



Achieving Higher Availability Through Reduced Syngas Cooler Fouling

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Overview

- Microbeam Technologies Inc.
- Fate and behavior of fuel impurities in gasification systems
- Technology for controlling and removing deposits from syngas cooling systems

Microbeam Technologies Inc.

- Commercial spin-off from Energy & Environmental Research Center of the University of North Dakota
- Mission
 - Provide advanced combustion and gasification system analysis services to minimize the impact of fuel impurities on combustion and gasification system performance

Experience Base

- Analysis of fuel and deposit characteristics > 5000 samples
- Behavior of inorganic components in gasification systems
 - Ash behavior issues in all major gasification technologies, including entrained flow, fixed bed, fluid bed, transport reactor
- Characterization and optimization of system operating conditions
- Advanced tools to predict the impacts of fuel impurities on gasification and combustion system performance
- Conducted nearly 1000 projects for utilities, coal companies, power system developers, and research organizations worldwide since 1992



Fate and Behavior of Fuel Impurities in Gasifiers

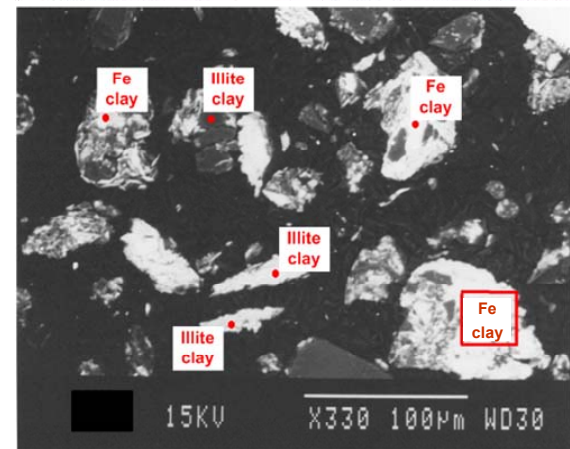
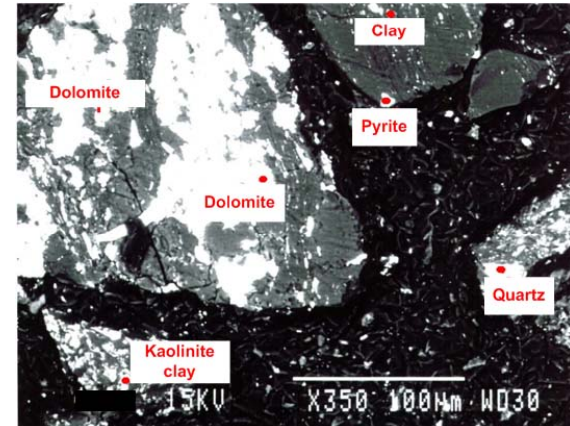


Coal Impurities

Mineral and Organically Associated Species:
Major, Minor and Trace Elements

Major Minerals in Coal

- 50 to 60 different types including (not limited to)
 - Clay
 - Most common, important minerals
 - Sulfides
 - Pyrite
 - Sulfates
 - Include gypsum and barite
 - Carbonates
 - Calcite, dolomite, ankerite
 - Silicates
 - Quartz



Organically Associated Inorganic Elements

- Elements – Na^+ , K^+ , Ca^{2+} , Mg^{2+} , Ba^{2+} , Sr^{2+}
 - North American subbituminous/lignite coals
 - Australian brown coals
 - German brown coals
 - Indonesian coals

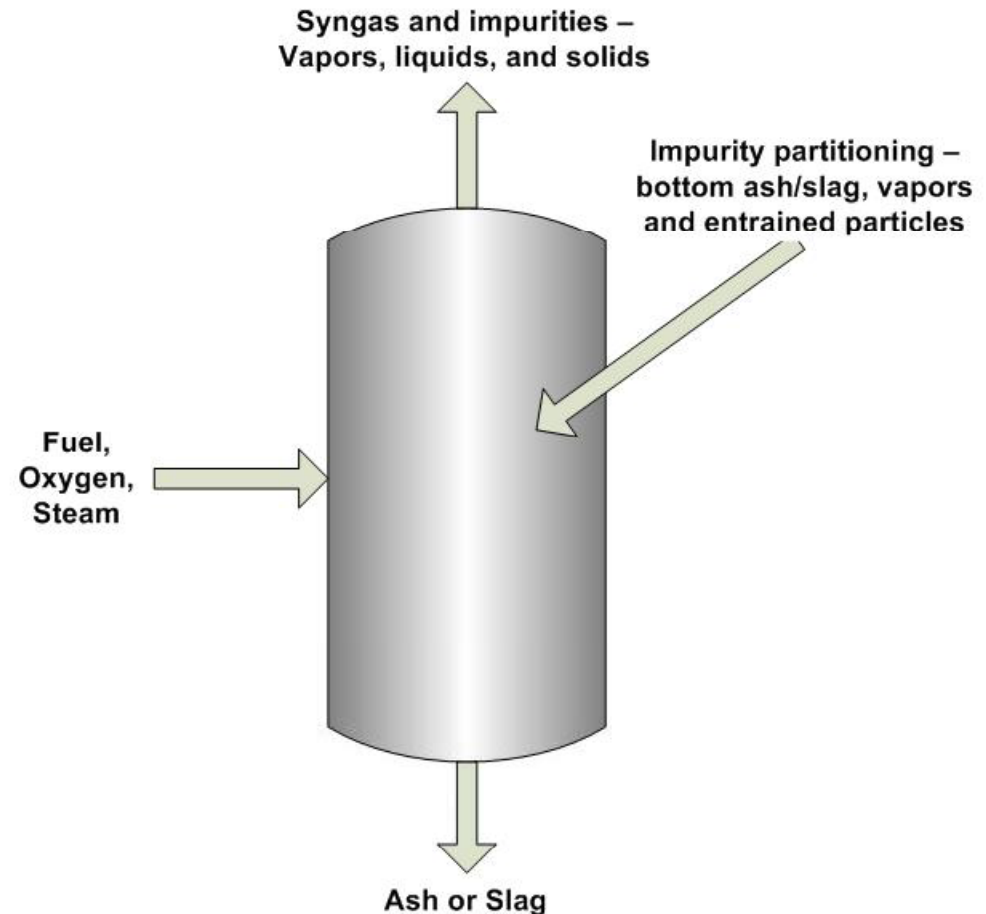
Inorganic Partitioning During Gasification

