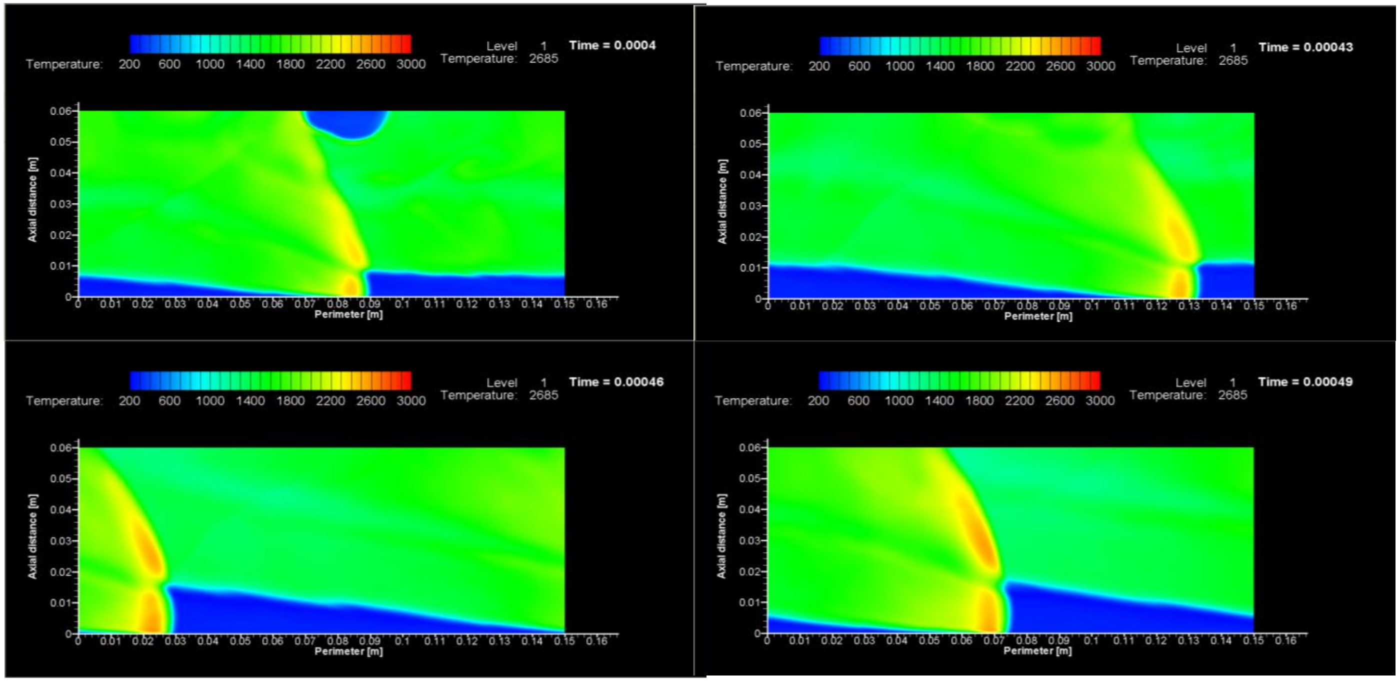
Simulations of rotating detonation wave experiment.

Successful modeling of H_2/O_2 rotating detonation wave (WVU).



Temperature contours at several instances in time.



Conditions at the fuel and oxidizer manifold

Pm/Po = 5 with Po= 1 atm

Tm/ To = 1 with To = 300K

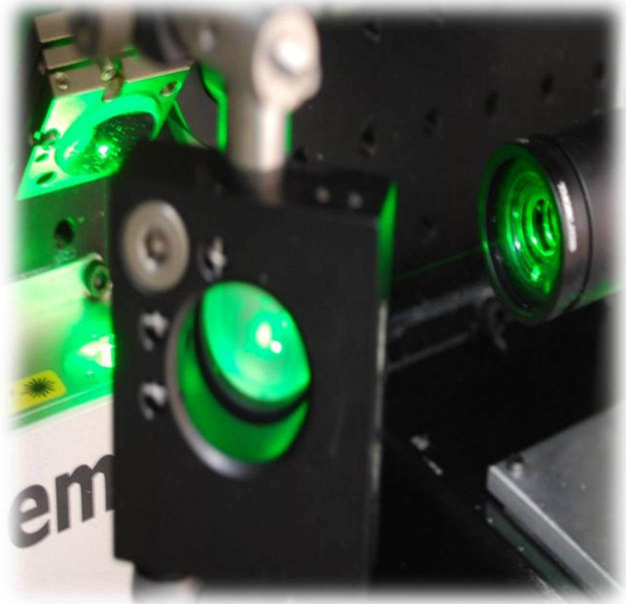
Inlet Mixture:

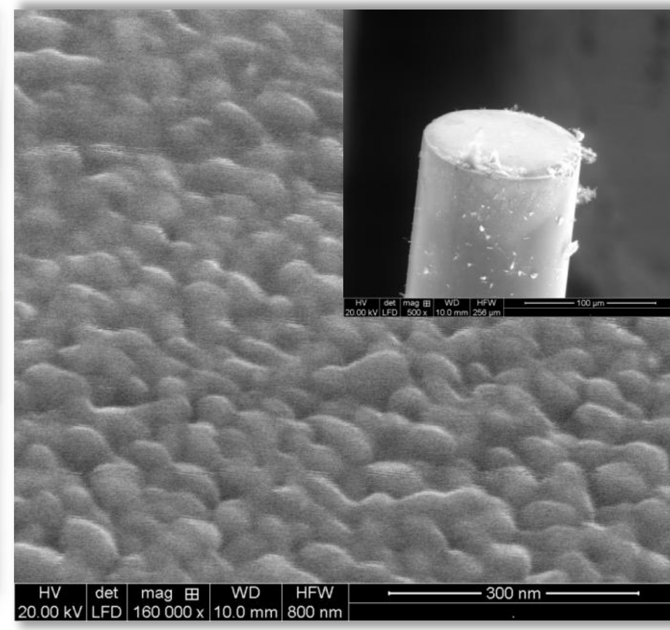
$2H_2 + O_2 + 5N_2$

Inlet Mass flux

67.70 kg/s-m^2

Auto-ignition and self-propagation successfully captured.





Innovative Process Technologies

Sensors & Controls

Developing advanced sensors & controls to improve efficiency, fuel flexibility, operational flexibility, and reduce emissions in FE power generation.

