Catalytic Fast Pyrolysis of Lignocellulosic Biomass with Manganese-Incorporated MFI & MTW Zeolite Catalysts

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ABSTRACT

Manganese-incorporated zeolites were synthesized using two different structure directing agents to produce MFI and MTW type zeolites. Tetrapropylammonium hydroxide (TPAOH) was used as the organic template to produce MFI, while tetraethylammonium hydroxide (TEAOH) was the template for MTW. Using a hydrothermal method, manganese (III)-acetylacetonate was incorporated within the two zeolite types. These catalysts along with the MFI and MTW catalysts without Mn were studied for the catalytic fast pyrolysis of biomass. Corn stover and glucose were used as the lignocellulosic biomass. They were pyrolized and then passed through the catalyst and analyzed by gas chromatography and mass spectroscopy to determine the type and abundance of products. Selectivity of the products was calculated and compared between the catalysts studied.

LIGNOCELLULOSIC BIOMASS

- **Composed of three primary components:**
  - Cellulose (38%-50%)
  - Hemicellulose (15%-20%)
  - Lignin (15%-30%)
- **Attractive Properties**
  - Renewable form of carbon with potential to convert to liquid
  - Alternative to fossil fuels
  - Use of waste agricultural biomass yields more neutral CO_2 cycle with emissions with uptake of produced CO_2 in new plant growth

Image courtesy of At'l Do Farms

OBJECTIVES

- Gain experience in experimental techniques and methods used for catalyst synthesis and catalytic fast pyrolysis
- Determine selectivity and mass yield (%) of manganese incorporated MTW zeolite catalyst
- Incorporate experimental techniques and methods used into secondary school curriculum

CATALYST SYNTHESIS

- **MFI-Framework Zeolite Catalyst**
  - Precursor gel was made from water, aluminum isopropoxide, tetraethyl-orthosilicate (TEOS), and TPAOH.
  - Manganese (III)-acetylacetonate was then added and solution heated at 180 °C for 48 hours.

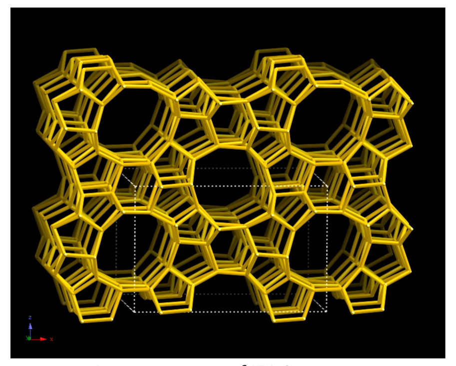
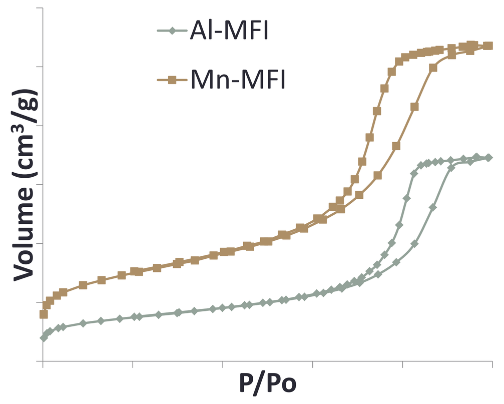


Image courtesy of IZA Structure

MFI framework viewed along [010]



N_2 physisorption isotherms

- **MTW-Framework Zeolite Catalyst**
  - Precursor gel was made from water, sodium aluminate, LUDOX 30% wt. suspension, and TEAOH.
  - Manganese (II) nitrate tetrahydrate was then added and solution heated at 160 °C for 120 hours.

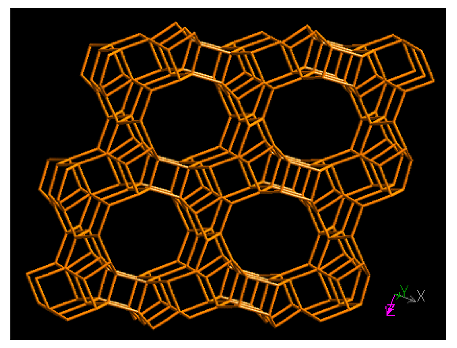
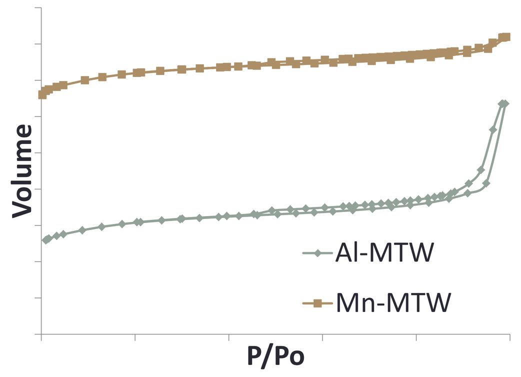


Image courtesy of IZA Structure

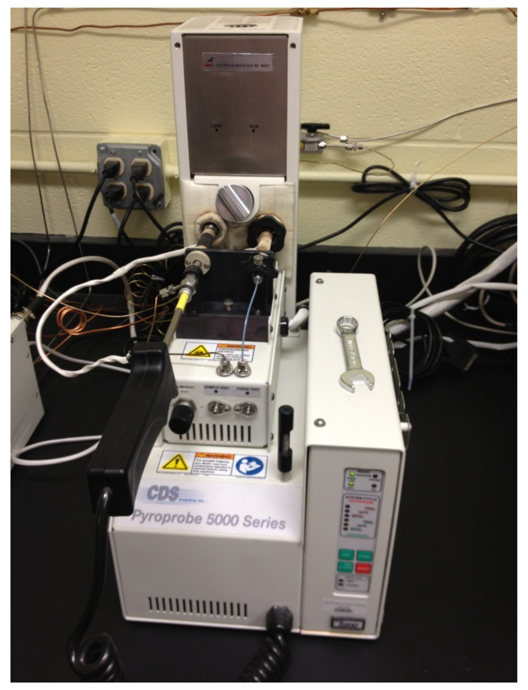
MTW framework viewed along [010]

