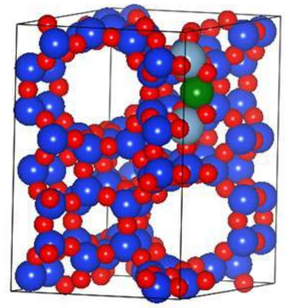
Nanocatalysts for Diesel Engine Emissions Remediation

Zeolite-Based Nanocatalysts Offer Enhanced Catalyst Performance and Durability



Left: Optimized structure of high-silica Cu-ZSM-5 (employing density functional theoretical methods).
Right: Diesel engine–based construction equipment, a large potential application for the nanocatalyst technology.

Illustration courtesy of Oak Ridge National Laboratory, photo by William John Grimes.

Each year, the United States consumes a large volume of petroleum fuel, with more than half of crude oil imported from foreign sources. Diesel engines, which are approximately 30 percent more fuel efficient than gasoline engines, provide one pathway for reducing dependence on imported oil and improving overall energy efficiency. The use of improved diesel engines can also reduce carbon dioxide emissions; however, diesel engine emissions typically contain large amounts of nitrogen oxides (NO_x), particulate matter, and air toxins, all of which can contribute to serious public health problems.

Diesel engines typically utilize catalyst systems to reduce harmful emissions and meet regulatory emissions requirements. Specifically, urea selective catalyst reduction (urea-SCR) has been identified as the leading approach in diesel engine exhaust treatment for the removal of NO_x exhaust emissions. However, the large-scale deployment of diesel engines in the transportation and nonroad diesel engine sectors is still inhibited by catalyst durability and operating temperature issues.

This project addresses these barriers by developing a zeolite-based nanocatalyst system. This project is modifying the nanostructure of the zeolite-based catalyst for urea-SCR technology in order to improve catalyst durability and widen the catalyst operating temperature window. Addressing these issues will facilitate large-scale deployment of this technology.

Benefits for Our Industry and Our Nation

The nanocatalyst technology being developed in this project will result in significant environmental, energy, and economic benefits for diesel engine applications in the U.S. There would be further benefits from nanocatalyst use in the petrochemical industry and in non-road diesel engines.

Applications in Our Nation's Industry

The zeolite nanocatalyst will apply to three key industrial sectors: diesel engines for transportation, nonroad diesel engines, and the petrochemical industry. The largest potential consumer of the nanocatalyst is the U.S. transportation sector, which typically represents 10–16 million passenger vehicle sales annually. The nanocatalyst will also have applications in the estimated 12 million nonroad diesel engines in use today for the farm, industrial, airport service, construction, mining, railway, logging, recreational, and light commercial sectors. In the petrochemical industry, the nanocatalyst will have applications in fluid cracking and hydro-cracking processes.

Project Description

The goal of this project is to develop durable zeolite nanocatalysts with broad temperature operating windows to treat diesel engine emissions, thus enabling diesel engine equipment and vehicles to meet regulatory requirements.

Barriers

- Preventing nanostructural changes that can lead to catalyst performance deterioration
- Ensuring sufficient removal of nitrogen oxide (NO_x) emissions to meet regulatory requirements

Pathways

The large-scale deployment of zeolite-based nanocatalysts for diesel engine emissions treatment is dependent on addressing several key materials issues. Catalyst performance gradually but persistently decreases under operating conditions due to several proposed failure mechanisms. A more thorough understanding of the contribution of each of these mechanisms to ultimate catalyst failure is needed in order to a design a catalyst system that can withstand the extreme environment of emissions.

This research project is developing an understanding of the catalyst failure modes in order to synthesize new zeolite nanocatalyst systems. The catalysts are then characterized using modern characterization tools and evaluated using a bench-top reactor that simulates operating conditions. Using an accelerated aging protocol, the best catalysts are aged under simulated operating conditions to determine their performance, degradation, and ability to meet regulatory requirements. The catalyst that performs best in laboratory testing will be sent to project partner John Deere for dynamometer testing. The criteria for a successful catalyst will include high-temperature hydrothermal durability, a larger operating window for the zeolite catalyst, and NO_x treatment performance.

Milestones

This project started in September 2008.

- Determination of zeolite nanocatalysts' failure modes via identification and testing of catalyst systems using simulated exhaust under operating conditions (Completed)
- Synthesis of modified and hydrothermally stable nanostructured zeolite catalysts; determination of their catalytic performance, operating window, and durability; and identification of the two leading candidate materials
- Laboratory evaluation and testing of the two leading candidate materials in powder form and on a honeycomb substrate
- Systematic nanostructural materials characterization and monitoring of nanostructural changes in new materials under test conditions
- Dynamometer evaluation of the best catalyst system on the honeycomb substrate

Commercialization

Successful completion of this project will lead to deployment of diesel engines utilizing zeolite nanocatalyst technology. The final product will consist of a catalyst that will be deposited on a honeycomb substrate with 600–900 channels per square inch. The honeycomb substrate, considered to be a commodity item, will be manufactured by Corning, Inc. The size of the honeycomb needed, which is dependent on the engine emission characteristics, is already well-established. The coating technique is also already well-known and well-established in current production. Project partner John Deere, Inc. will be an end user for the nonroad diesel engine industry. Great interest in this technology is also expected from vehicle original equipment manufacturers (OEMs). Ongoing collaborations with several OEMs will support rapid transfer of this technology to the transportation sector.

Project Partners

Oak Ridge National Laboratory (ORNL)
Oak Ridge, TN
Principal Investigator:
Chaitanya Narula
E-mail: narulack@ornl.gov

John Deere Power Systems
Waterloo, IA

For additional information, please contact

Gideon Varga
Technology Manager
U.S. Department of Energy
Industrial Technologies Program
Phone: (202) 586-0082
E-mail: Gideon.Varga@ee.doe.gov

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