Sensors & Controls Team

Benjamin Chorpening (NETL), Task Lead

Optical Sensors:
Benjamin Chorpening, Steven Woodruff (NETL), Michael Buric (NETL), Jessica Mullen (ORISE)

Sensors Materials:
Paul Ohodnicki (NETL), Thomas Brown (NETL), John Baltrus (NETL), Michael Buric (NETL), Mark Andio (ORISE), Charter Stinespring (WVU-ORISE), S. Chaudhari (ORISE), James Poston (NETL)

Controls Testing in Hyper:
David Tucker, Paolo Pezzini (ORISE), Larry Banta (WVU), Mark Bryden (AMES Laboratory), Peter Finzell (AMES Laboratory)

High Temperature Sensors Testing:
Douglas Straub (NETL), Mark Tucker (NETL), Jeffrey Riley (URS)

Optimal Sensors Placement:
Stephen Zitney (NETL), D. Bhattacharyya (WVU), P. Paul (WVU)

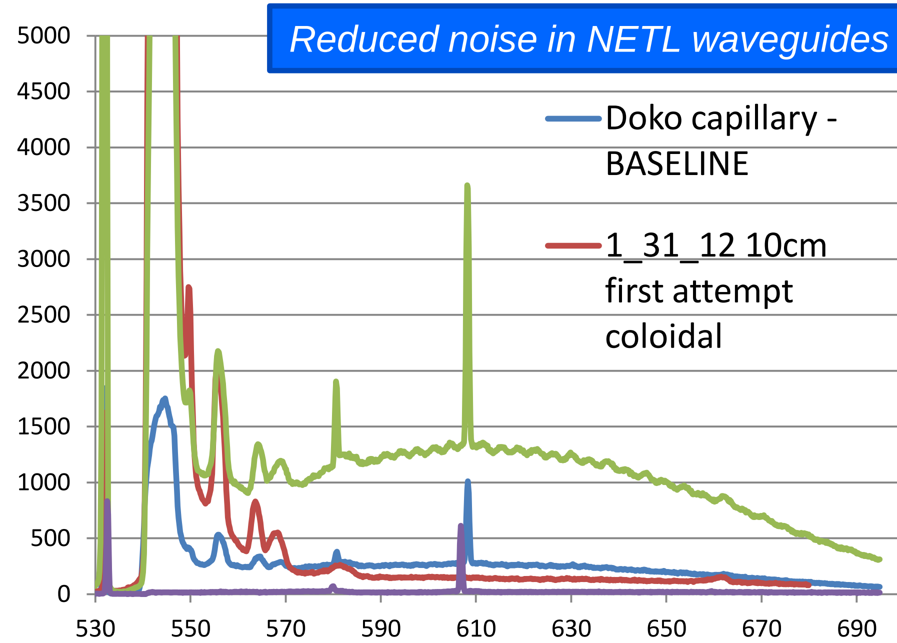
NETL-RUA URS West Virginia University NETL

Optical Sensors

Improvement, field testing, and technology transfer of the Raman gas composition sensor for real-time monitoring of fuel gas composition.

- **Joint patent filed by U. of Pittsburgh, already licensed**
- **CRADA Phase I - testing at turbine facility - completed**
- **NETL field unit redesign near completion**
  - Revised heating
  - Revised capillary cell
  - Revised enclosure
- **NETL silver waveguides better optically than commercial; SNRs ~180, better than exhibited by commercial waveguides (~70)**

Reduced noise in NETL waveguides



Field System Design
- *800 psig, 200 °C*
- *1-second response*
- *CH4 – C4H10, CO, CO2, H2, N2, O2, H2O*
- *Suitable for NEC Class I, Div. 2*

Oxy-fuel products measurement

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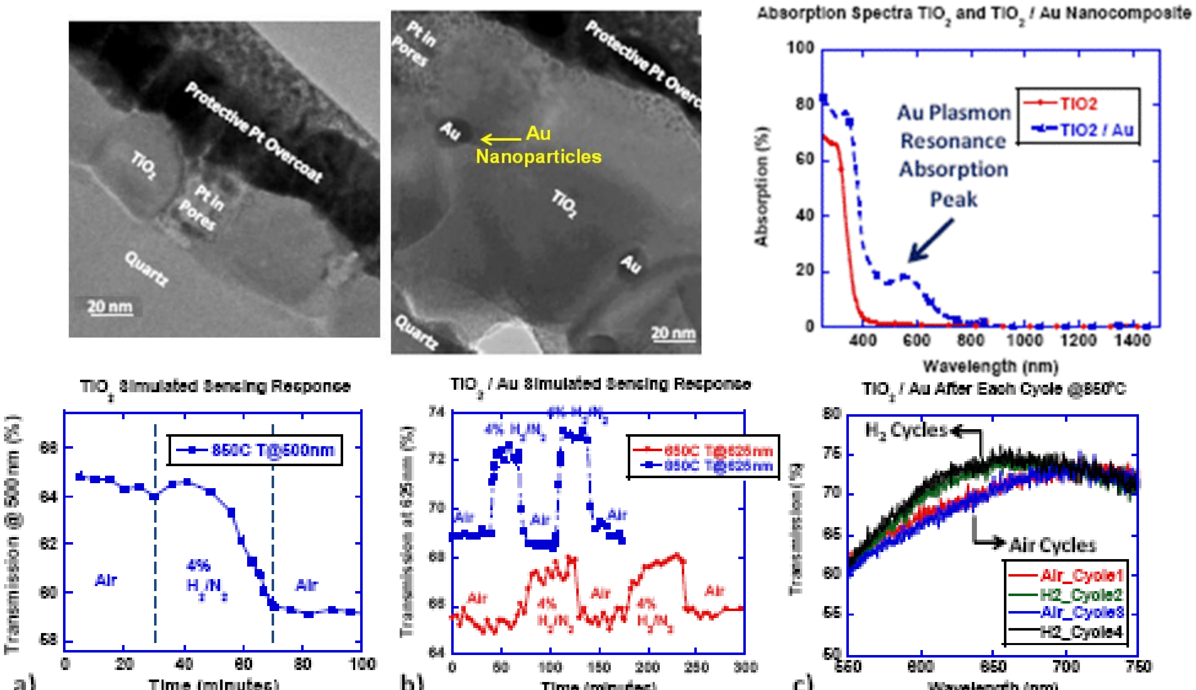
Advanced Sensor Materials

Investigation of novel composite nanomaterials for high temperature, harsh environment gas sensing for fossil energy process control applications.

