Thermal Thrust: Thermochemical Conversion of Woody Biomass to Fuels and Chemicals

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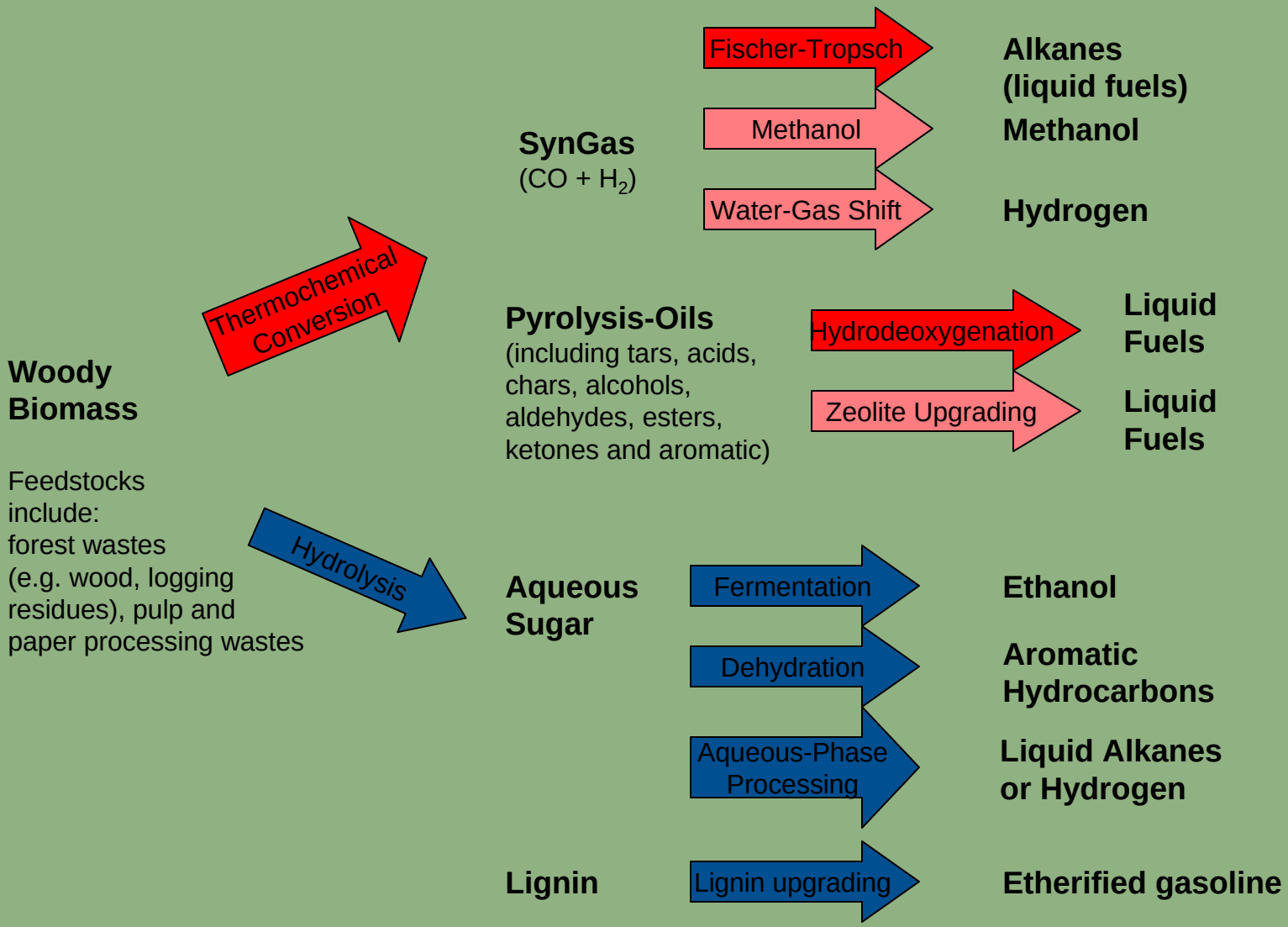
Opportunity