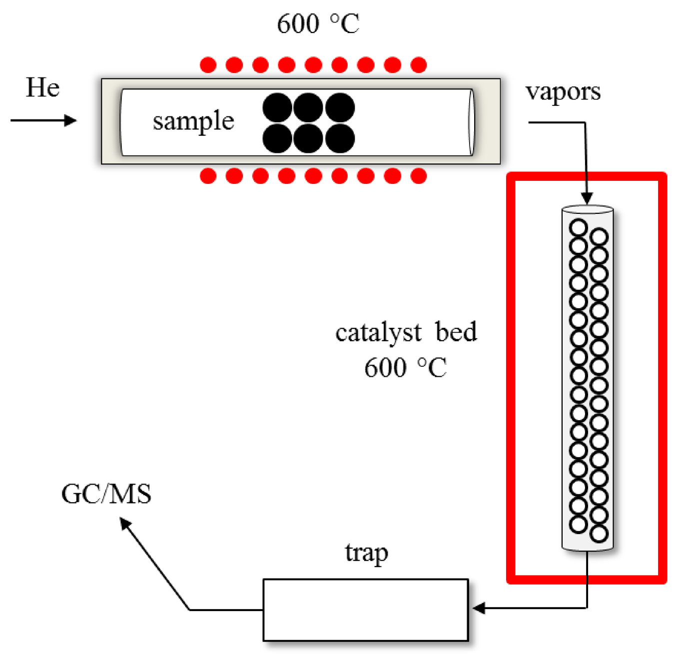


N_2 physisorption isotherms

EXPERIMENTAL SETUP

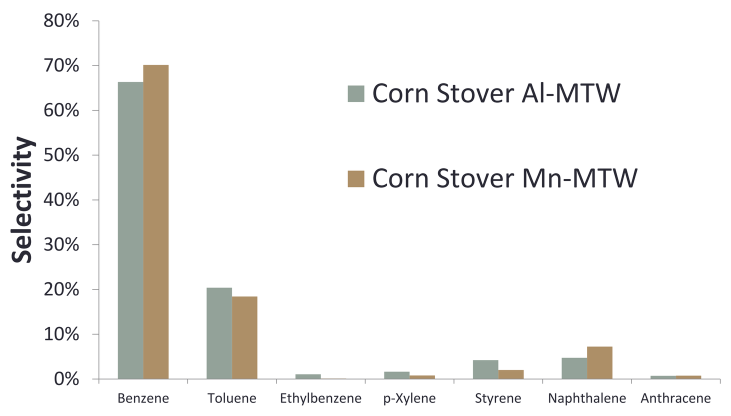
- Lignocellulosic biomass is pyrolized at 600 °C and sent through the catalyst using He as a carrier gas.
- Product vapors are then analyzed in line by gas chromatography with a mass spectrometer detector.





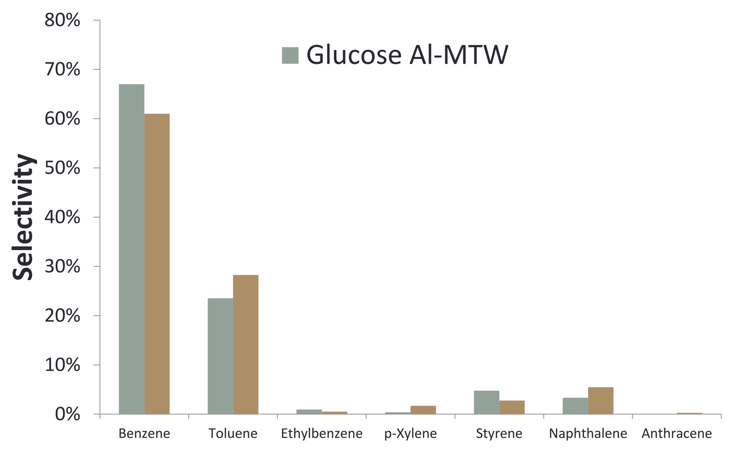
RESULTS

Selectivity of corn stover catalytic fast pyrolysis with MTW at 600 °C



Increased yields with Mn incorporated MTW

Selectivity of glucose catalytic fast pyrolysis with MTW at 600 °C



- Mn-MTW Framework had similar selectivity but higher yields for benzene and naphthalene type products compared to Al-MTW.

CONCLUSIONS

- The manganese incorporated MTW framework performed better in producing higher quantities of product, that are essential for biofuels, compared with the basic Al-MTW framework.

CURRICULAR APPLICATION

- Students will research lignocellulosic biomass for use as an alternative energy source.
- Students will synthesize the LUDOX 30% wt. suspension to use in the MTW-Framework catalyst
- Students will use stoichiometry to determine the amount of LUDOX 30% wt. suspension needed to react with a prescribed amount of the other reactants needed to develop the catalyst.
- Students will synthesize the MTW-Framework catalyst and present their findings in a Powerpoint presentation.

REFERENCES

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