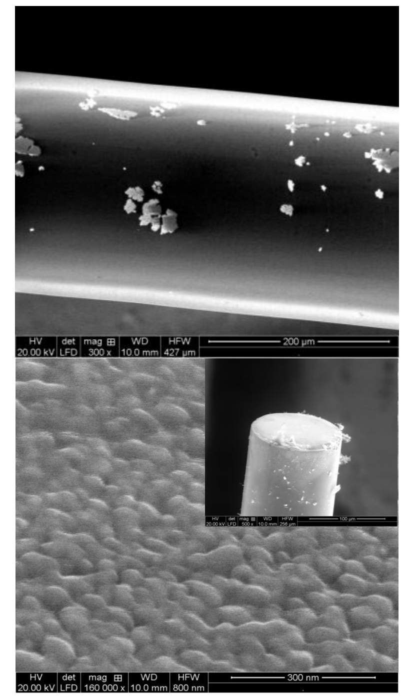
Novel composite nanomaterials are being investigated for optical and electrical response under exposure to high temperature reducing and oxidizing gas conditions. Promising materials to be incorporated in optical fiber sensors or electrochemical sensors.

Functionalization of TiO_2 Using Au Nanoparticles



Without Au Nanoparticles **With Au Nanoparticles**

Nano-structured thin Films Have Promise for High Temperature Optical Gas Sensing Up to 850°C Through Localized Surface Plasmon Resonance Effects.



Testing adherence of dip-coated composite nanomaterials on optical fibers. Transmission sensing coating (top), and reflection probe (bottom).

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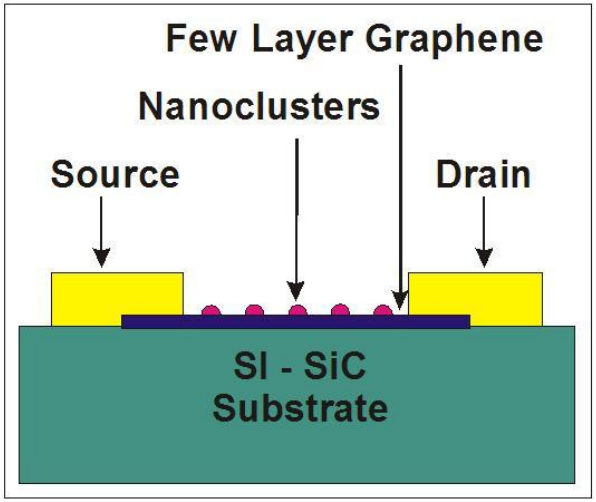
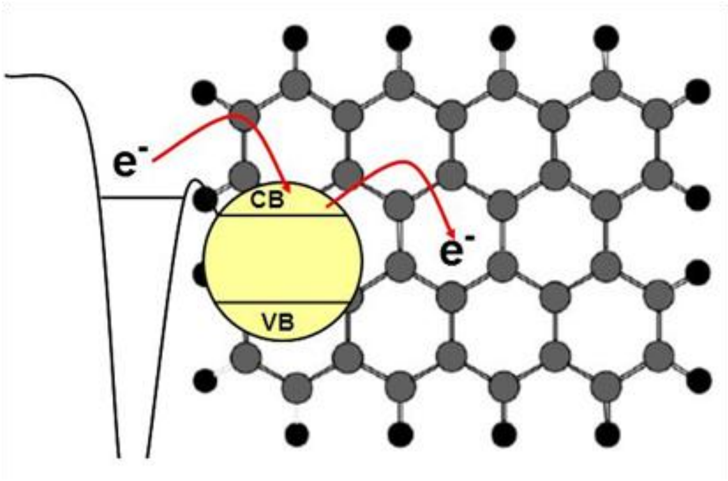
Research on Graphene for Sensors

Fabricate and characterize large scale graphene films using the WVU synthesis process. Optimize the film properties with respect to the fabrication control parameters. Fabricate graphene sensor and deposit metal and metal. oxide clusters to form graphene nanocomposite structures

Graphene is an exciting, novel material with many possible applications; however, it has not been developed in a manner that is readily applied in manufacturing processes. This project will first optimize a potential industrial manufacturing process for high-quality large graphene films. Those films will be evaluated for harsh environment application, and in sensor fabrication.





Graphene's 2D carbon lattice.

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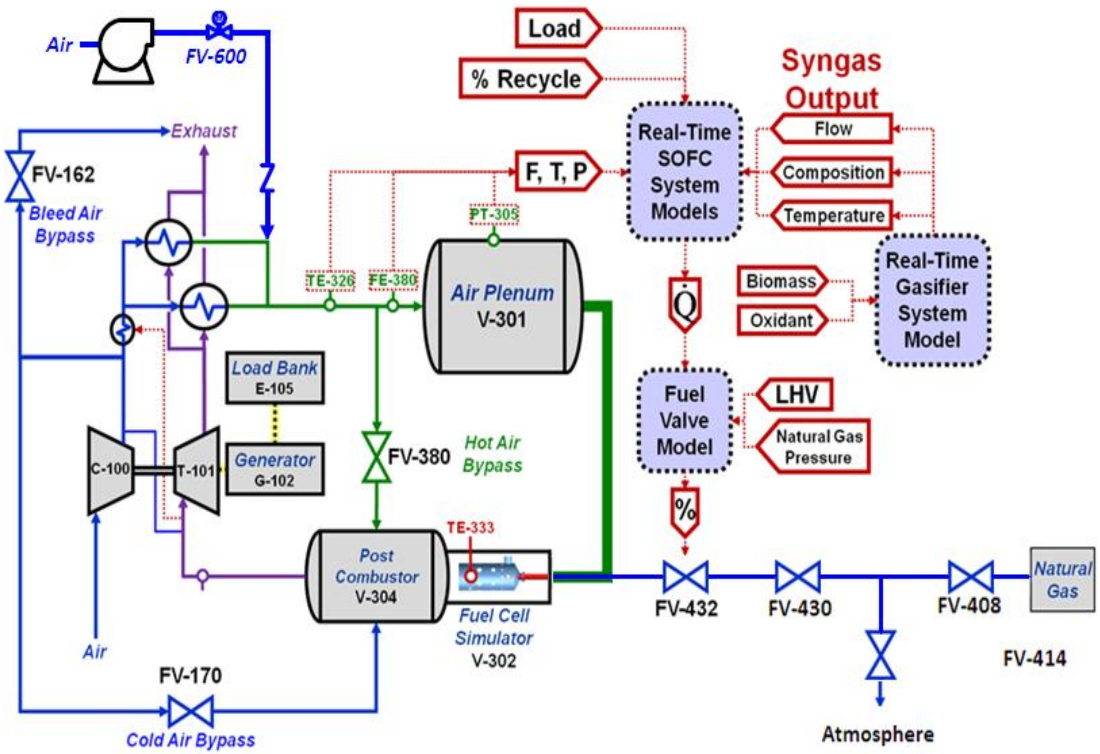
Sensors & Advanced Controls Testing in HyPer

Testing of massive heterogeneous sensors networks and advanced control methods for power plant systems at the NETL HyPer facility.