- *Maine relies heavily on its forest resource*
  - *Forest Bioproducts Research Initiative*
    - *Forest sustainability*
    - *Process development*
    - *Economic viability*
    - *Public Relations/political support*
- *Industry recognizes the need to diversify its product base derived from the forest*
- *Infrastructure for aqueous conversion of woody biomass to fuels and chemicals*
  - *Fermentation processes funded through NSF*
- *Thermochemical conversion routes*
  - *Develop processing schemes compatible with existing Maine industries and infrastructure*
  - *Focus of DoE EPSCoR*

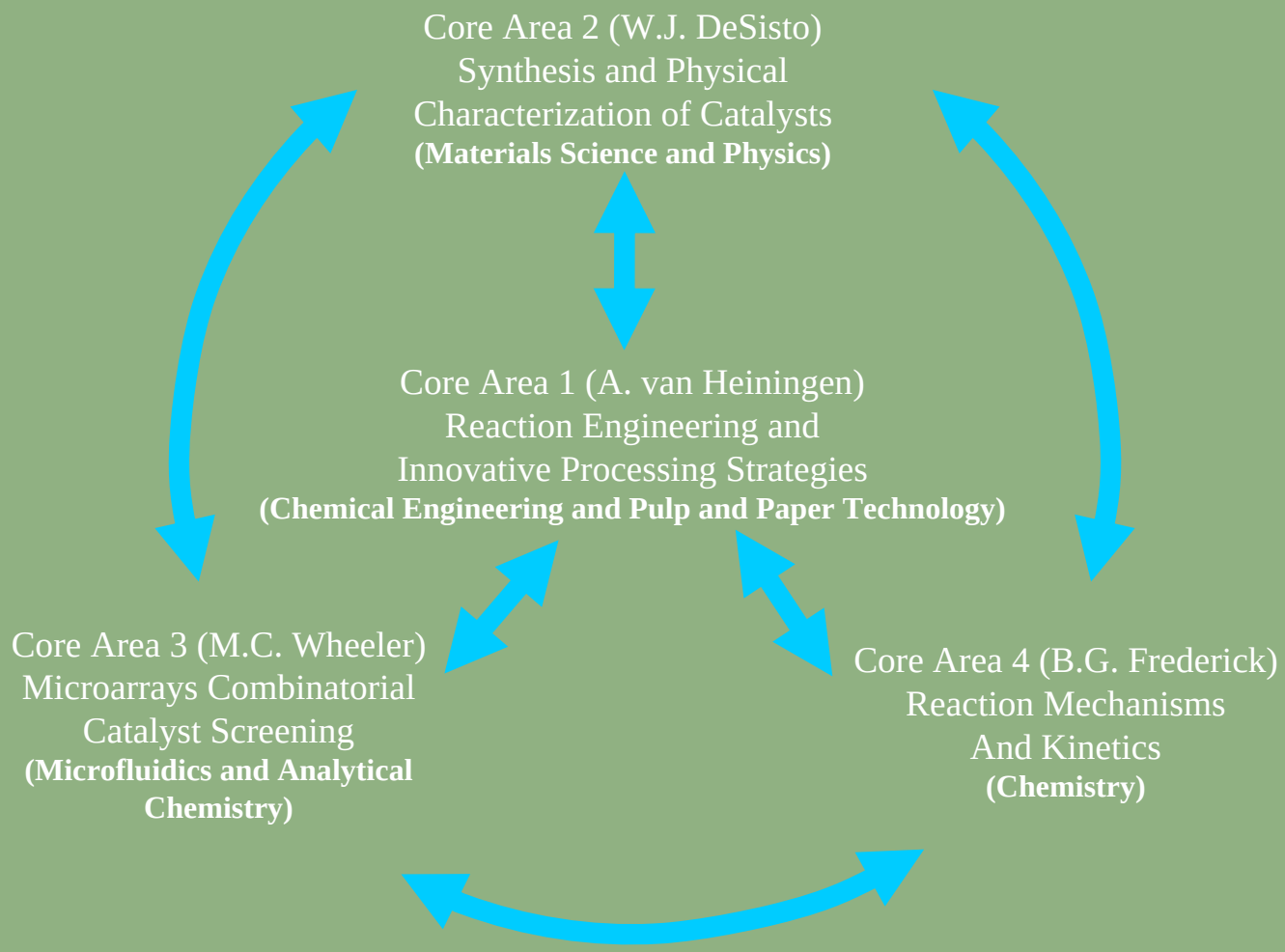
Strategies for Fuels and Chemicals from Woody Biomass



