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POKE Symposium 2014

Catalytic Oxidation of Dimethyl Disulphide by Monometallic Catalysts

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Dissertation topic:

"Novel Catalyst Materials in Volatile Organic Compound Abatement: Development of Industrial VOC Abatement for Harmful Compounds"

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*** Developing the Application of Catalytic Oxidation

*catalyst preparation *characterization
*reaction *reactor set-up *activity testing *stability

*** Further objectives

*** Hydrothermal Carbonization

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Introduction

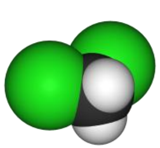
VOCs cause direct and indirect air pollution

- Direct (e.g. toxicity, odour) – indirect (e.g. smog formation)

e.g. sulphur is present virtually in all hydrocarbon feedstock.

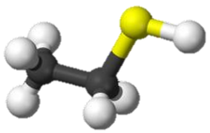
VOCs originate from natural sources as well as from pharmaceutical, solvent, coating, and wood industry (pulping), chemical production, landfill sites, and wastewater treatment plants

wikipedia.org

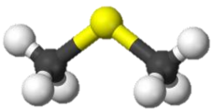


dichloromethane
DCM

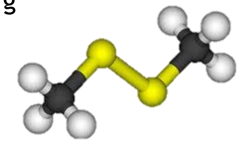
perchloroethylene
PCE



methyl mercaptan
MM



dimethylsulfide
DMS



dimethyldisulfide
DMDS

- CVOCs can be extremely toxic for the environment and human health
- SVOCs not extremely toxic but repulsively malodorous at very low concentrations

→Both require highly efficient treatment methods

Regulations under EU legislation

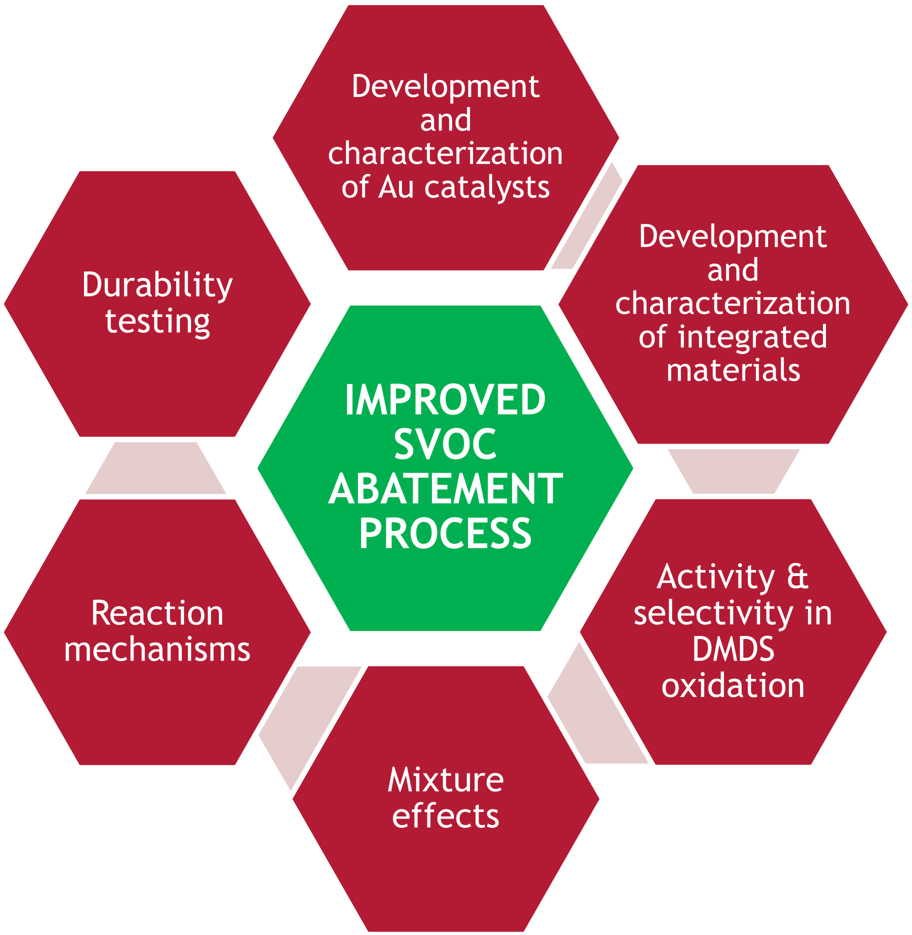
Catalytic oxidation is a tempting possibility for the abatement due to its high energy and purification efficiencies

→Poisoning and further deactivation is problematic

→ Durability, activity, and stability need to be improved

TASKS

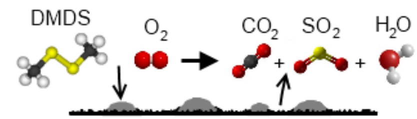
"Novel Catalyst Materials in Volatile Organic Compound Abatement"