Experimental testing in the HyPer facility supports evaluation of advanced controls for use in a power plant application, and hybrid power plant model development and validation.



- *Initiation of collaboration on stigmergy for power plants (Ames Lab)*
- *Collaborative research on heat exchanger flow splits with the Univ. of Genoa*
- Collaborative research on dynamic simulation of hybrid power systems with Univ. of California - Irvine
- Collaborative research on polygeneration system control with McMaster Univ. (Canada)
- *Development of advanced controls (MIMO) for load following with hybrids (WVU)*

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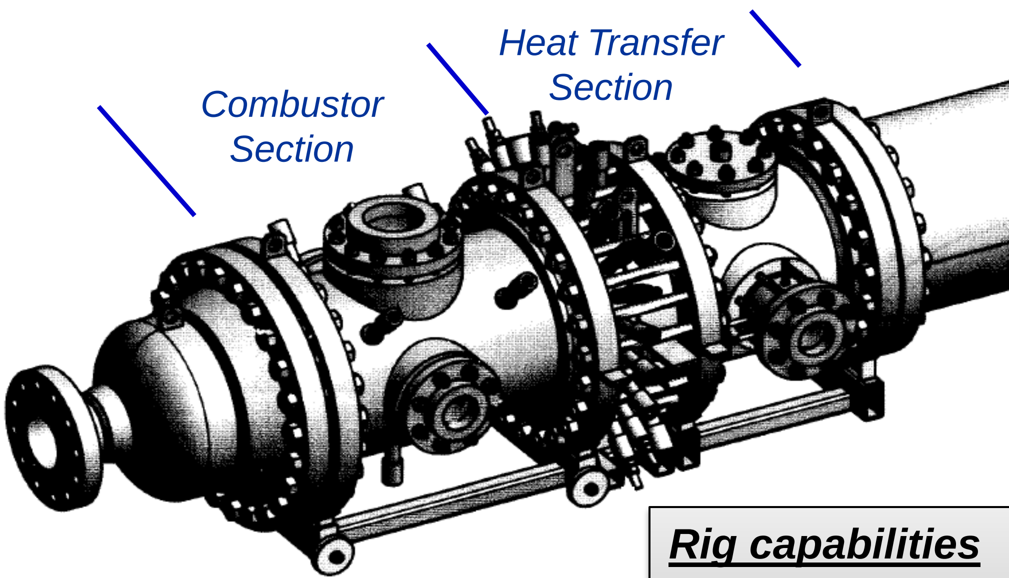
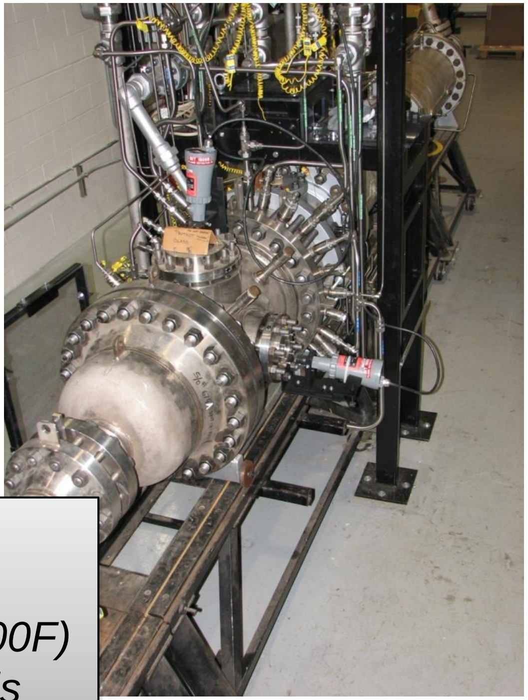
High-temperature Sensors Testing in an Application-relevant Environment

Testing of high temperature sensors for in the B6 high pressure combustion facility's aerothermal test rig.

Testing in the NETL aerothermal test rig provides a cost efficient path to advance the Technology Readiness Level of sensors that are being developed with DOE FE funding, or are of particular interest to the DOE Crosscutting Technologies Program.

