ZSM-5 Modifications Enhance Liquid Hydrocarbon Yields and Carbon Numbers for Jet Fuel Produced from Biologically Derived Alcohols

Background

- Biomass provides an inexpensive resource uniquely suited for large-scale conversion into low carbon footprint sustainable aviation fuels (SAF). Novel consolidated alcohol deoxygenation and oligomerization (CADO) ZSM-5 catalysts offer low-cost, one-step, complete conversion of biologically produced ethanol into hydrocarbons without adding hydrogen. However, CADO products mostly contain less than 8 carbon atoms while jet fuel includes up to 16, likely restricting jet fuel blending to 50% or less.

Approach

- To overcome this limitation, ZSM-5 was reacted with 0.2, 0.6, 0.8, and 1.0 M sodium hydroxide over a range of temperatures and times to enhance the zeolite pore structure to accommodate longer hydrocarbon chain lengths that are desirable for jet fuel.

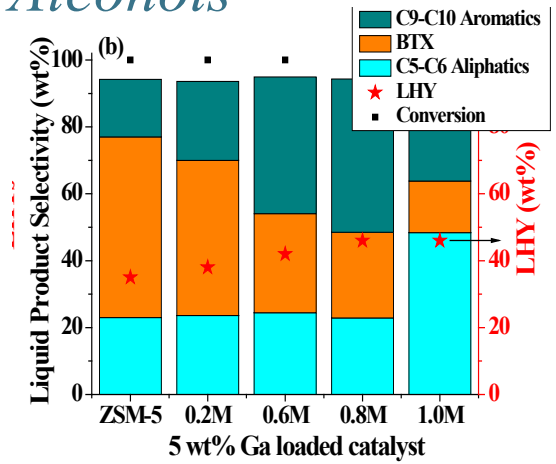
Results

- X-ray diffraction, N2-physisorption, X-ray photoelectron spectroscopy, H2-TPR, and STEM showed that treating ZSM-5 with 0.8 M NaOH at 60°C for 0.5 h increased metal migration into large pore volumes with strong metal-support interactions and retained crystallinity.
- The enhanced pore volume/size and crystallinity of ZSM-5 with 0.8 M NaOH increased liquid hydrocarbon yields (LHYs) from pure ethanol to 46% and C9-C10 aromatics selectivity to 46%.
- Cofeeding 60% water with ethanol further enhanced LHY and C9-C10 aromatics selectivity to 53% and 55%, respectively, while extending catalyst stability.

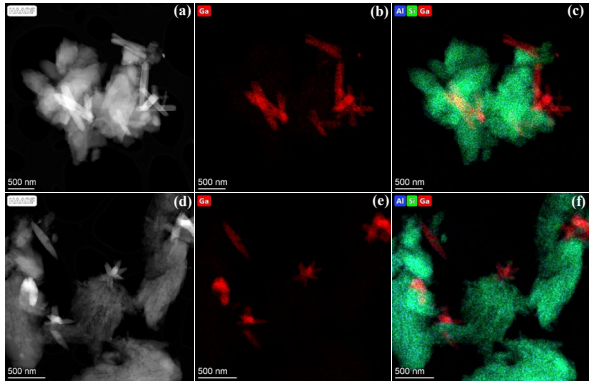
Significance

- CADO offers simple, low-cost conversion of alcohols to jet and other hydrocarbon fuels compatible with the existing infrastructure without adding hydrogen, thereby extending the use of biologically produced molecules.
- This study reports the first direct increase in C9-C10 aromatics from ethanol that will extend the blend levels with jet fuel. Cofeeding water offers synergistic benefits in rate, selectivity and greater process integration.

Seemala B, Wyman CE. Catalysis Science & Technology (2022). DOI: 10.1039/d2cy00288d



Selectivity to C5-C6 paraffins, BTX, and C9-C10 aromatics produced by ethanol oligomerizations over Ga(5wt%)/ZSM-5 and Ga(5wt%)/ZSM-5_{xM} at 350°C and 0.4h^{-1} WHSV. Product selectivity is based on the total mass of just liquid hydrocarbons.



(a) STEM images of Ga(5 wt%)/ZSM-5, (b) Ga, and (c) overlaid Ga/Si/Al elemental mapping. STEM images of (d) Ga(wt5%)/ZSM-$5_{0.8M}$, (e) Ga, and (f) overlaid Ga/Si/Al elemental mapping.