Project Overview

- Thermochemical processing routes are *catalysis-based*
- Three major Projects:
  - Develop a rapid screening approach to identify new catalysts relevant to Maine's forest bioproducts infrastructure
  - Fischer-Tropsch Liquids catalysts
  - Pyrolysis Oil upgrading catalysts

Core Research Areas



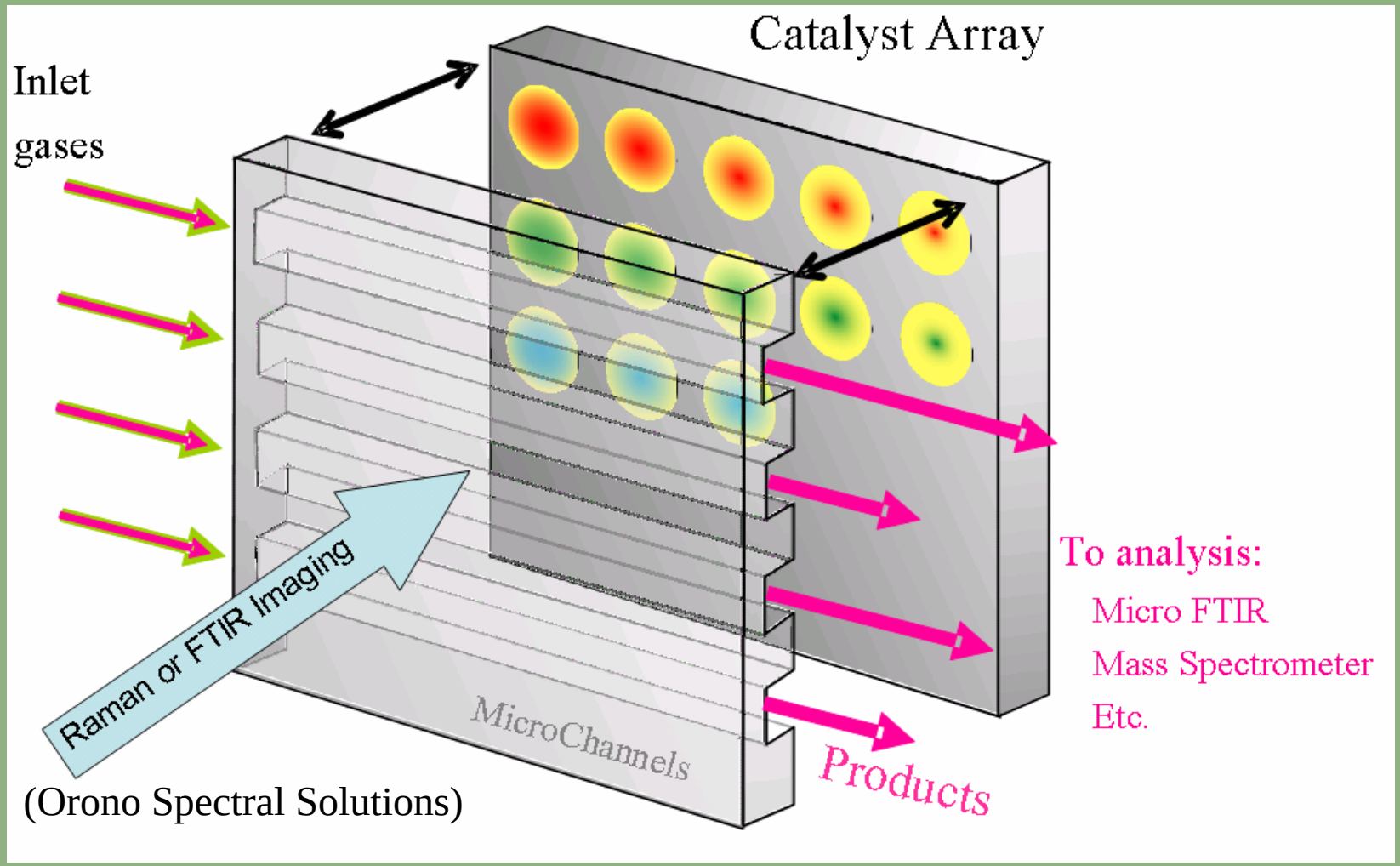
Research Thrust and Core Area Integration