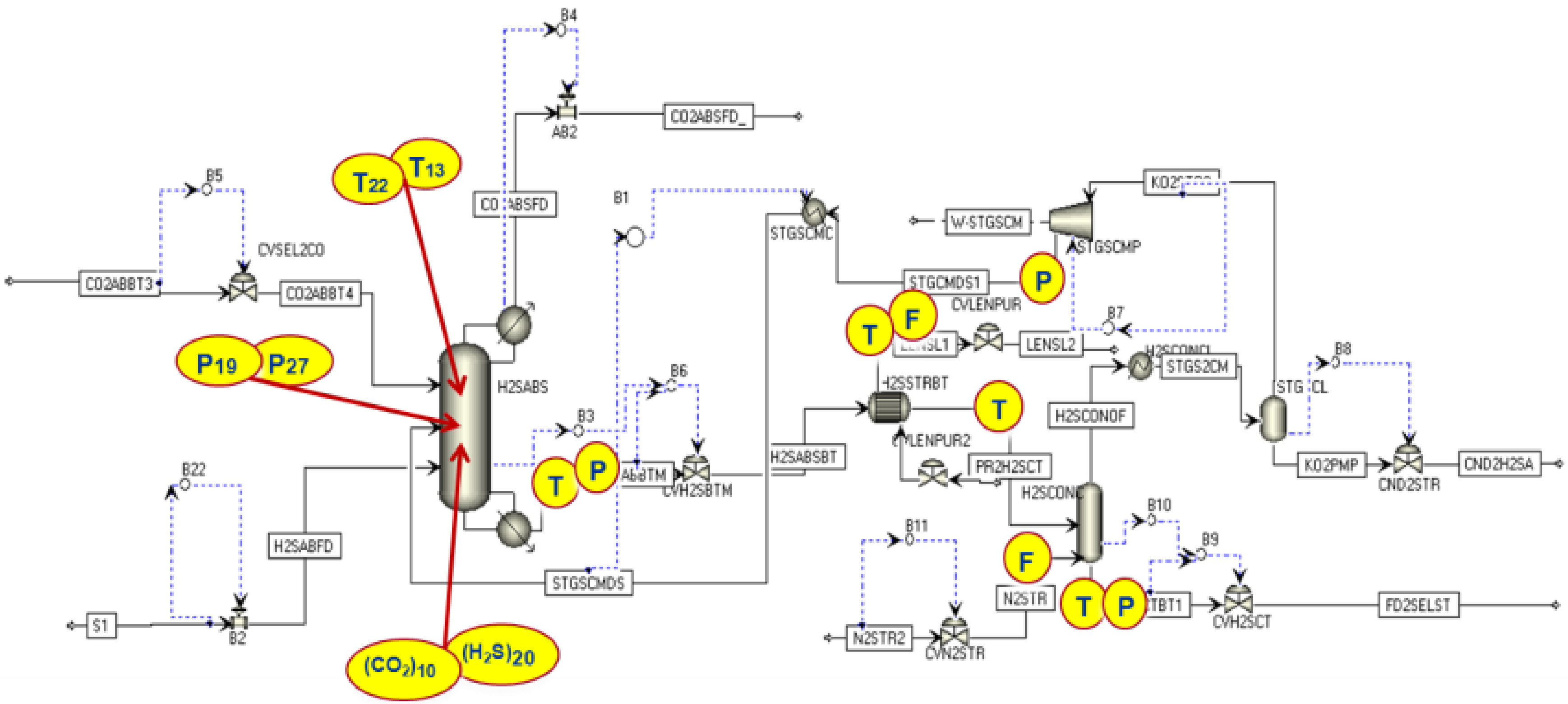




Rig capabilities
2 lb/s air flow @ 10 atm
Max inlet air temperature (800F)
Natural gas or hydrogen fuels

Optimal Sensor Placement for IGCC with CO_2 Capture

- ★ Developing sensor placement algorithm and solution methodology for maximizing plant efficiency subject to budget constraint while satisfying desired estimatioerrors in state and disturbance.



Optimal set of sensors for H_2S recovery for IGCC power plant with CO_2 capture

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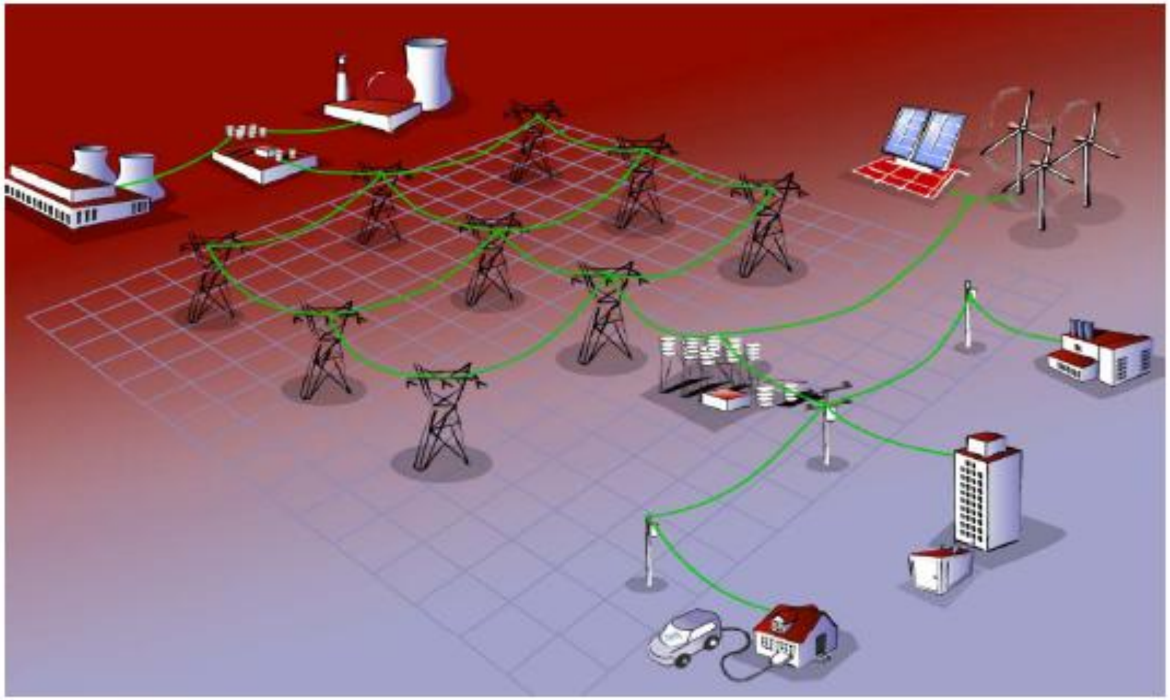


Innovative Process Technologies

Power Electronics and Energetic Materials

Developing & demonstrating lab scale electrochemical systems suitable for grid scale power electronics and energy storage to promote efficiency and reduce emmisions from advanced FE systems

U.S. DEPARTMENT OF ENERGY

Energy Storage and Smart Grid

NETL-RUA Regional University Alliance

Electrical Energy Storage -A key enabler for the smart grid
www.netl.doe.gov/smartgrid

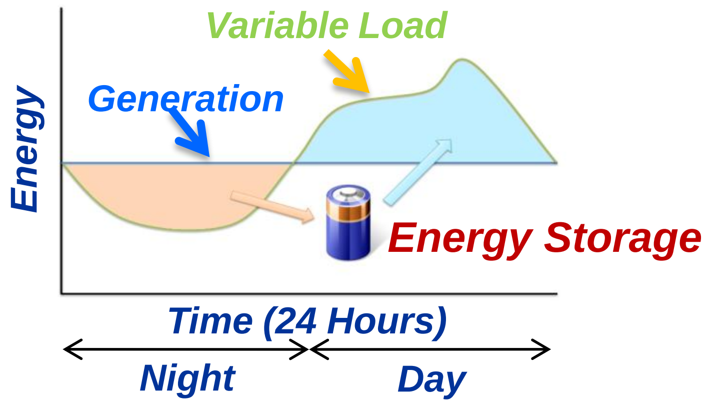
- Improve reliability and stability of the grid
- Provide responsive power to meet minute-to-minute fluctuations in electricity demand and increase margins against system upsets.
- Provide capacity to "peak shave or load shift," enabling peak loads to be met during periods when generation, transmission and distribution assets can not yet be brought on line.
- Improve efficiency of off-grid solar and wind power enabling the integration onto the grid of large scale renewable energy plants.
- More stable and efficient delivery of electrical power including power generated from fossil fuel sources.