Processes

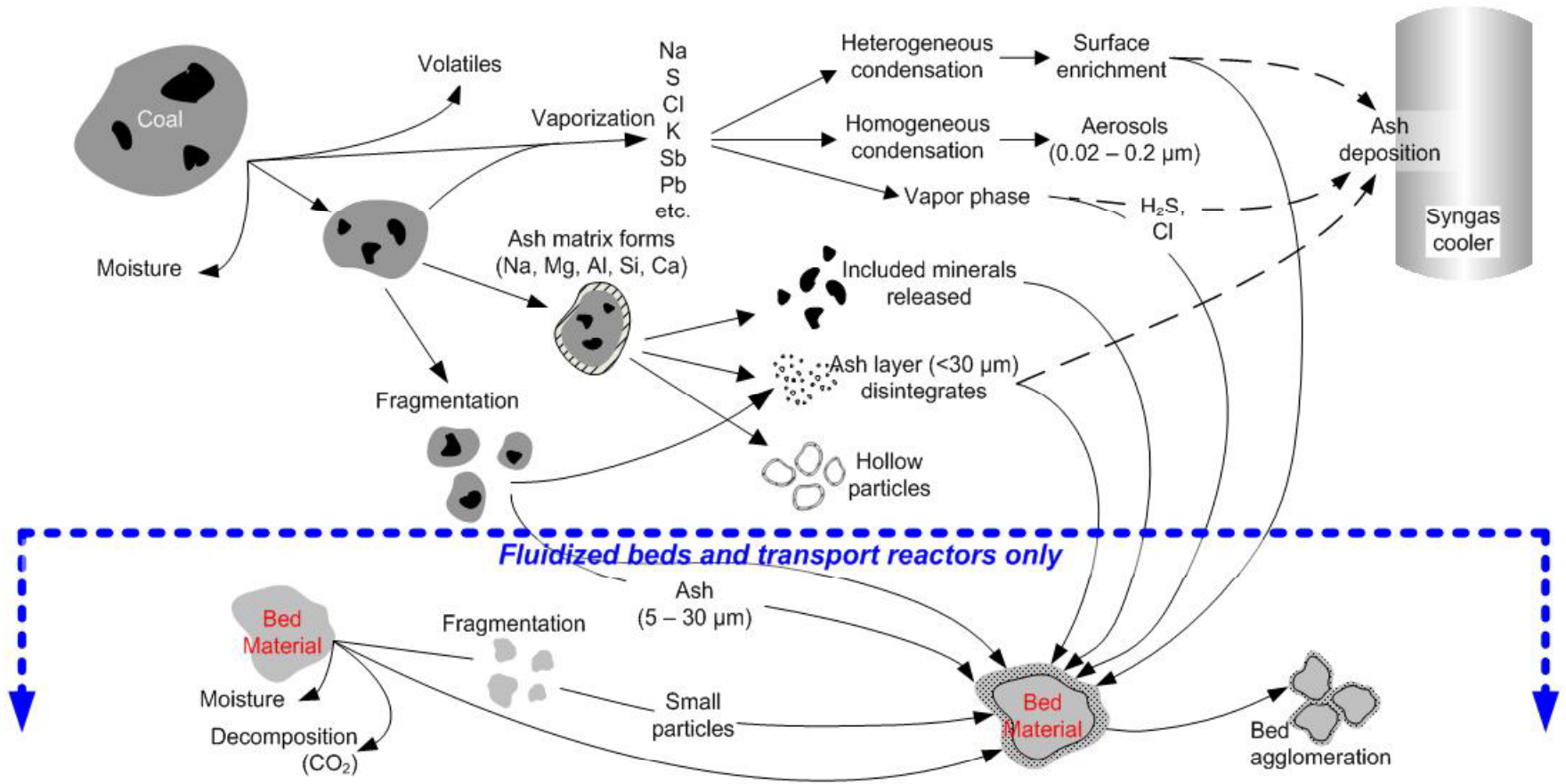
- Vaporization
- Condensation
- Melting and coalescence
- Slag flow