	Project 1	Project 2	Project 3
Title	**Micro-Array Combinatorial Catalyst Screening**	**Fischer-Tropsch Liquids from Biomass-Derived Syngas**	**Pyrolysis Oil Upgrading and Characterization**
Core Area 1 Reaction Engineering	Define representative compounds, processing conditions, and thermodynamics as input for combinatorial studies. Define catalyst compositional matrices.	Compare effects of tar-like contaminants such as benzene on bulk catalyst activity.	Create pyrolysis oil from Maine biomass. Study kinetics and reaction products for model compounds (furfural and guaiacol). Characterize bulk hydro-deoxygenation catalysts using purchased and in-house produced pyrolysis oils.
Core Area 2 Catalyst Synthesis and Characterization	Synthesize compositional matrix for inkjet catalysts. Identify catalyst/support systems for bulk synthesis.	Synthesize and physically characterize bulk and inkjet deposited catalysts.	Synthesize and physically characterize bulk catalysts.
Core Area 3 Combinatorial Platform Integration and Methods	Develop microhotplate platform. Integrate inkjet deposition system. Couple microarray with FTIR and Raman. Analysis of combinatorial data.	Synthesize micro-support/catalysts on MACCS platform and evaluate arrays using model compounds	Synthesize micro-support/catalysts on combi platform and evaluate arrays using model compounds.
Core Area 4 Fundamental Reaction Mechanisms	Compare bulk to micro-support/catalyst performance and properties. Determine critical input parameters for catalytic screening evaluation.	Correlate bulk activity with model compounds to combinatorial results.	Correlate bulk activity with model compounds to combinatorial results. Characterize complex products and identify model compounds for pyrolysis oil upgrading.

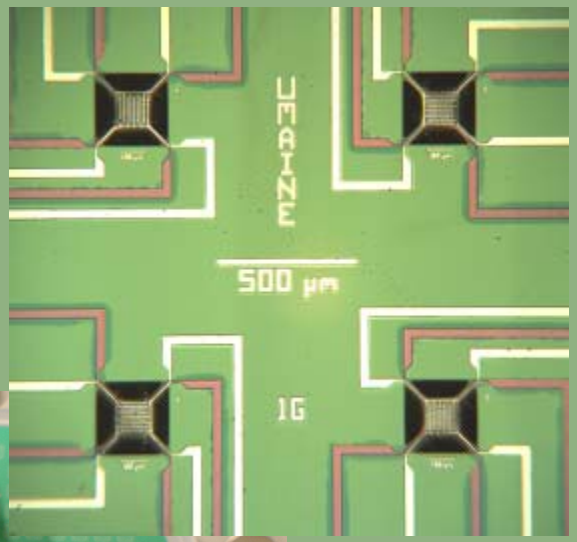
Catalysis Rapid Screening (Project 1)

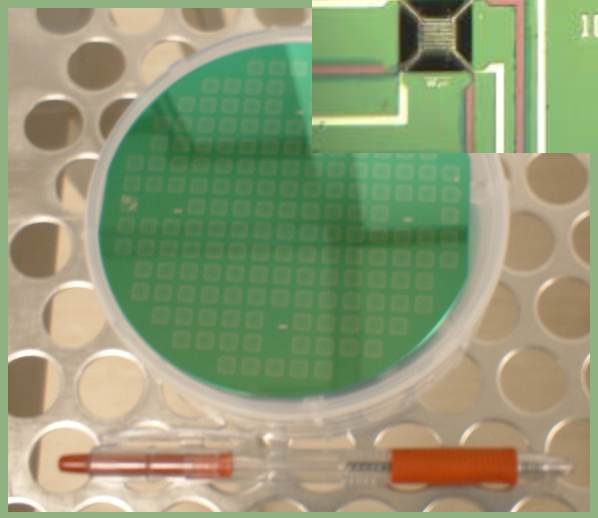
- Innovative micro-array combinatorial catalyst screening platform integrated with vibrational spectroscopies
  - Silicon-based processing of microhotplates as microreactors
  - Parallel microreactor evaluation
- Rapid ink-jet synthesis techniques for micro-support/catalyst library generation

