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Clean Fuels & Catalysis

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Heightened public interest in cleaner air and increasingly stringent regulations on transportation fuel quality have resulted in worldwide research and development efforts to find ways for more efficient production of cleaner fuels that contain ultra-low sulfur or zero sulfur and low aromatics. The mission of the Clean Fuels and Catalysis (CFC) Program is to promote comprehensive, efficient, and environmentally friendly utilization of hydrocarbon resources for making and using clean fuels and chemicals through catalytic and chemical research.

CFC research focuses on ultra-clean fuels, chemicals, applied catalysis, reaction chemistry, new materials, and new processing methods related to energy conversion, energy utilization, chemical processing, and environmental protection. The production of clean fuels and chemicals from coal, petroleum, and natural gas require a thorough understanding of the chemical and physical properties of the starting feedstock, and how to tailor processing and/or reaction chemistry to produce a clean fuel or chemical with specific properties. The clean fuels and catalysis research at the EMS Energy Institute garners international attention and attracts a diverse mix of scholars who collaborate to develop a wide range of clean fuels and chemicals using environmentally benign technologies.

Research

CO_2 Capture & Utilization

Penn State is developing new methods for carbon dioxide capture and separation of gas mixtures and flue gases from fossil fuel-based power plants. A new concept, CO_2 ?molecular basket? sorbent (MBS) was proposed, and the nano-porous sorbent materials that were developed based on MBS were demonstrated to be effective for selective CO_2 separation and regeneration in the laboratory and pilot plants. Laboratory scale CO_2 MBS was also successful for H_2S capture and separation for purification of gases such as synthesis gas or hydrogen. In addition, CO_2 utilization is being explored for sustainable development, including CO_2 hydrogenation to clean fuels and chemicals using novel catalysts and catalytic conversion of CO_2 and H_2O in flue gas to syngas via tri-reforming.

Selective Adsorption for Sulfur Removal from Liquid Fuels

Penn State researchers are developing a process concept called selective adsorption for sulfur removal (PSU-SARS) as well as new adsorbent materials for selective adsorption as a new approach to deep desulfurization for ultra-clean fuels at ambient temperatures without using hydrogen gas. Researchers are developing various materials for effective sulfur removal from different types of liquid hydrocarbon fuels and gaseous fuels, in particular, the air-regenerable, mixed-metal oxides-based adsorbents.

Sulfur-Tolerant Catalysts for Conversion of Hydrocarbons

Penn State researchers developed new approaches to the design and preparation of sulfur-tolerant and carbon-resistant catalysts. One new material is the multi-component supported catalyst for low-temperature reforming of liquid or gaseous hydrocarbons that still contain some sulfur at thirty parts per million levels. Another is the new design concept for the sulfur-tolerant noble metal catalysts for low-temperature hydrotreating and dearomatization (LT-HDA).

Advanced Jet Fuel Program

In high-performance jet planes, fuel must serve as the source of propulsion and as a heat sink to absorb excess heat. Future requirements call for fuel capable of withstanding 900°F (JP-900) without decomposing. Penn State has shown that components derived from coal can provide the high degree of thermal stability needed for JP-900. A process involving blending a coal tar distillate product (from the metallurgical coke industry) with petroleum products has been successfully tested at pilot-plant scale. A second process involves adding coal directly to the delayed coking units in oil refineries.

Other Research Activities

- Production of advanced thermally-stable jet fuels using coal-based feedstocks
- Adsorption desulfurization of diesel fuels, jet fuels, and gasoline for ultra-clean fuels
- Reforming of liquid hydrocarbon fuels and alcohols for fuel cell applications
- New catalytic materials for fuel deep desulfurization and hydrogenation
- Chemistry and stabilizers for thermally stable jet fuels for high-Mach aircraft
- Nano-porous sorbents for capture of CO_2 from flue gas of power plants
- Nano-sized bimetallic catalysts for CO_2 hydrogenation to clean fuels and chemicals
- Capture of H_2S from reformate of hydrocarbon fuels for fuel cell applications
- Novel sorbents for deep cleanup of anaerobic digest gas for solid oxide fuels cells
- Shape-selective catalysis over molecular sieves for value-added organic chemicals
- Catalytic reforming of natural gas to produce syngas and hydrogen
- Tri-reforming of natural gas using CO_2 in flue gas without separation
- Computational analysis of reaction pathways in catalytic processes
- Computer simulation of molecular dynamics in pore channels of catalytic materials
- New catalytic materials for fuel processing and synthesis of organic chemicals
- Analytical characterization of catalytic materials and fuels

- Upgrading of coal liquids, heavy oil, and biomass to clean fuel