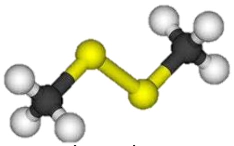


DEVELOPMENT OF CATALYTIC TREATMENT METHOD

"Novel Catalyst Materials in Volatile Organic Compound Abatement"

- Oxidation of DMDS over mono and bimetallic materials
  activity, deactivation, optimization
- Preparation, characterization, and testing of catalysts
  BET, H_2-TPR, H_2-chemisorption, TPIE, IIE, ICP-OES, XRD,TEM, TG-DTA, acidity, activity and stability
- Target properties – **active**, **durable**, **selective**



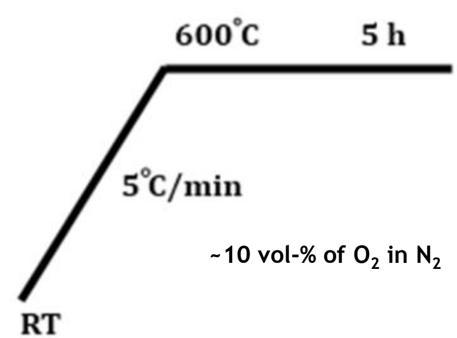


wikipedia.org

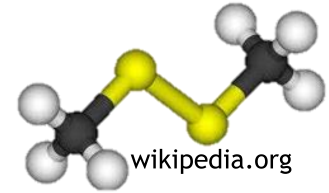
ENERGY EFFICIENCY | MAINTENANCE COSTS | DESIRED PRODUCTS

Catalyst	Preparation method
1/A	Deposition-precipitation
2/A	Wet impregnation
3/A	Wet impregnation
1/B	Deposition-precipitation
2/B	Wet impregnation
3/B	Wet impregnation
1/C	Deposition-precipitation
2/C	Wet impregnation
3/C	Wet impregnation
1-2/A	Redox reaction
1-3/A	Redox reaction
1-2/B	Redox reaction
1-3/B	Redox reaction
1-2/C	Redox reaction
1-3/C	Redox reaction