Microarray Combinatorial Catalyst Screening with In-situ Spectroscopic Analysis



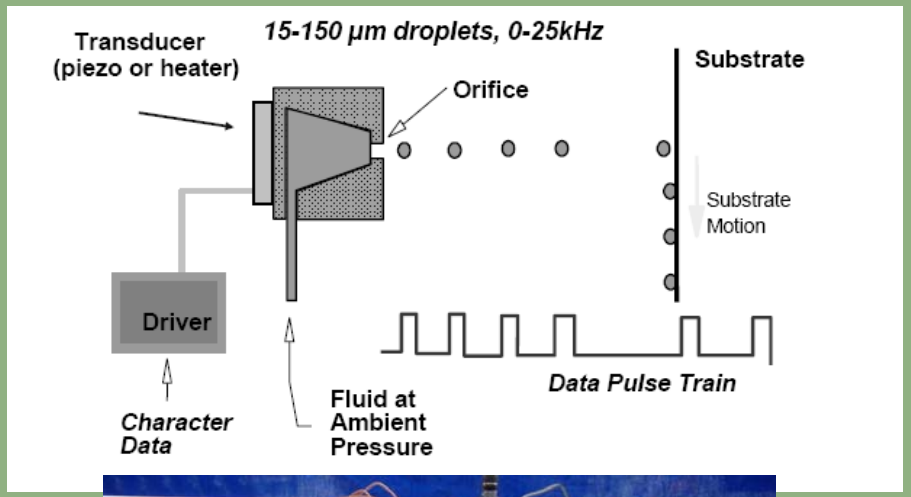
Combinatorial Catalyst Screening Platform

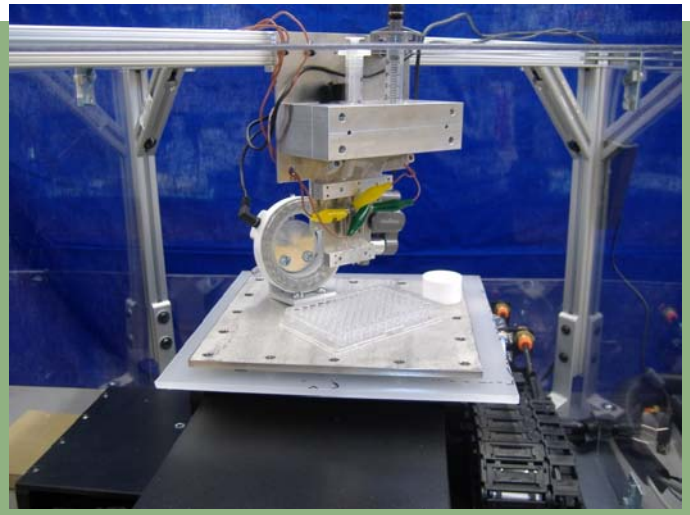




Individually addressable microreactors to be combined with in-situ infrared and Raman microscopy