Electrical Energy Storage - result in more stable and efficient delivery of electrical power while reducing overall CO_2 emissions.

Electrochemical Materials Energy Stiorage Needs*:

- ***Optimize materials and chemistries and modify current technologies to improve their performance and reduce costs.***
- ***Discover new materials and components that can lead to new technologies meeting the performance and cost requirements of grid storage applications.***

**DOE Office of Electricity Delivery & Energy Reliability (OE), Energy Storage Planning Document, February, 2011*



NETL-RUA: Mg Battery Development

Advantages

Mg batteries involve cycling Mg^{2+} .

Mg compounds are environmental stable &, non-toxic.

Mg as a raw materials is cheap & abundant

- Mg: ~ $2700/ton
- Li: ~ $64,000/ton
- Mg: ~ 13.9% earth's crust
- Li: ~ 0.0007% earth's crust

Technical Challenges:

Poor performance of cathodes (intercalation of Mg ions)

Poor performance of electrolyte (reactivity and formation of passive layers).

Poor capacitance and stability of the anode (which will allow the use of safe aqueous electrolytes

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Current Battery Technologies for Grid Storage:
Mg a possible solution to the grid-lock

BATTERY	ZEBRA	NaS	Mg
Anode	Molten metallic Na	Molten Metallic Na	Solid Mg alloy
Cathode	$NiCl_2$ or $NaAlCl_4$	Molten S or Na_2S_x	$Mg_{1.03}Mn_{0.97}SiO_4$
Electrolyte	β''-Al_2O_3 solid electrolyte (BASE)	β''-Al_2O_3 solid electrolyte (BASE) membrane	$Mg(AlCl_2BuEt)_2$/THF (0.25 mol L^{-1})
Cell Voltage	2.58 V	2.1 V	2.1 V
Specific Capacity*	305 Ah/kg	377 Ah/kg	315 Ah/kg**
Specific Energy*	100 Wh/kg	110 Wh/kg	~500 Wh/kg
Operating Temperature	***High 270°C***	***High 350°C***	***Room Temp***

**Theoretical*
***based on cathode*

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Mg Battery Development for Grid Applications

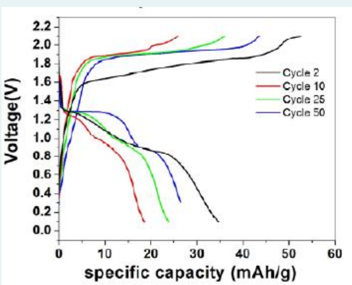
NETL-RUA Research Team

FY 13: A. Manivannan (NETL), P. Kumta (Pitt)

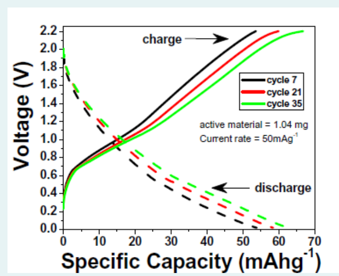
University of Pittsburgh NETL

Integrated Materials Systems Approach: Develop Mg Cathode, Anodes and Electrodes with Improved Performance – That work together in a system

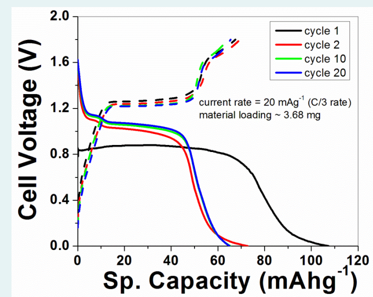
Cathode: Spinel



Cathode: Defect-Oxide

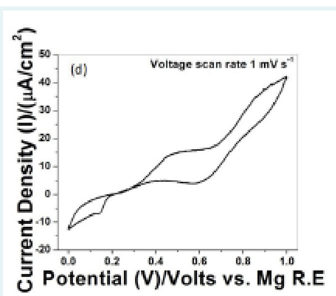


Cathode: CP

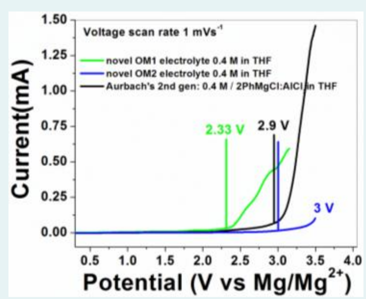


Cathodes tested with "Aurbach 1 or 2 Gen" Electrolyte: $Mg(AlCl_2BuEt)_2$/THF or 2(PhMgCl)-$AlCl_3$ /THF

Anode: Mg Compound

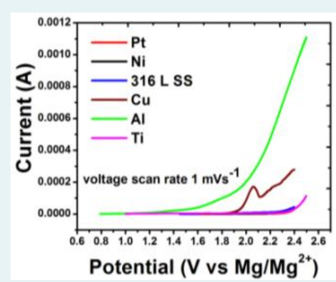


Electrolyte



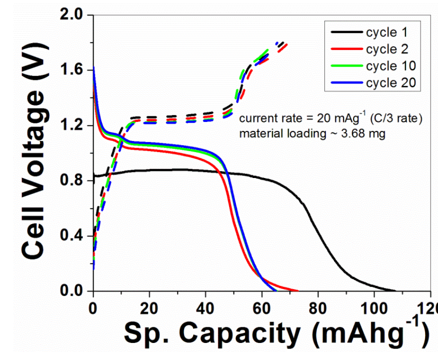
Comparison of NETL-RUA Electrolyte with "Aurbach 2 Gen" Electrolyte

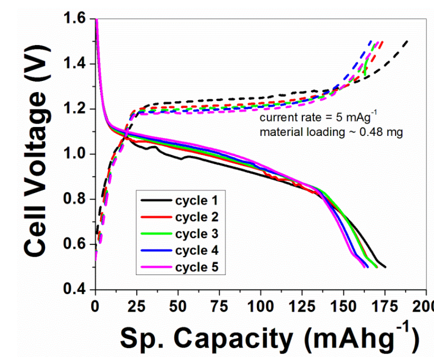
Current Collector



Current Collectors with "Aurbach 1 Gen" Electrolyte:

NETL-RUA CP Cathode
Aurbach 2-Gen Electrode





NETL-RUA CP Cathode
NETL-RUA Electrolyte

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NETL

Innovative Process Technologies

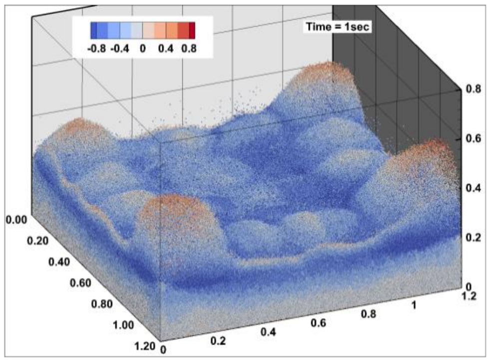
Multiphase Flow

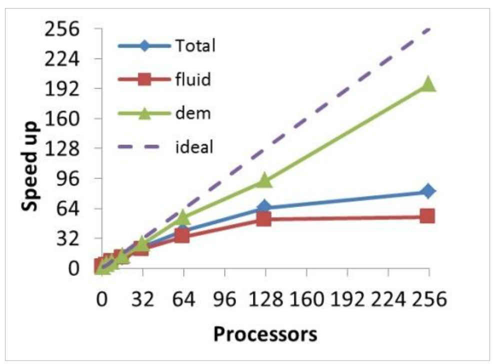
Improving physics-based CFD capability for simulating reacting multiphase flows

U.S. DEPARTMENT OF ENERGY

MFIX Acceleration

Scaling analysis of a shallow fluidized bed. A speed up of factor of about 80 is achieved with 256 cores (blue line)





- D. Tafti (VT), N. Nystrom (PSC) M. Shahnam (NETL)
- Reduction of "time to solution" of multiphase CFD simulations through porting MFIX to Graphics Processing Unit (GPU) architecture and other advance parallelization techniques
- Multi- and many-core parallel architectures, where thousands of cores can work on the solution simultaneously to speed up time to solution is being developed for NETL's multiphase software MFiX.
- Port some of the most computationally intensive subroutines in MFIX-DEM to Graphics Processing Unit (GPU)
- To date, an acceleration of factor of 2 is achieved for a fluidized bed with 75,000 particles by porting the neighbor search subroutine in MFIX-DEM to GPU (serial CPU: 2177 seconds: serial GPU: 1072 seconds)

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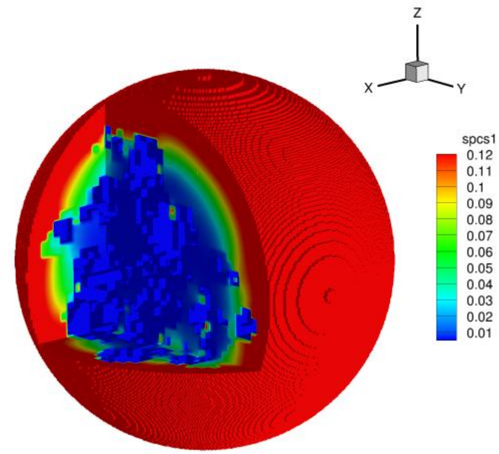
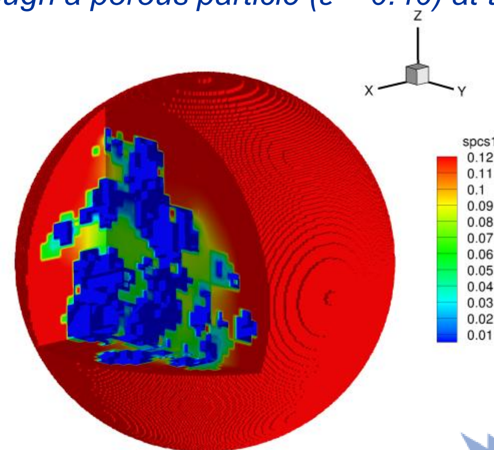
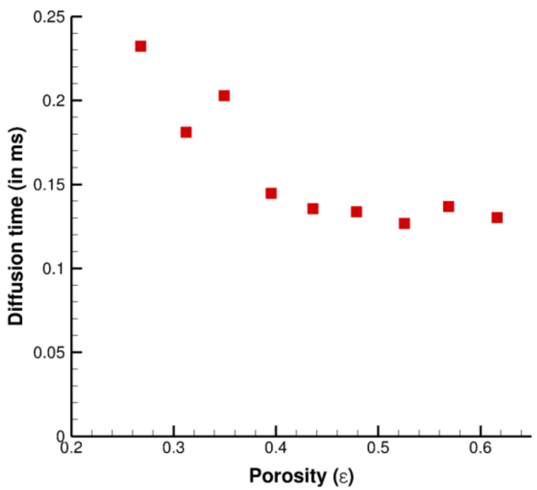
HEAT AND MASS TRANSFER IN POROUS CO_2 SORBENT PARTICLES

- **D. Tafti (VT)**
  M. Shahnam (NETL)
- **Develop models to characterize flow, heat and mass diffusion at the pore level inside porous sorbent particles in CO_2 capture**



Contour plots of CO_2 levels obtained from a 3D diffusion simulation through a porous particle (ε = 0.40) at two time instants.





Time for 95% CO_2 level saturation in the porous particle

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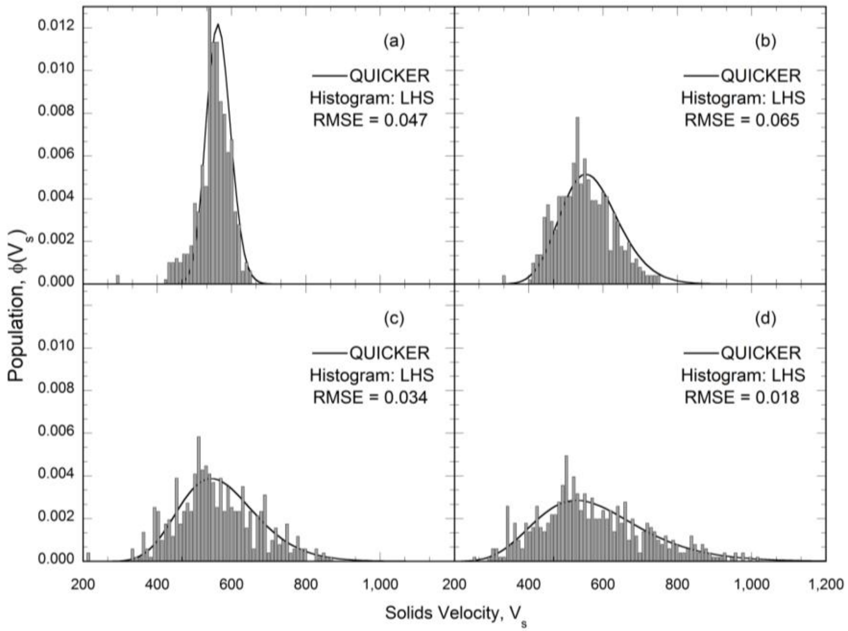
Uncertainty Quantification in Reactive Multiphase CFD

- **R. Pittchumani (VT)**
  M. Shahnam (NETL)

- **CFD based acceleration of technology deployment from pilot scale to commercial scale requires confidence intervals on CFD model predictions**

- **A novel methodology for rapidly quantifying uncertainty in multiphase systems with minimal sampling (QUICKER) is being developed**



Solid velocity in a fluidized bed. The conventional sampling method (LHS) required 500 simulations—a total of 4.6 hours. QUICKER required only 11 simulations—a total of 0.1 hours.