Impacts

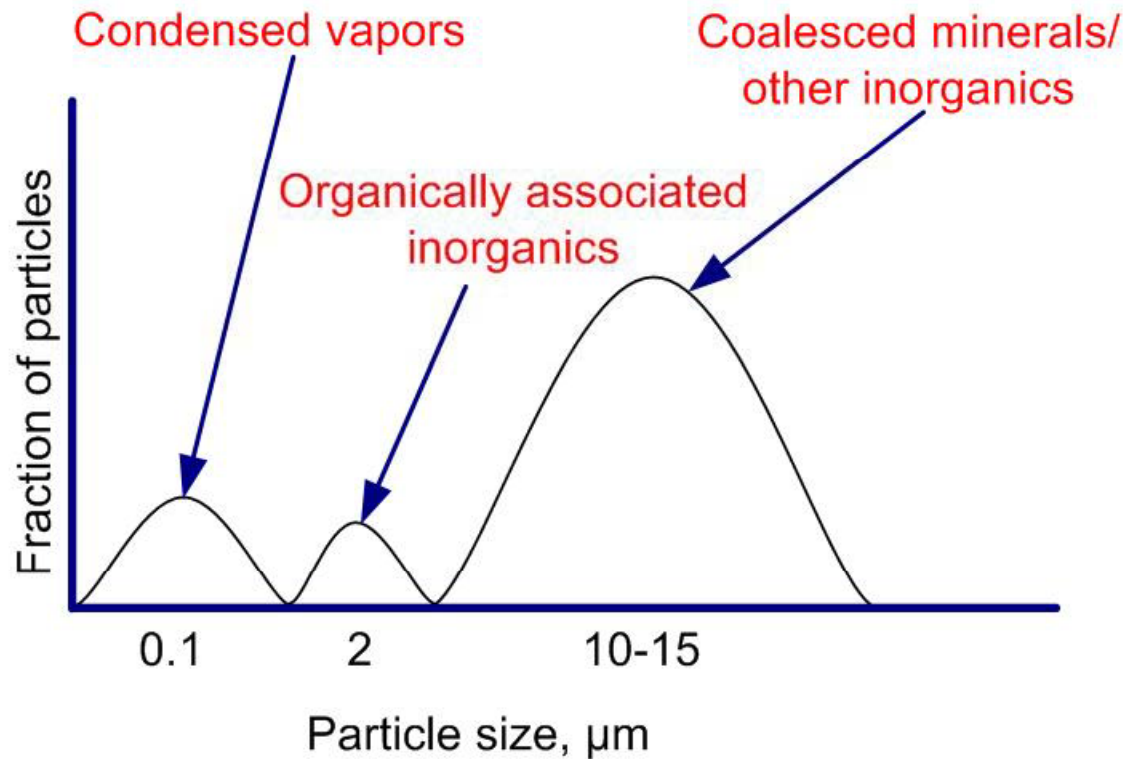
- Fuel type and composition
 - Type, abundance, form of ash-forming species
- Gasification temperature
- Recycle
- Gas composition
 - Halogens and sulfur



Mechanisms



Ash Formation: Partitioning



Submicron Particle Formation

□ Vaporization/Condensation

■ Submicron particle formation

- 0.2-2% of ash, possibly up to 4% of ash

□ Vaporization

■ Depends upon:

- Coal particle temperature
- Relative volatility of the inorganic components
- Depends upon association and environment

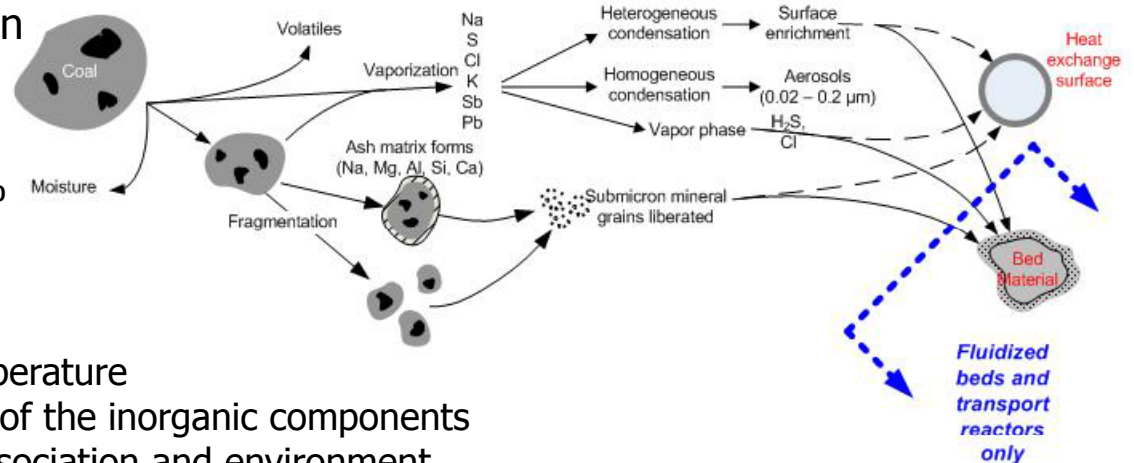
■ Volatile elements: Na, K, S, Hg, Pb, As, Zn, Sb...