Inkjet printing of sol-gel supports and metal salts





Zeomatrix ZeoJet Platform

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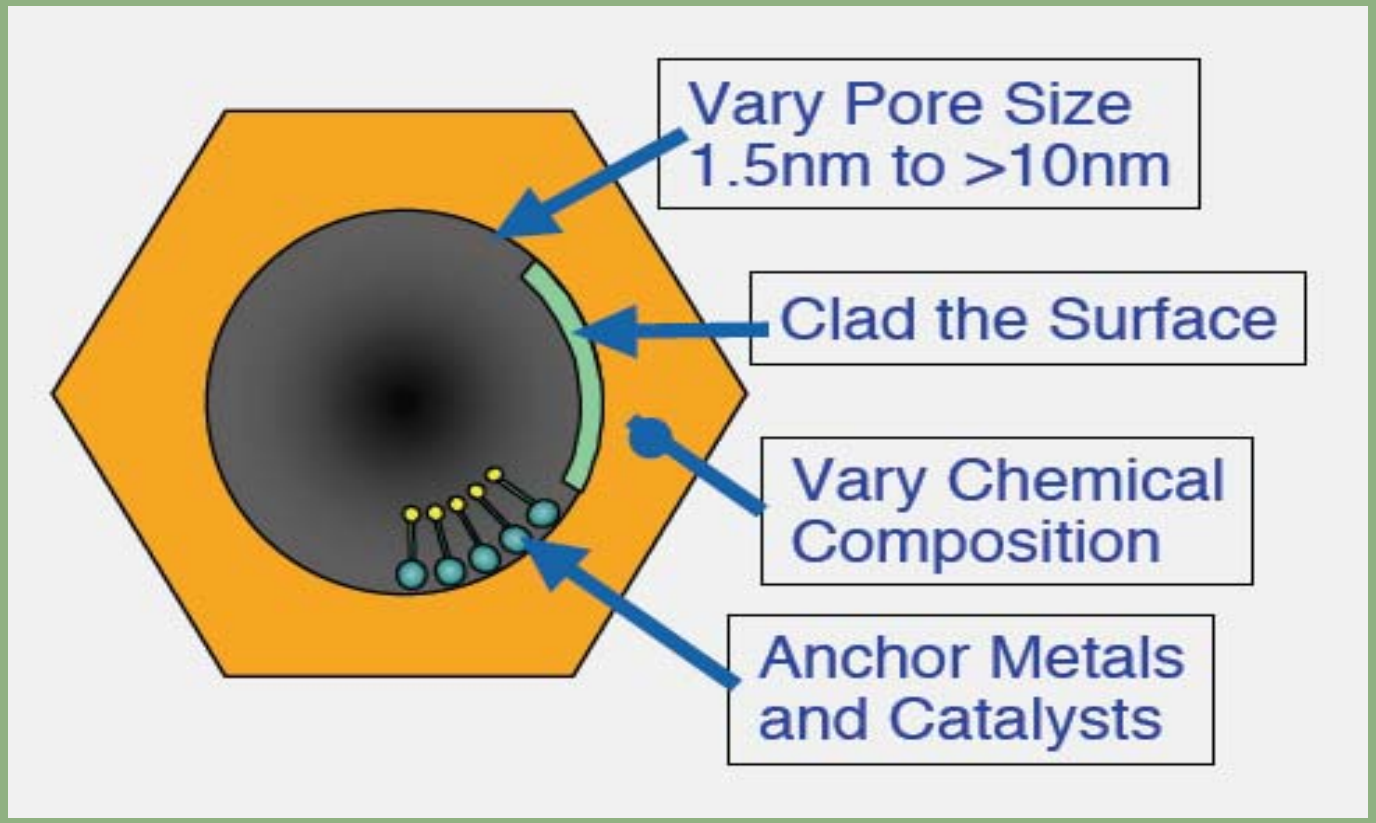
Fischer-Tropsch Liquids (Project 2)

- Synthesis and physical characterization of novel size-selective catalyst/supports using engineered mesoporous (1-10 nm diameter pores) materials
  - Qualification of our rapid screening methodology
  - Novel rapid synthesis methods
  - Atomic level microstructural characterization
  - Tar tolerant catalysts needed for woody biomass-derived syngas
  - Combined reaction/separation
- Fundamental interactions between model compounds and the catalyst/support surface
  - Binding strength
  - Size exclusion