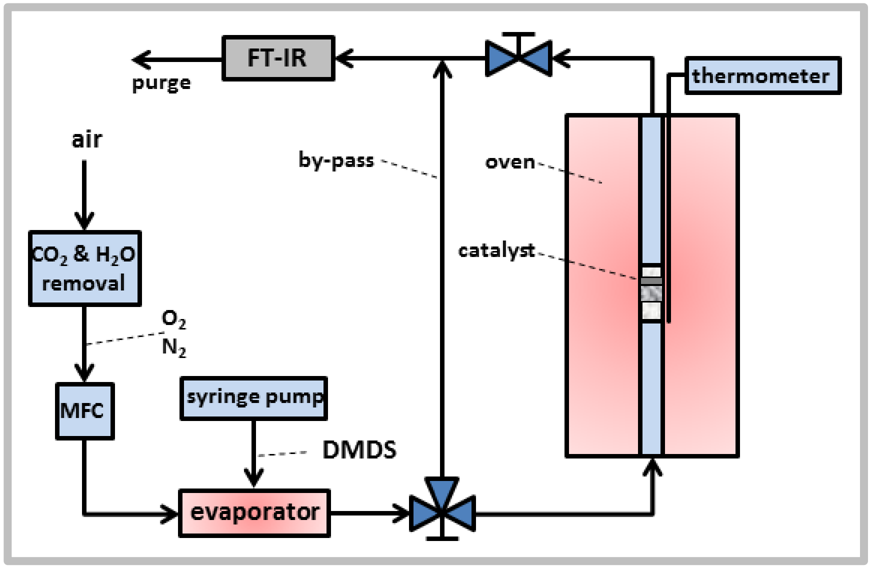
Calcination profile

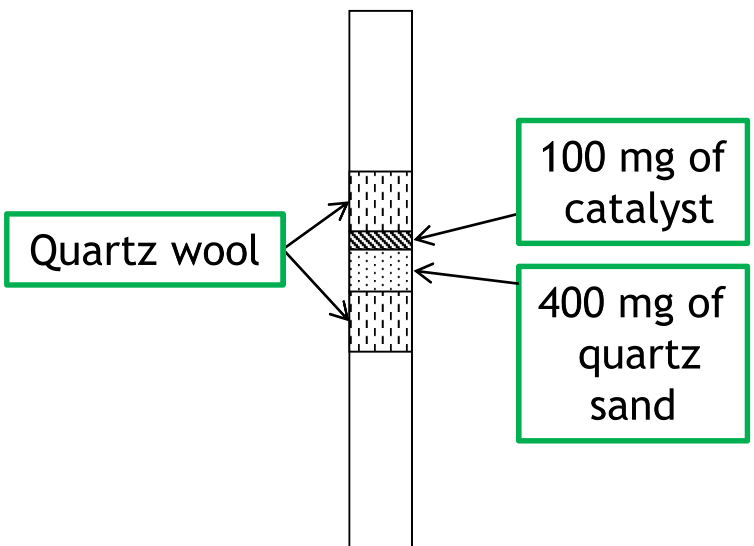


LIGHT-OFF TEST

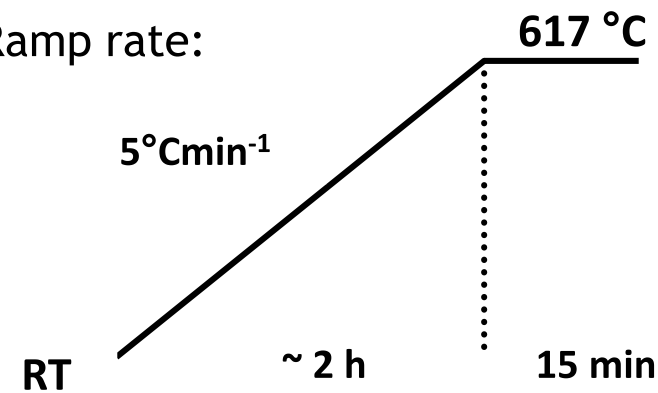


Schematic of the experimental setup



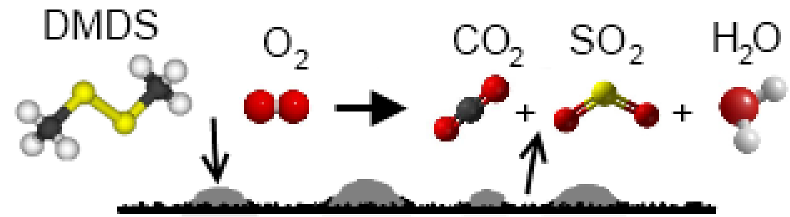


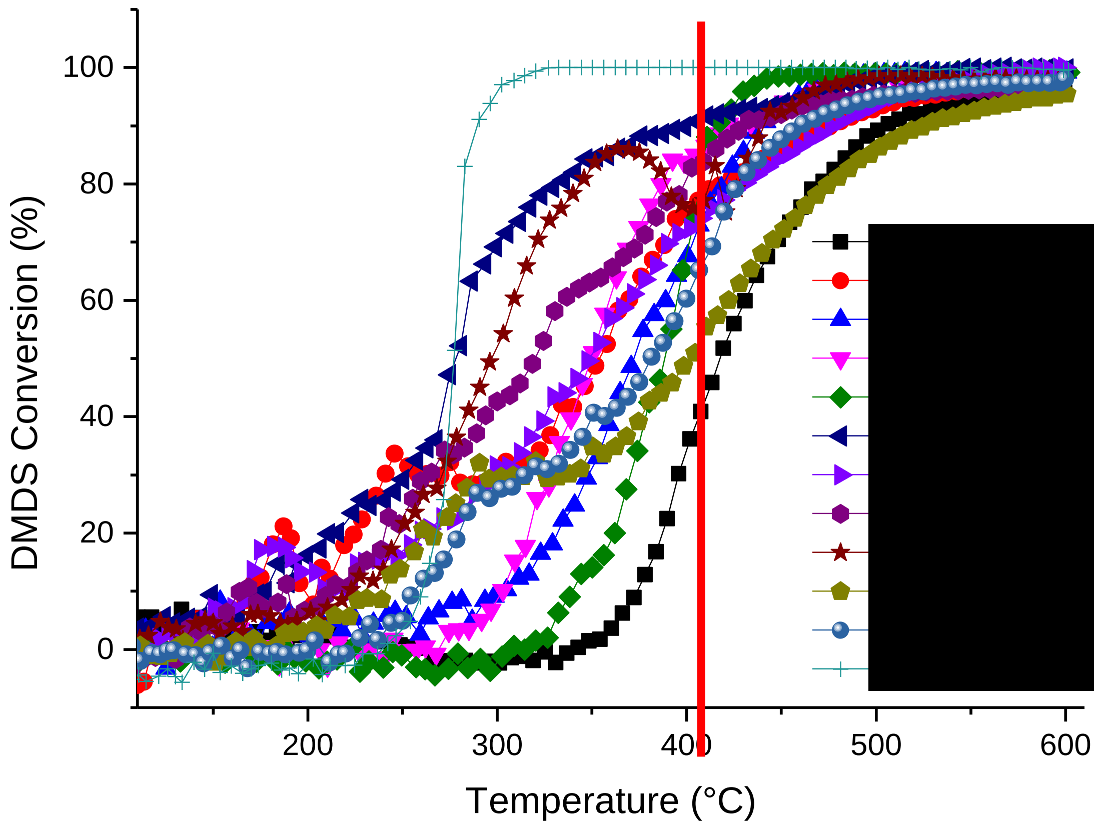
- ~ 500 ppm of DMDS
- Air flow rate: 1000 mlmin^{-1}
- CO_2 and water removed from incoming gas by an adsorber unit
- Ramp rate:

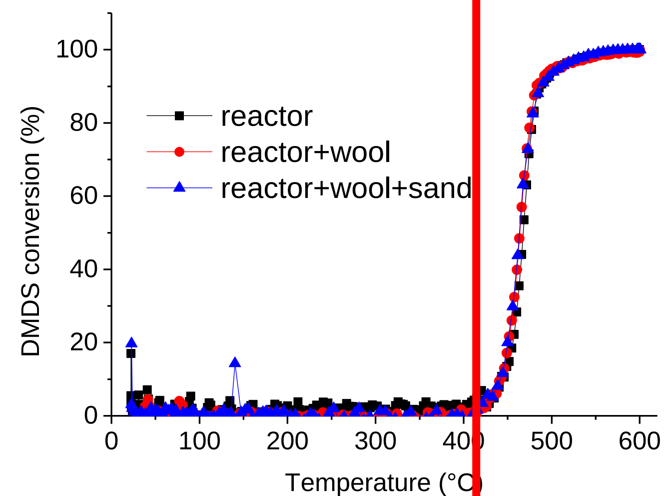


- Continuous measurement of product concentrations by FTIR gas analyzer

ACTIVITY
light-off tests



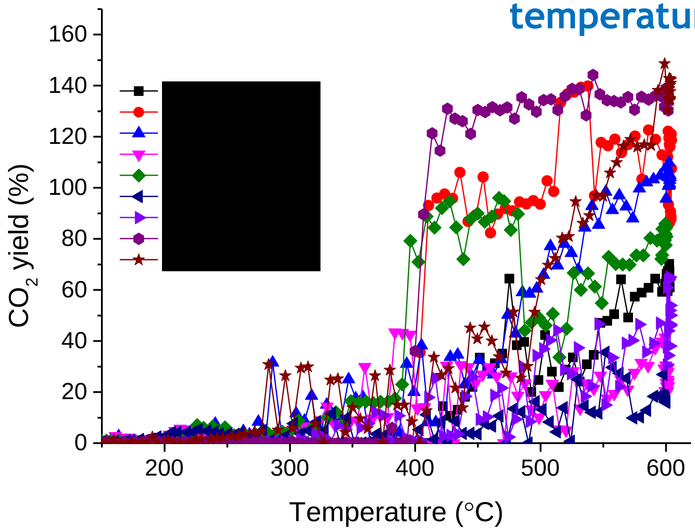




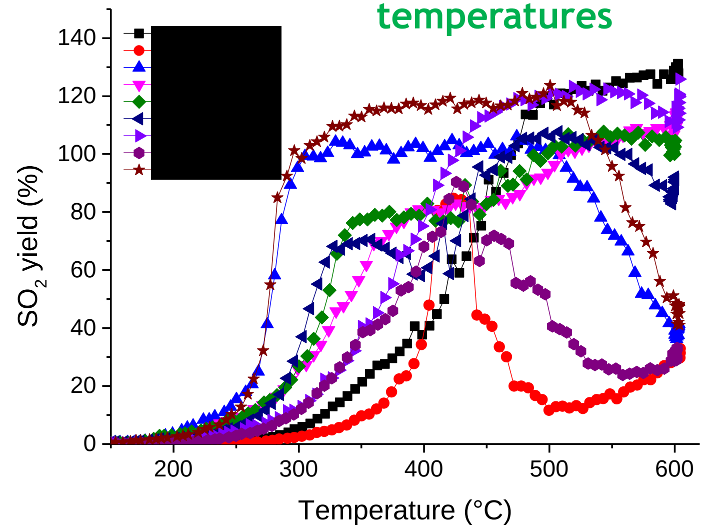
YIELDS

CO_2, SO_2 & CH_2O yields

Pt catalysts CO_2-selective at higher temperatures



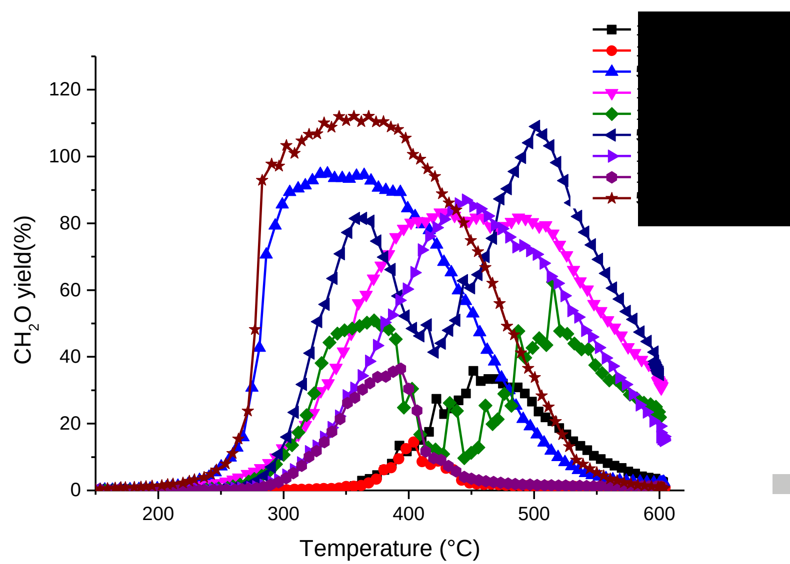