□ Reducing conditions

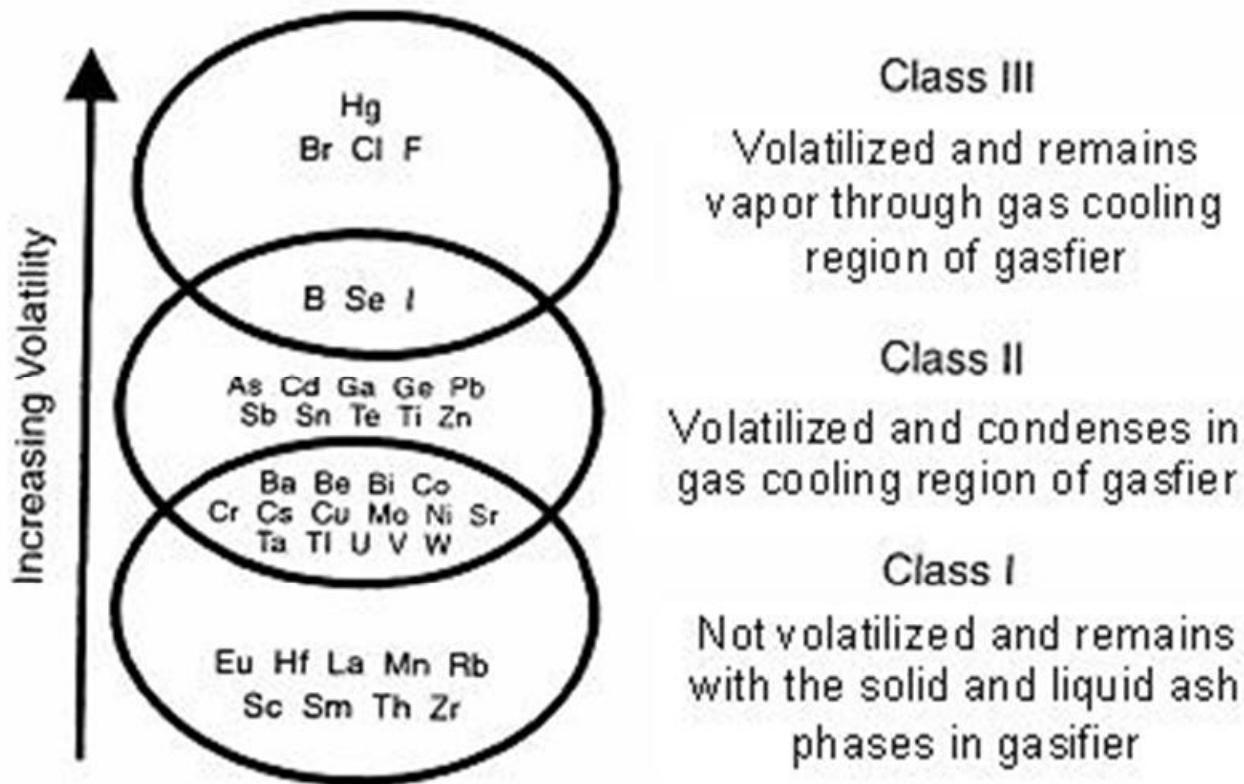
- More refractory elements may volatilize – Ca, Mg, Fe – converted to a more volatile reduced state in the reducing zones – will oxidize rapidly if oxygen is available

□ Other sources of submicron-sized ash particles

- Submicron mineral grains
- Fragmentation of minerals such as calcite, dolomite
- Organically associated elements

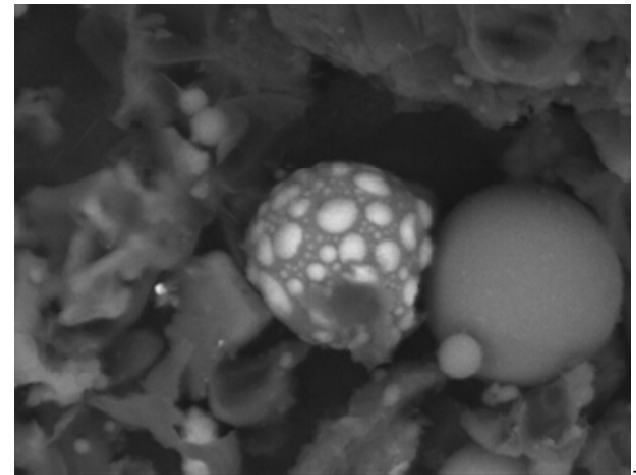
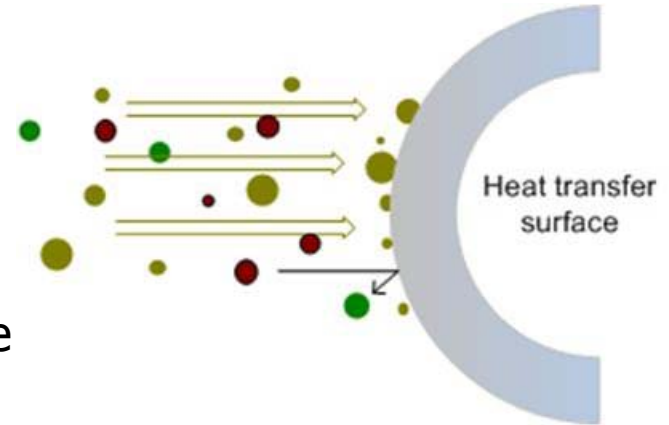


Trace Elements



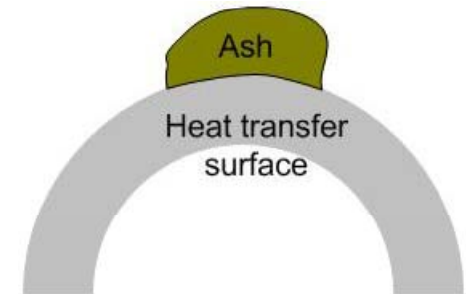
Deposit Growth: Transport and Adhesion

- Transport of ash species to the heat transfer surface
- Adhesion – causes the particles to remain on heat transfer surface
- Transport/Adhesion factors:
 - Chemical, physical properties of surface
 - Precursor forms of depositing species
 - Deposition/adhesion probability of ash particle or vapor depends upon:
 - Melting point
 - Vapor pressure
 - Chemical affinity to the surface
 - System conditions to be considered:
 - Gas temperatures
 - Gas composition
 - Residence time
 - Tube temperatures