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Innovative Process Technolgies

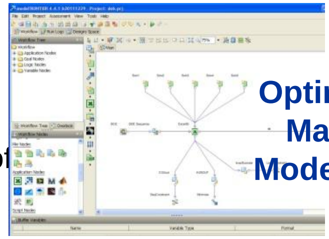
Techno-Economic Analysis & Stategic Growth Areas

U.S. DEPARTMENT OF ENERGY

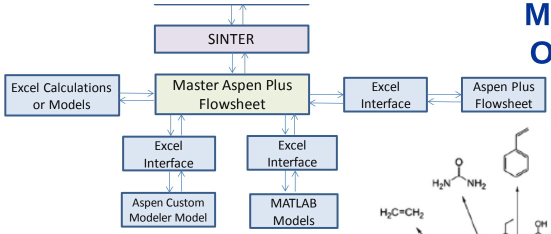
Techno-Economic Studies

- **Impact of Wind Penetration on Fossil Assets**
  - J. Apt (CMU), P. Jaramillo (CMU), P. Balash (NETL)

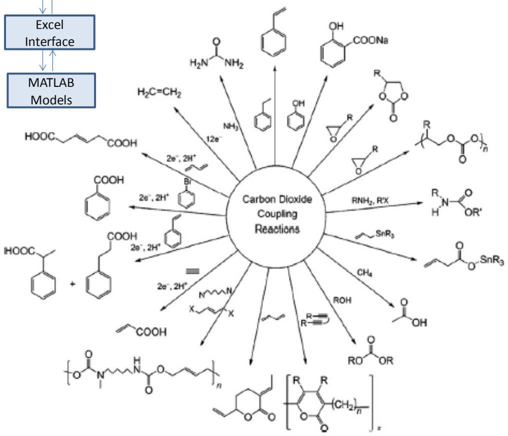
- **Optimization of Process and Energy Plants with Integrated CO_2 Capture and Utilization Processes**
  - D. Bhattacharyya (WVU), Stephen Zitney (NETL)
    - **Multi-Objective Optimization Software Framework**
      - Systematic model-based approach to conduct techno-economic optimization of
        - Baseline industrial process or energy plant as source of CO_2, low-level waste heat, and utilities
        - Source of renewable energy (e.g., solar), and
        - CO_2 utilization technologies for chemicals production
    - **Process Models for Techno-Economic Optimization**
      - Baseline supercritical pulverized coal (SCPC) power plant
      - CO_2 utilization processes
        - Methanol production
        - Fluor's Econamine FG Plus®
        - Tri-reforming of methane
    - **Key Collaboration Partners**
      - NETL AVESTAR Center
      - WVU Chemical Engineering
    - **Benefits**
      - Optimal synthesis of energy plants integrated with CO_2 capture and utilization processes
      - Maximize economic objective while minimizing emissions



Optimization Master in ModeFrontier



Model-Based Optimization Framework



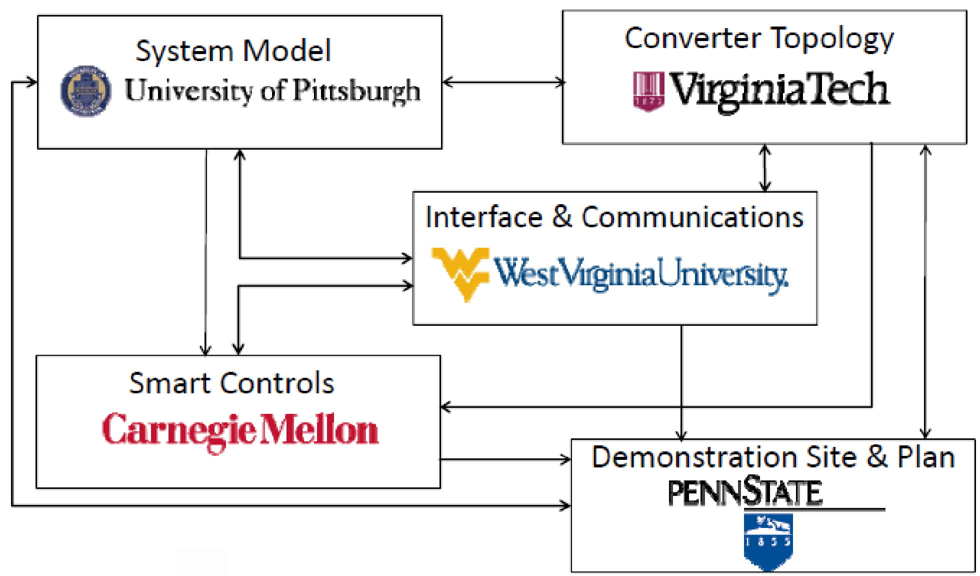
CO_2 Utilization for Chemicals Production

DOE NETL-RUA – Grid Technologies Collaborative

- **The Next Generation Power Converter: Applications for Enhanced T&D Grid Performance and Resource Integration**
- The work of the GTC contributions to improve power systems integration, optimization, and intelligence through the development of advanced power converter technology and its application to various enhancements including:
  - **Energy generation integration**: Cleaner, lower emission power production
  - **Energy storage interconnection**: Power generation and delivery optimization
  - **Control methodology development**: Automated operations and intelligence
  - **Emerging load supply**: Seamless power delivery at any load level
  - **Next generation power converter technology development:** Advances in overall technology intelligence, improved system performance, efficiency, and operation in electrical energy conversion, advanced material and device applications, and new controls development

GTC TEAM

D. Boroyevich (VT)
S. Bossart (NETL)
G. Dobbs (PSU)
K. Dodrill (NETL)
P. Famouri (WVU)
W. Honath (UEP)
G. Hug (CMU)
J. Nelson (URS)
G. Reed (Pitt) LEAD



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