Au catalysts SO_2 selective at higher temperatures

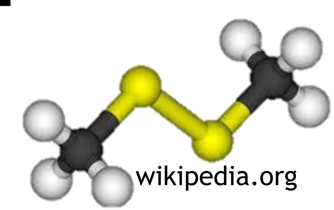


Cu catalysts very CH_2O selective at temperatures of ~300-400 °C

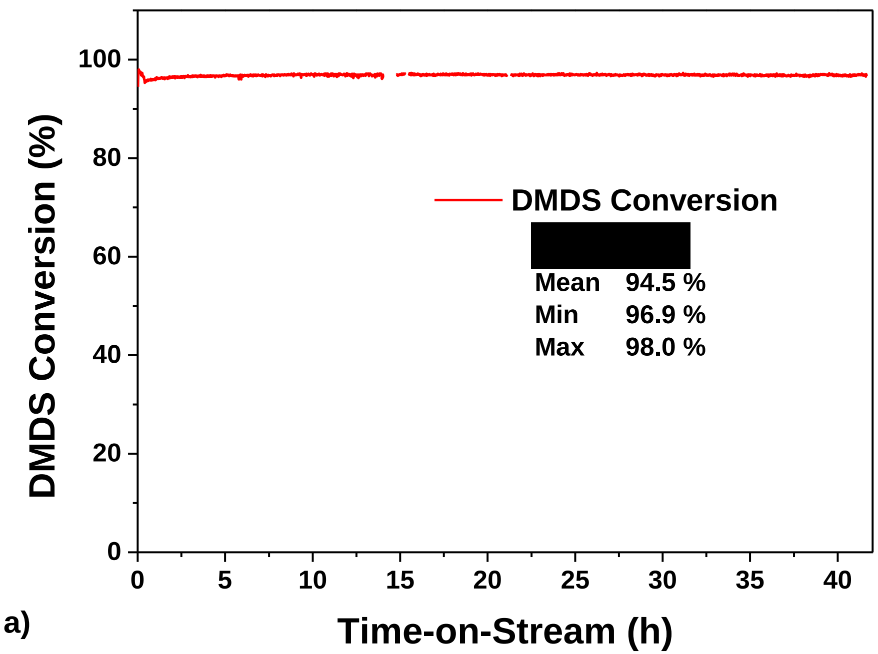
Au less CH_2O selective

Pt CH_2O selective barely at all

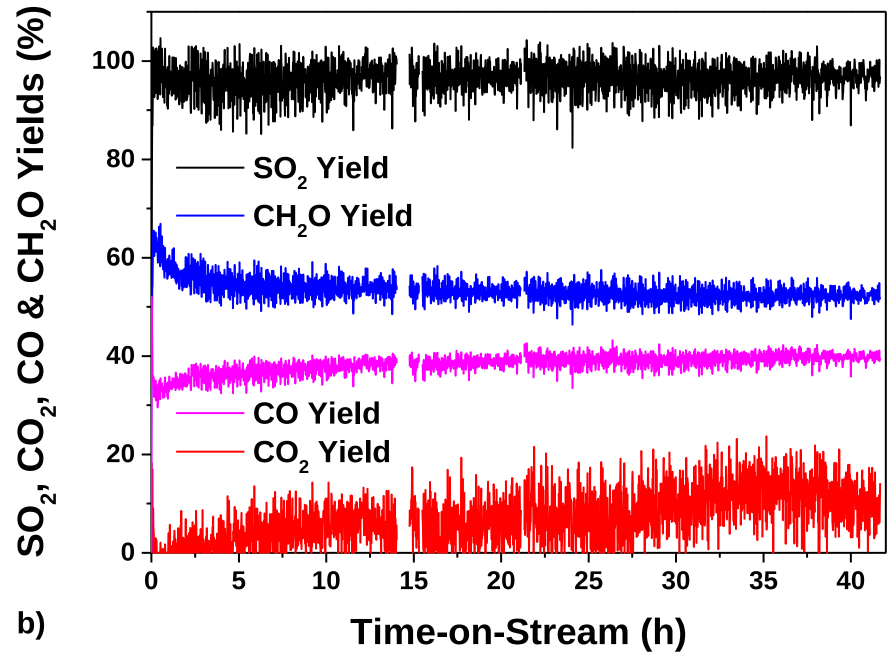




STABILITY OF Au CONTAINING CATALYST



a)