Deposit Initiation and Bonding

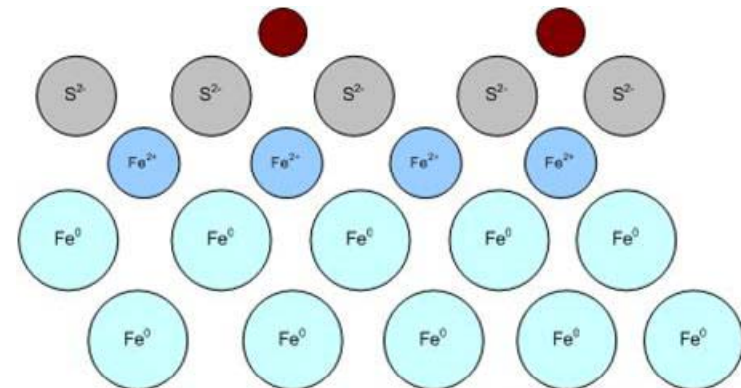
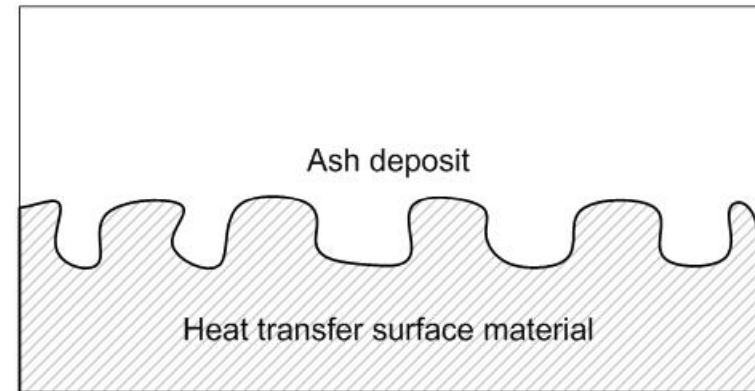
- Factors influencing adhesion of ash deposits to heat transfer surfaces include:
 - Temperature of steel or refractory surface
 - Thermal compatibility between deposited material and heat transfer or refractory surface
 - Thermal expansion
 - Chemical compatibility between the initiating particles and the heat transfer or refractory surface
 - Surface tension of the ash droplet



Bonding Mechanisms

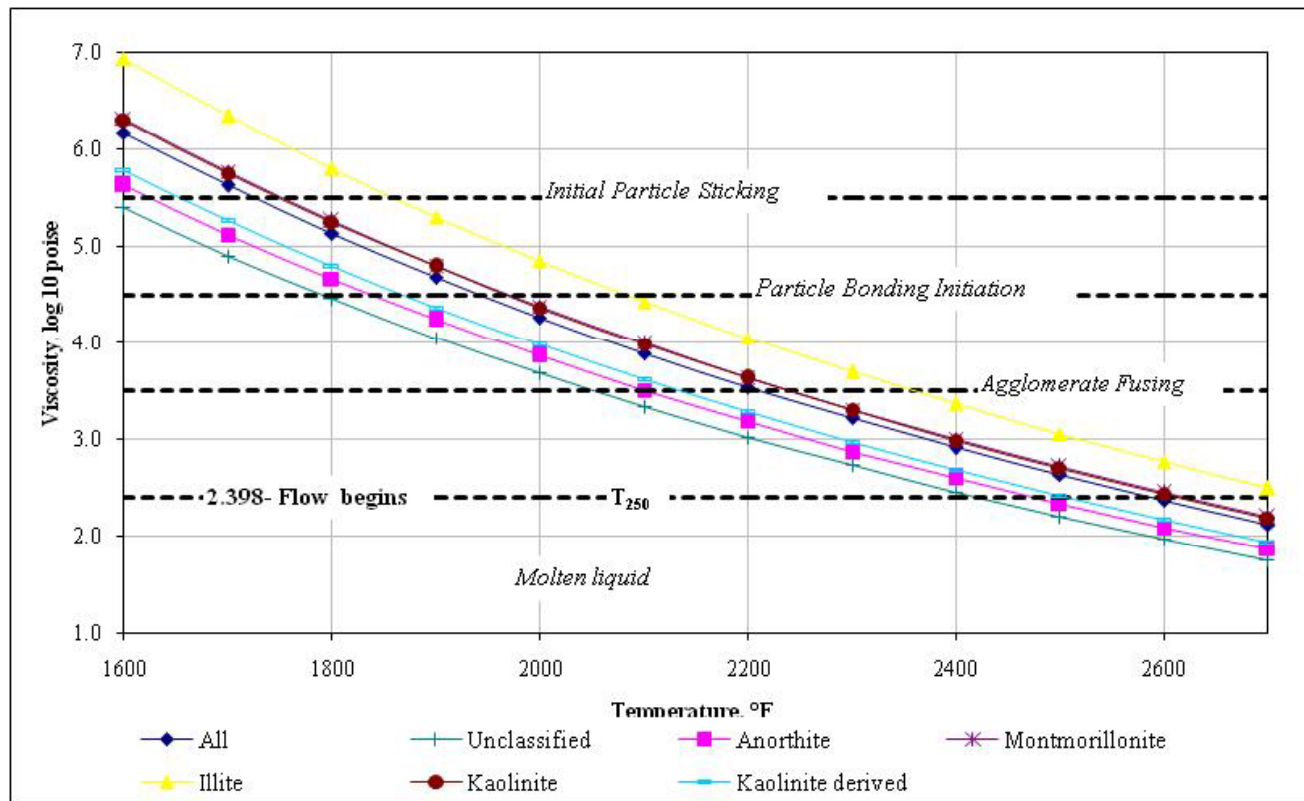
- Mechanical
 - Extended surface by oxidation and chemical reactions
 - Potential exists for allowing the ash melts into the surfaces