Catalyst Preparation and Physical Characterization

Pore size controlled metal oxide nanostructures

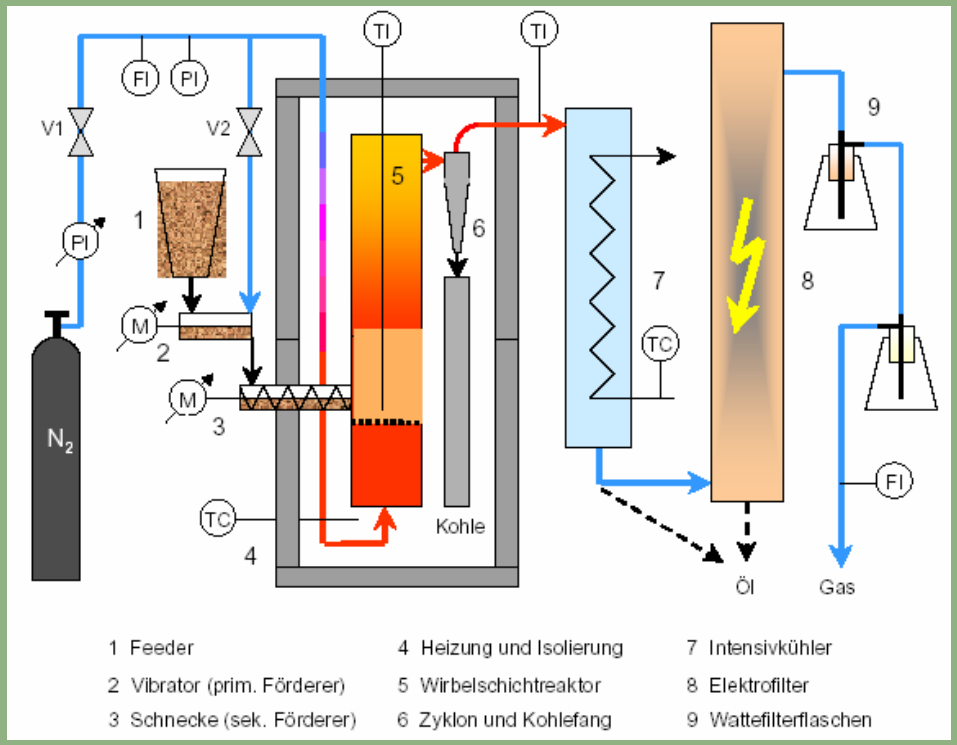


- higher activity/selectivity
- poison tolerant/longer life
- improved regenerability
- combined reaction/separation

Pyrolysis Oil Upgrading (Project 3)

- Pyrolysis oil generation and characterization from Maine biomass
- Synthesis and characterization of novel support/catalysts for hydro-deoxygenation of pyrolysis oil
  - Kinetics and reaction products with model compounds (furfural and guaiacol)
  - Rapid screening of ink-jet printed catalyst libraries
    - Catalyst activity and resistance to poisoning
  - Upgrading and analysis of complex pyrolysis oil mixtures
    - Process development (catalyst lifetime)
    - Physical (viscosity), elemental (C/N/O/H) analysis
    - Spectroscopic analysis (NMR, IR, MS)
  - Reaction mechanism studies

Maine Pyrolysis Oil Characterization and Pilot Reactor Studies



University of Hamburg Lab-scale Fast Pyrolysis Reactor

Reaction Mechanism Studies

- Product characterization
- In-situ FTIR
- AMI-200 catalyst characterization unit
  - Catalyst surface area with flow BET
  - Reduction/oxidation pretreatment
  - Temperature programmed reaction
  - Catalyst aging

Altamira Instruments AMI-200

Participants

- UMaine
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  - B. G. Frederick Co-I
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  - R. J. Lad
  - S. D. Collins
- Colby - T. W. Shattuck
- Bates – R. N. Austin
- Bowdoin – E. A. Stemmler
- Maine Small Businesses
  - Zeomatrix
  - Orono Spectral Solutions
- Oak Ridge National Laboratory
  - Nanomaterials and materials characterization
- NSF:Research Experience for Undergraduates
- Orono High School Juniors

Core Research Areas	Contributing Disciplines	1	2	3	4	5	6	7	8	9	10	11	12
		UMAINE						Businesses		3 ME Colleges			LAB
		AvH	MCW	WJD	BGF	SDC	RJL	ZEO	OSS	TWS	RNA	EAS	ORNL
Reaction Engineering & Process Integration	Chemical Engineering, Chemistry & Pulp & Paper Technology	Leader	Co-Leader	X	X					X		X	
Synthesis & Physical Charactrization of Novel Catalysts	Material Science, Chemistry, & Physics			Leader			X	X	X	Co-Leader	X		X
Combinatorial Catalyst Screening using Microarrays & in-situ spectroscopy	Microfludics, Spectroscopy & Analytical Chemistry		Leader		X	Co-Leader		X	X				
Fundamental Reaction Mechanisms and Kinetics Model Ststems	Chemistry, Surface Science, & Chemical Engineering	X	X	X	Leader					X	Co-Leader	X	

Leader
Co-Leader
Team Member X

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- Del Raymond — Weyerhaeuser (retired)

Additional FBRI Members

- Paul Davis — Plum Creek
- David Thompson — Idaho National Laboratory
- Rob Bryan — Maine Audubon
- Tom Doak — Small Woodlot Owners Association of Maine (SWOAM)
- Sean Mahoney — Conservation Law Foundation
- Ken Kehrer — Armstrong World Industries
- Steve Schley — Seven Islands Land Company
- Alfred Carlson — Tate & Lyle
- Jay Vreeland — SAPPI (retired)