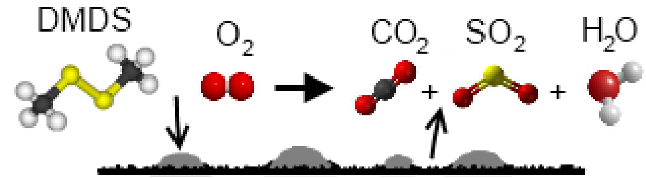


→ **stable** catalyst
selectivity must be improved

→→ to combine properties of two tested catalyst (activity, selectivity) and (durability) as a bimetallic catalyst

OBJECTIVES

- 2 publications
  - Mono/bimetals
- TPDx (reaction mechanisms)
- Activity tests for bimetallic catalysts
- Characterizations:
  - TEM, acidity



Research visit to Federal Institute of Goias, Brazil
Work plan

- Preparation of carbon-like material via hydrothermal carbonization

- Utilisation as an adsorbent, support, or catalyst material in the treatment of industrial air emissions

- Physical and chemical properties are investigated:
    - optical microscopy, dry mass, absorbent capacity, ion exchange properties, SEM, BET, BJH, XRD,ICP-OES

- Testing in the treatment of industrial air emissions in lab scale

Hydrothermal carbonization

“Hydrothermal carbonization (HTC) exhibit attractive advantages allowing the production of a variety of inexpensive and sustainable carbonaceous products with beneficial porosity at nanoscale and functionalization structures for a diverse range of applications.”

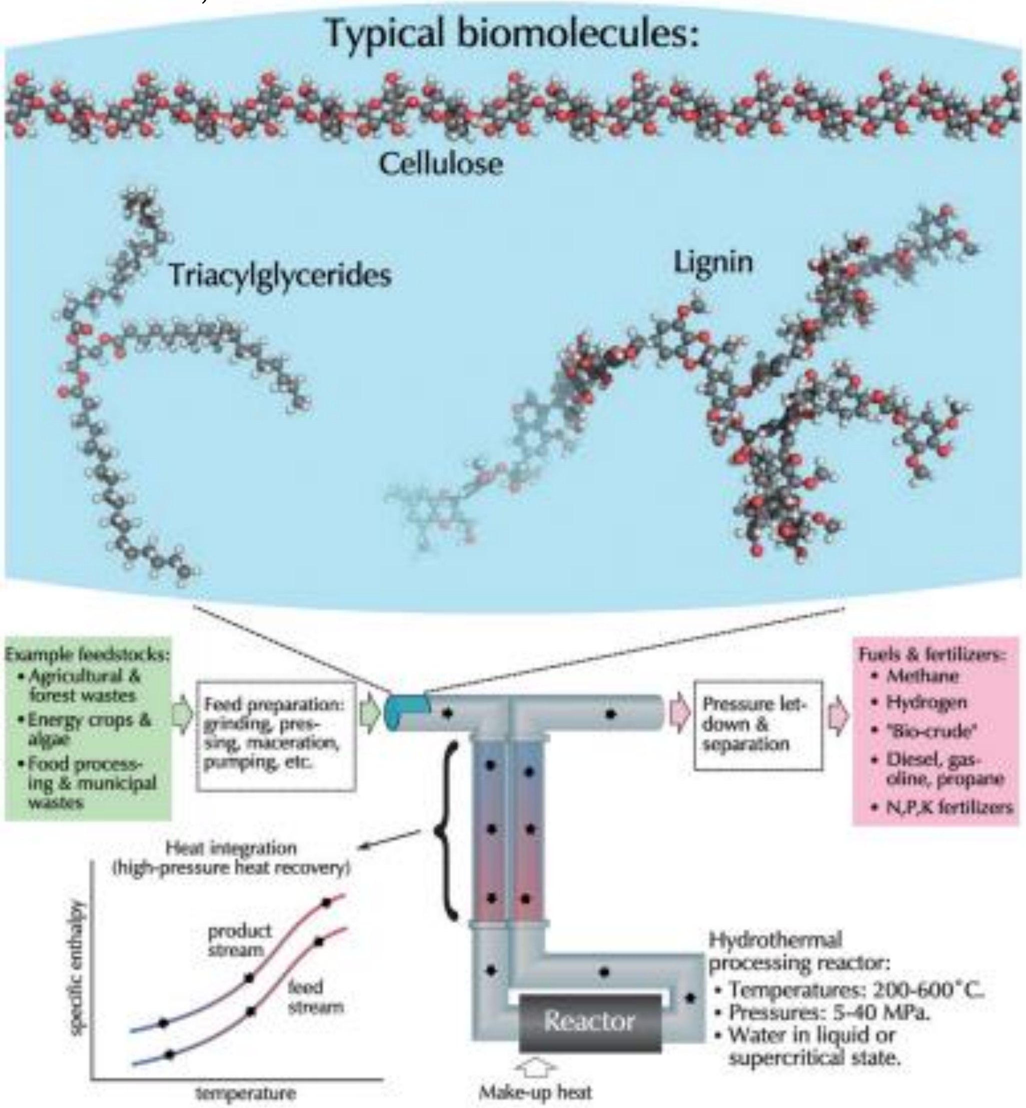
•Considering the concepts of sustainability in terms of environmental, economic, and social impacts, HTC potentially a model case