- Chemical
 - Ionic or covalent
 - Potentially very strong
 - Stronger than mechanical bonds



Bonding Phases in Deposits: Viscosity Prediction

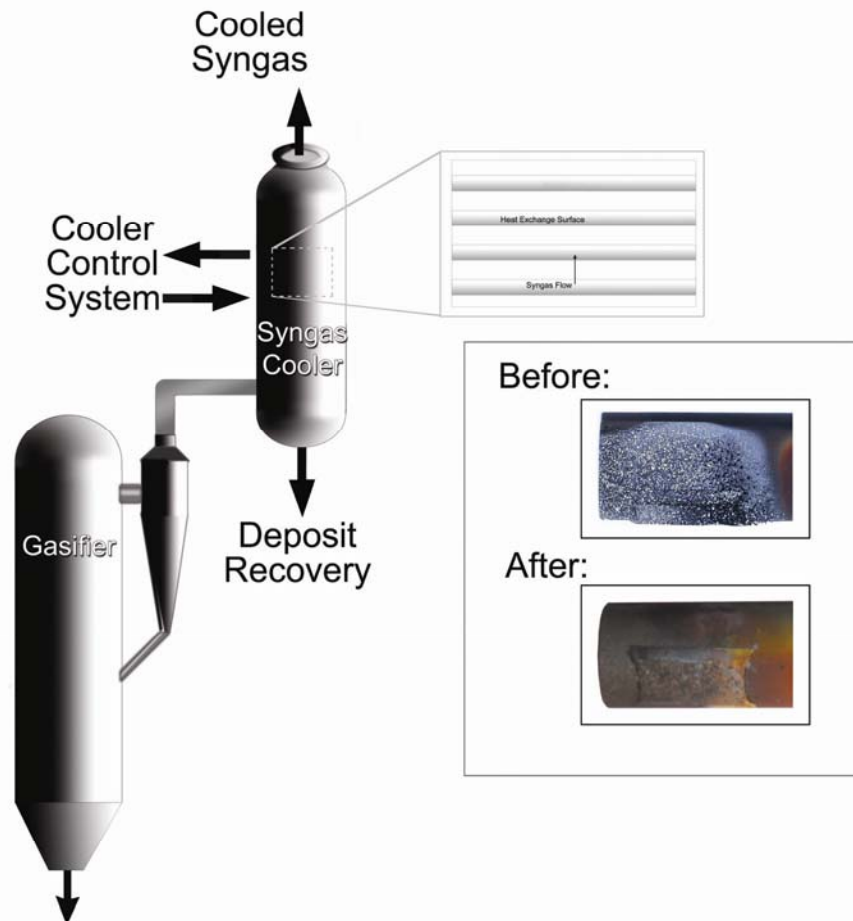
- Example: Phase viscosity based on SEMPC results





Technology for Controlling and Removing Deposits from Syngas Cooling Systems

Schematic of Technology

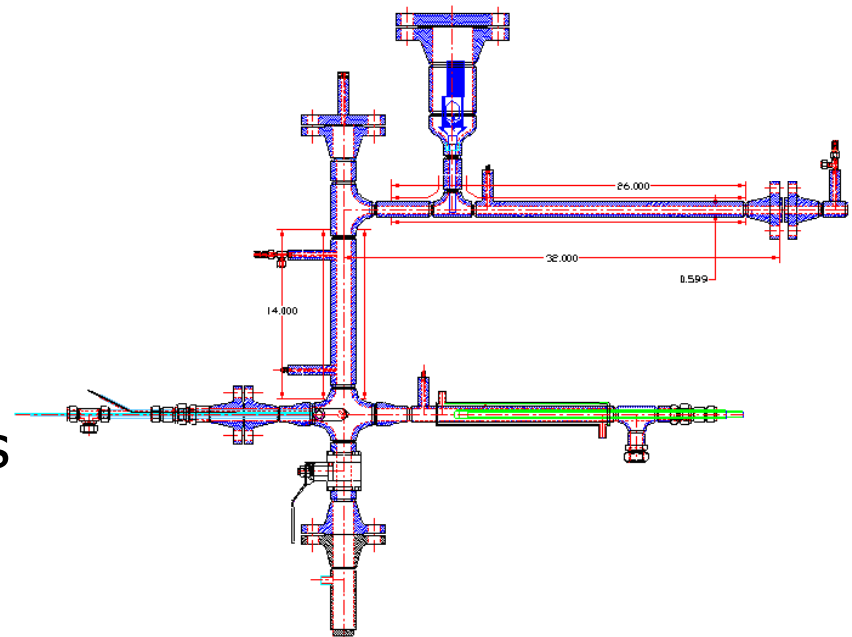


Technology Basis

- Fuel properties and fate of impurities upon gasification
- Metallurgy composition/properties
- Gas temperature
- Surface temperature
- Thermal properties

