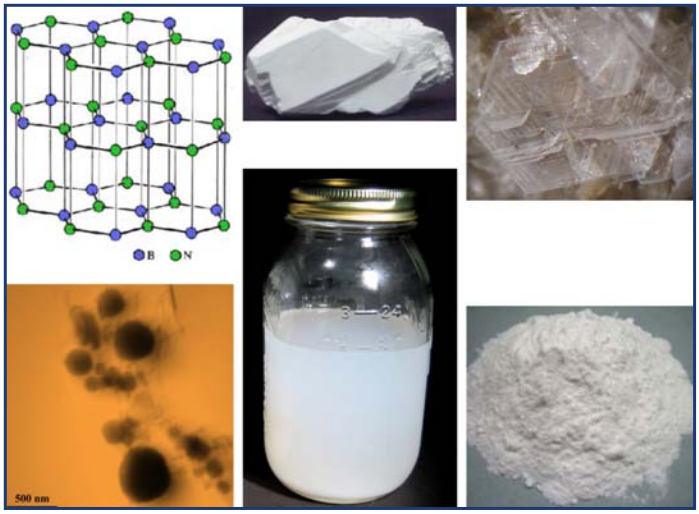
Large-Scale Manufacturing of Nanoparticulate-Based Lubrication Additives

Development of Boron-Based Nanolubrication Additives for Improved Energy Efficiency and Reduced Emissions

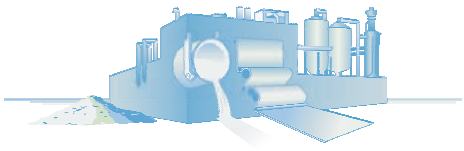
Lubricants play a vital role in machine life and performance, reducing friction and wear and preventing component failure. Poor lubricant performance can cause significant energy and material losses. In highly industrialized nations, the total annual cost of friction-and wear-related energy and material losses is estimated to be 5%–7% of national gross domestic product.

Global demand for lubricants is approximately 250 million barrels per year and is expected to continue growing in the future. Engine oils account for half of this demand, and industrial lubricants represent the second-largest and fastest-growing segment by volume. Performance-enhancing additives are a vital part of today's modern lubricants, accounting for 5%–15% of the total market volume. Due in part to projected growth in manufacturing activities worldwide, the lubricant market is in need of lower-cost and higher-performing additives that meet end-user performance specifications and environmental safety requirements.

In response to this need, this project will develop boron-based nanoparticulate lubrication additives that can drastically lower friction and wear in a wide range of industrial and transportation applications, and will scale up these additives for large-scale production. The primary components of this project will be the formulation, testing, and verification of additive performance in engine and fleet tests and the scale-up and optimization of these additives at reasonable commercial costs.



Various boron-based nanomaterials. Clockwise from top left to bottom left: Crystal structure of hexagonal boron nitride; borax; solid boric acid (H_3BO_3); powdered boric acid; mineral oil with 1% nano-boric acid particles; individual nano-boric acid particles.



Benefits for Our Industry and Our Nation

By reducing friction and wear, boron-based nanolubrication additives can reduce fuel use, energy consumption, and carbon dioxide emissions. Specific potential savings include the following:

- A reduction in petroleum consumption exceeding 0.5 million barrels per day (around 1 quadrillion Btu annually), which could save billions of dollars in annual energy expenses
- An annual reduction in carbon dioxide emissions exceeding 68 million metric tons

By replacing sulfur- and phosphorous-bearing additives in lubricants, nanolubrication additives may also help to eliminate the main sources of environmentally hazardous emissions and wastes. In addition, the raw materials for boron-based additives are naturally occurring, nontoxic, abundant, and inexpensive.

Applications in Our Nation's Industry

Almost all moving mechanical systems rely on effective lubrication for smooth and long-lasting operations. The potential applications of nanolubrication additives are thus very broad across multiple industries, processes, and uses. Impacted industries include the transportation (particularly in engine use), manufacturing, and power generation industries, and other industrial sectors.

Project Description

The project goal is to design, develop, manufacture, and scale up boron-based nanoparticulate lubrication additives. Additive performance in greases and oils will be tested and verified in order to achieve higher energy efficiency, better environmental compatibility, and longer durability. Large-scale production at a reasonable cost will also be demonstrated using commercial-size manufacturing systems.

Barriers

- Scale-up to larger volumes to conduct fleet tests
- Adverse interactions or chemical reactions with engine oil and/or additives, especially after use at higher engine running temperatures

Pathways

The research team will leverage years of experience in the development of a series of boron-based liquid and solid lubricants with improved friction and wear-reducing properties under a wide range of tribological conditions. The project team will focus on nano-colloidal versions of boron-based lubricants, including boric acid, boron nitride, and boron oxide. Building on previous systematic bench-top test machine studies of these compounds, this project will focus primarily on product optimization, scalability, and environmental and energy benefits. The development and optimization of the nanomanufacturing process will conclude with engine and fleet testing and eventual large-scale and commercial implementation of the developed nanolubrication additives.

Milestones

This project started in September 2008.

- Years 1–2: Feasibility lab studies, including friction, wear, and scuffing surface characterization, and pilot-size production of nanopowders
- Year 2: Engine screening tests, including fuel efficiency, catalytic, and 'no harm' engine tests to determine overall engine performance
- Year 3: Full engine and fleet tests, including vehicle economy tests and tear-down tests and characterization
- Years 1–3: Scale-up of powder and lubricant production and determination of the optimum powder specifications; process selection, design, and prototyping; process optimization and trial runs; and
- Years 2–3: Cost and feasibility studies leading to commercial scale-up of powder production

Commercialization

To enhance the successful commercialization of nanolubrication technology, the project team includes a large company in the lubrication field and a nanomaterials leader. With its combined manufacturing and marketing resources, the project team will be able to offer boron-based nanolubrication additives in various commercial forms, including concentrates that can be diluted by end users and motor oils blended with optimized additives at ideal concentrations. Very rapid market penetration of nanolubrication technology is expected because of its nontoxic and inexpensive nature. To maintain an effective development schedule, the project team will carefully monitor and control issues such as production cost, quality assurance protocols, environmental issues, and safety and health matters.

Project Partners

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