Follows “chimie douce”:

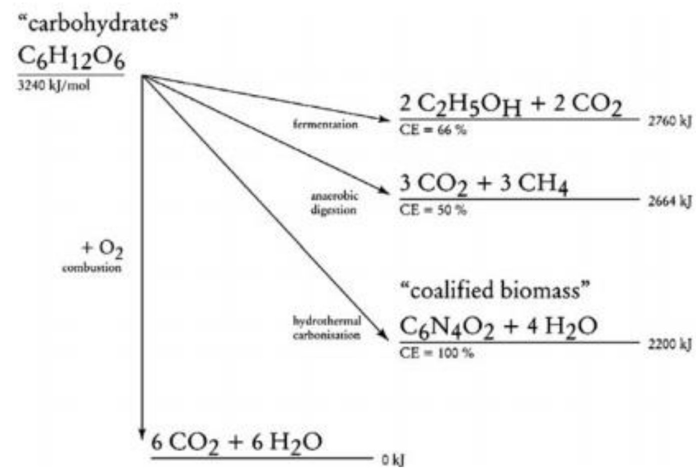
1. reaction preferably occur in a solvent medium, favorably water or water-alcohol mixture
2. less extreme conditions compared to other applications in terms of temperature, or used additives
3. chemical condensation and single step generation of various shapes

Hydrothermal carbonization

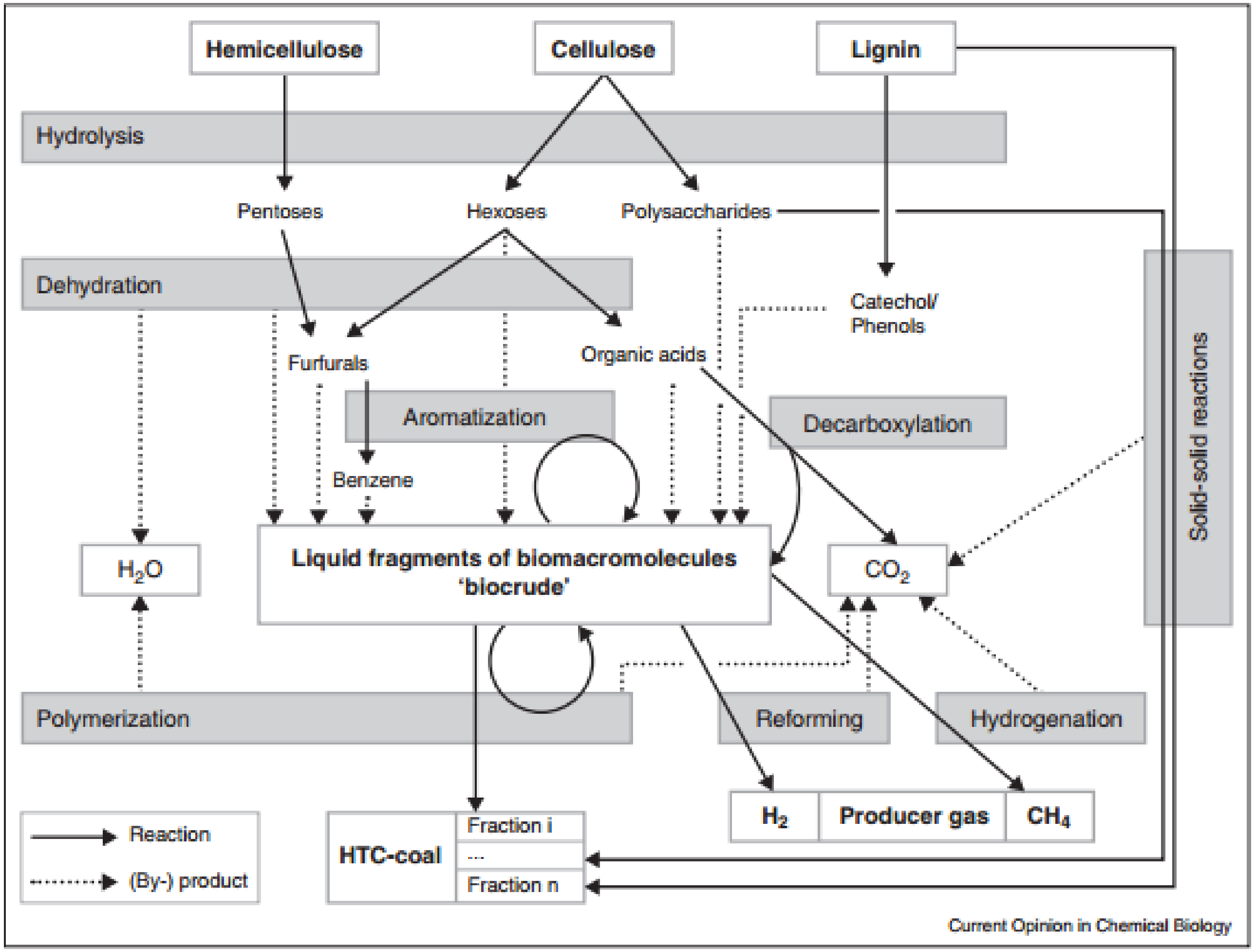
Peterson et al. (2008) Energy Environ. Sci. 1, 32-65.