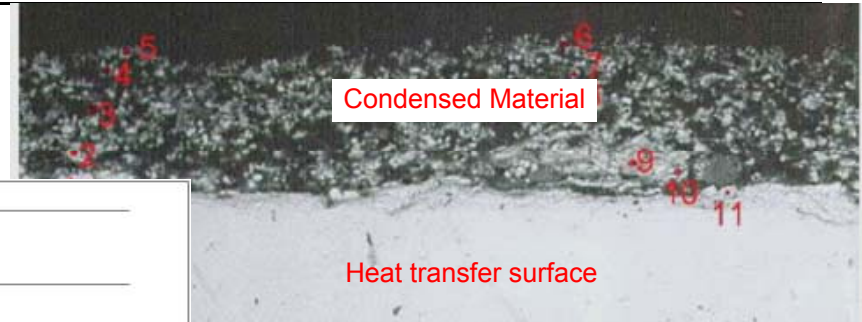
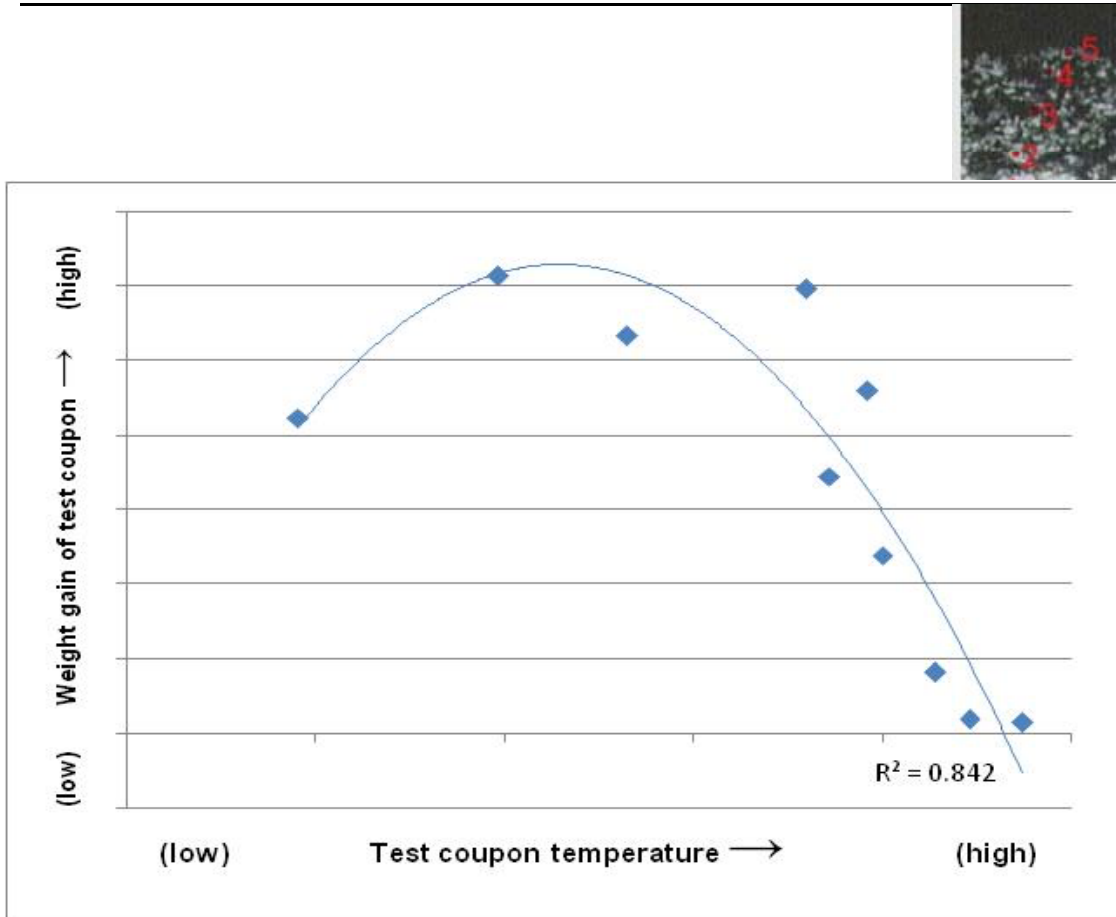
Technology Status

- Bench-scale system
 - Testing completed
- Pilot-scale testing
 - Completed
 - Simulated syngas
 - Multiple system pressures
- Slipstream testing with pilot-scale gasifier
 - Completed
 - Metals-doped fuel

