Accelerated Deployment of Nanostructured Hydrotreating Catalysts

Nanomanufacturing Techniques to be Developed for Use in Used Oil Re-refinement Pilot Test

Hydrotreating is a catalytic technique used extensively in petroleum refining, primarily to remove sulfur from crude oil fractions. As an integral part of the modern, used lubricating-oil re-refining process, hydrotreating helps to rid used oils of contaminants gained through exposure to the severe conditions found in gasoline and diesel engines. Although re-refining is a potentially multibillion dollar market, over 85% of the more than 7 billion pounds of used oil today is simply burned as fuel—only about 14% is recycled. The growth of this industry depends on the development of improved hydrotreating catalysts with controlled process costs.

This project aims to address this issue through the design, development, and manufacturing of nanostructured hydrotreating catalysts that will reduce energy use and improve hydrotreating performance for oil re-refining. This project will demonstrate the rapid development, evaluation, and deployment of an atomic layer deposition (ALD) technique developed by Argonne National Laboratory for the manufacturing of nanostructured catalysts. This technique will be able to produce superior-performing hydrotreating catalysts for industrial utilization. The catalysts will be integrated into current and future re-refining facilities in partnership with Universal Lubricants, Inc. (ULI).

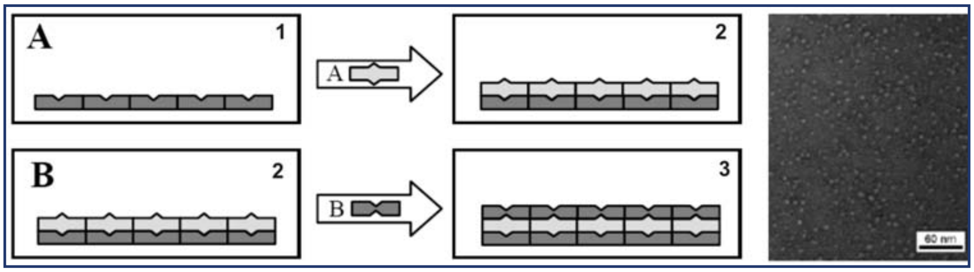
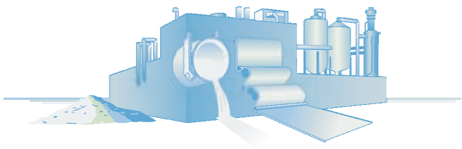


Figure 1. Left: Illustration of AB sequence for atomic layer deposition (ALD) of one monolayer. Notches in the starting substrate for reaction A represent discrete reactive sites. Exposing this surface to reactant A results in the self-limiting chemisorption of one atomic layer of A species. Subsequent exposure to molecule B covers the surface with a monolayer of B species that reacts with the A species surface. Thus, one AB cycle deposits one monolayer of compound AB and regenerates the initial surface.

Right: Scanning electron microscope (SEM) image of 6 nm diameter palladium (Pd) nanoparticles on an alumina (Al_2O_3) surface prepared using 100 ALD cycles.



Benefits for Our Industry and Our Nation

The potential energy savings from the implementation of improved catalyst selectivity throughout the entire U.S. petrochemical industry is estimated to be 280–600 trillion Btu/year (equivalent to the annual energy production of approximately 23–50 large power plants). This would result in annual industry cost savings of $1.9–4.0 billion. If ALD catalyst technology is only used to replace the high-temperature steam cracking process for producing olefins for ethylene and propylene, the resulting reduction in carbon dioxide (CO_2) emissions is estimated to be about 8 million metric tons/year, based on a potential energy savings of 149 trillion Btu/year. In addition, avoiding the use of waste oils as low-grade boiler fuel mitigates potential environmental hazards.

Applications in Our Nation's Industry

While the oil re-refining industry will be the initial and pioneering demonstration of ALD nanostructured catalyst technology, the largest market for this product will be the petroleum refining industry, due to their extensive use of hydrotreatment and enormous material throughput. Currently, there are 146 petroleum refineries in the United States that could utilize the catalyst technology platform. This cross-cutting technology can also be applied to a broad range of catalytic processes in energy-intensive chemical industries.

Project Description

The goal of this project is to develop and manufacture a novel hydrotreating nanocatalyst to reduce energy use and improve performance in oil re-refining. A further goal is to demonstrate that a new nanocatalyst can be rapidly designed and developed on a time scale that impacts energy-intensive, high-capital industries with low margins.

Barriers

- Design of nanocatalysts that perform at least as well as proprietary catalysts
- Acceleration of atomic layer deposition (ALD) nanocatalyst design for use in future projects
- Development of nanocatalysts with sufficient performance and stability to ensure economic and energy benefits over alternative products

Pathways

This project will use ALD to design improved nanostructured catalysts for hydrotreating in oil re-refining. ALD is a non-vacuum, thin-film growth technique that uses alternating, saturating reactions between gaseous precursor molecules and a substrate to deposit films in a layer-by-layer fashion. By repeating this reaction, films of virtually any thickness (atomic monolayers to micrometers) can be deposited with atomic-layer precision.

While conventional ALD is a mature technology, a completely new ALD coating system for manufacturing nanostructured catalysts has been designed to overcome process-specific technical limitations. This new system will be utilized to design and manufacture 100-gram quantities of nanostructured catalysts for pilot-scale testing. Through an iterative process, the project team expects to improve catalyst reactivity, thereby reducing the required temperatures and stabilizing the catalyst bed. The experimental optimization process will then be evaluated, and energy and capital savings will be estimated to guide future nanocatalyst design opportunities and scale-up decisions.

Milestones

This project started in September 2008.

- Year 1: Preparation of a bench-scale set of nanostructured catalysts using existing catalysts as the starting surface
- Year 1: Preparation of a bench-scale set of nanostructured catalysts using novel supports as the starting surface
- Years 1–2: Preparation of a pilot-scale set of optimized nanostructured catalysts selected from the initial bench-scale sets
- Year 2: Evaluation of the experimental optimization process to guide future nanocatalyst design opportunities
- Year 2: Selection of the two best-performing catalysts based on the performance properties of the post-treated oil

Commercialization

Upon successful project completion, the end products will be the licensable nanocatalyst product to be manufactured and the intellectual property and platform methods for manufacturing nanostructured catalysts for the hydrofinishing of petroleum products. Project partners Universal Lubricants, Inc. (ULI) and Chemical Engineering Partners will be the initial early adopters of the product in the oil re-refineries that they are presently constructing and servicing. CEP is the licensor of the re-refining technology and also provides process engineering and design services to the re-refining industry. ULI is a major brand lubricating oil distributor, used oil recycler, proprietary lubricant blender, and distributor and owner of used oil re-refineries. ULI will act as the field verification provider for the product. The ultimate technology product end-user market will be the energy industry sector, in which the hydrotreating of petroleum products is a commonly used process technology.

Project Partners

Argonne National Laboratory (ANL)
Argonne, IL
Principal Investigator:
Seth Snyder (seth@anl.gov)

Universal Lubricants, Inc. (ULI)
Wichita, KS

Chemical Engineering Partners
Irvine, CA

For more information contact:
EERE Information Center
1-877-EERE-INF (1-877-337-3463)
www.eere.energy.gov

U.S. Department of Energy
Energy Efficiency & Renewable Energy

March 2009