Titirici, Thomas & Antonietti (2007) New J. Chem. 31, 787-789.



Htc reaction pathways



Principle reaction pathways of hydrothermal carbonization.
Adapted from A Funke, PhD thesis, Technische Universität Berlin, 2012.

Example products

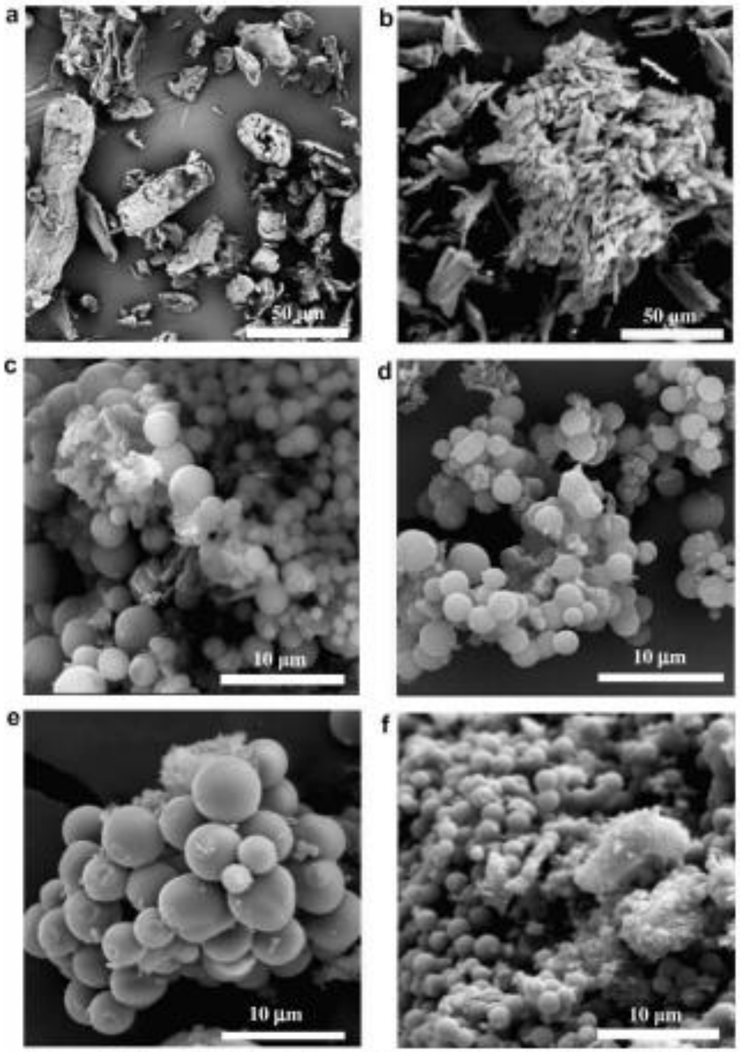


Fig. 1 – SEM images: (a) raw cellulose and (b–f) hydrothermally treated cellulose at: (b) 210 °C/40 g L^{-1}, (c) 220 °C/40 g L^{-1}, (d) 230 °C/40 g L^{-1} (CE-1), (e) 250 °C/40 g L^{-1} (CE-3) and (f) 250 °C/160 g L^{-1} (CE-4).

Sevilla & Fuertes (2009) Carbon 47, 2281-2289.

Properties of the material can be modified using different reaction conditions e.g.

- temperature
- reaction time
- additivies
- pH
- concentrations

HTC reactor

Sugarcane bagasse pith

Bagasse in reactor core

Hydrothermal carbonization

2h
>180°C
max. 33 bar

Product biochar

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Thank You for Your Attention.