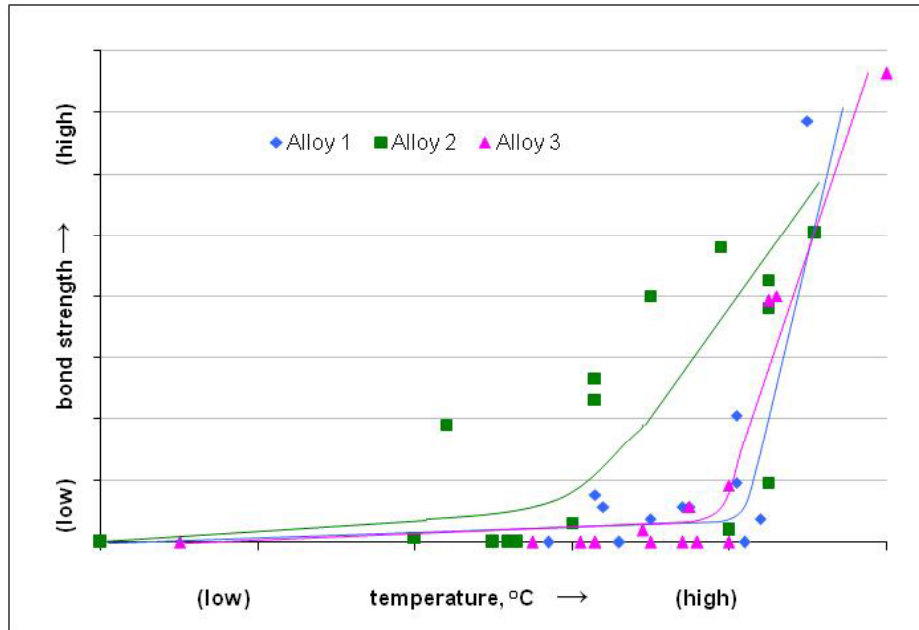


Pilot-scale test system

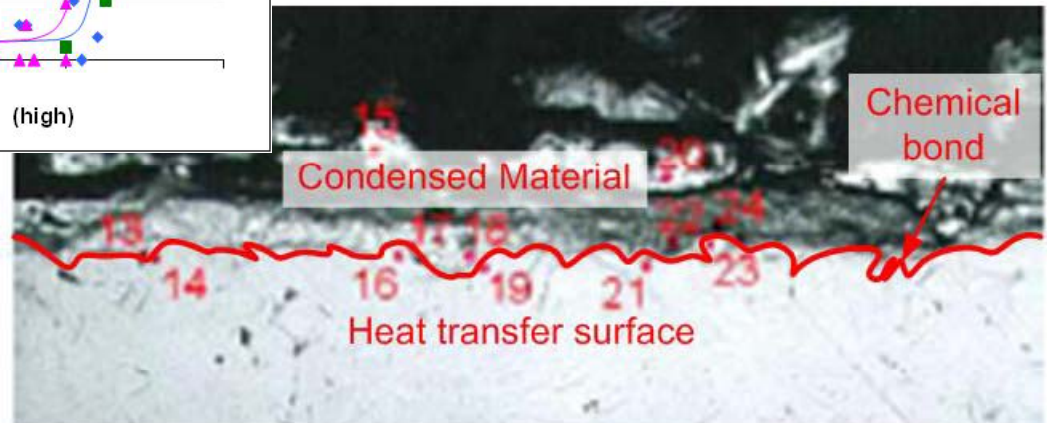
Bench-Scale Testing: Recovery of Materials



Bench-Scale Testing: Bond Strength

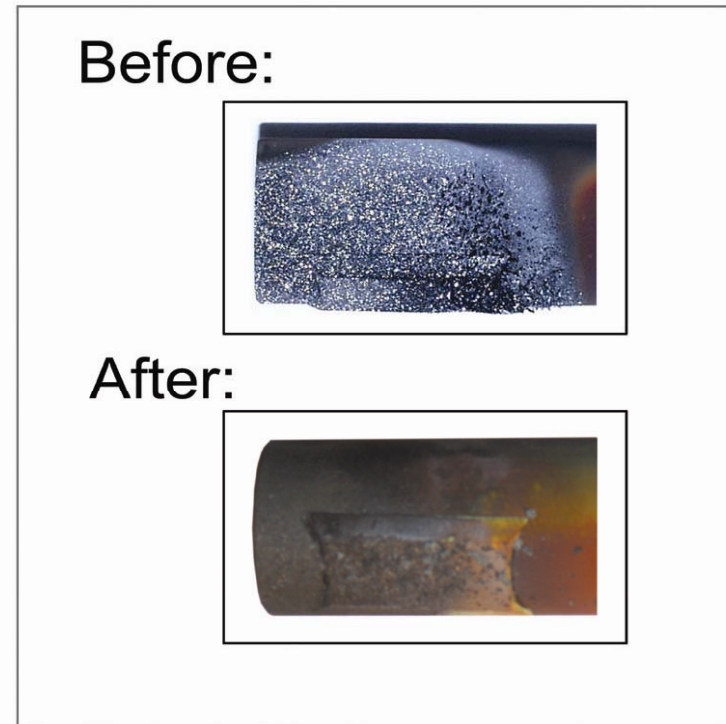


- Function of
 - Surface temperature
 - Alloy type



Cleaning Cycle Effectiveness

- Exposed to synthetic synthesis gas containing condensable impurities
- Cleaning showed removal of most of the materials



Milestones/Timeline

- Bench-scale testing completed
- Pilot-scale demonstration
 - Pilot-scale system design/construction completed in June 2005
 - Pilot-scale testing completed in June 2007
- Next steps...
 - Full-scale demonstration using advanced syngas cooler test equipment on slipstream at host site
 - Design, construct, and test larger scale system

Technical Risks

- Coal/fuel composition will have an influence on the effectiveness of technology
- Long-term corrosion impacts unknown

Acknowledgements

- National Science Foundation, Small Business Innovative Research program Phase I and Phase II
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Microbeam Technologies, Inc.

Please contact us with your questions or
comments

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