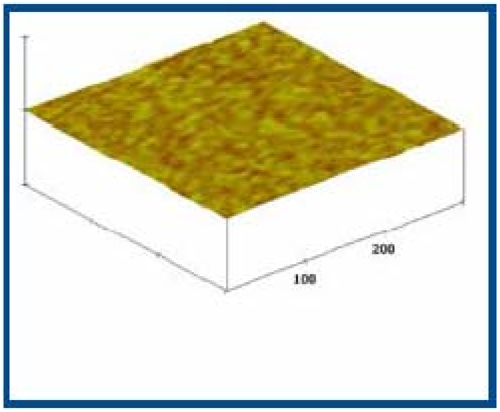
Nanocoatings for High-Efficiency Industrial Hydraulic and Tooling Systems

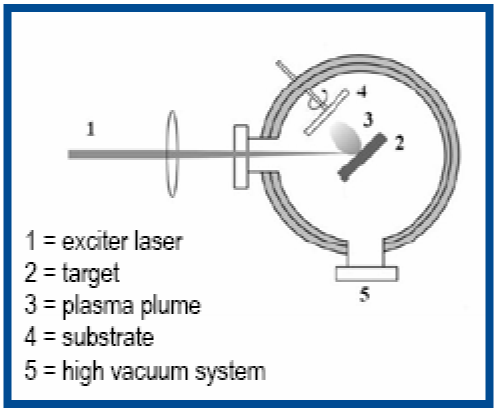
Superhard Nanocomposite Coatings Will Improve Degradation Resistance in Dynamic Applications

Industrial energy efficiency is directly linked to the wear and degradation of materials used in processing applications such as pumps and tooling components. The preferred route to minimizing wear is through application of a protective, hard coating to contacting surfaces so that these surfaces generate less friction and resist wear. With lower friction between contacting surfaces, less energy is required to overcome frictional forces during start-up and operation, thereby increasing energy efficiency. While the energy savings per component may be modest, substantial cumulative benefits are possible due to the large number of pumps and machining tools currently in operation.

Recently, a new family of "superhard" (greater than 40 GPa) composites has emerged in which the hardness is derived from microstructural engineering of the constituent phases. Preliminary studies involving the primary constituent phase, AlMgB14, have demonstrated the feasibility of producing thin film coatings of the compound on various substrates, including straight-grade cemented carbide. The coatings combine high hardness with a low friction coefficient, and have been shown to substantially reduce tool wear in lathe turning tests. This project will focus on materials degradation resistance for two distinct industrial applications: industrial hydraulic components and tooling systems.



Atomic force microscope mage of boride MgB14coating as deposited. The coating has a surface roughness of 0.17 nm and a dry friction coefficient of 0.05.



Schematic of pulsed laser deposition equipment

Benefits for Our Nation and Our Industry

Widespread use of the new superhard coatings will increase energy efficiency through diminished friction loss and increased seal reliability in hydraulic pumps. Further savings are possible through an extended lifetime of optimum cutting performance in machine tooling. Increased system reliability coupled with decreased downtime and replacement costs hold potential economic benefits. Environmental benefits include reduced pollutant leakage through pump seals and reduced emissions due to energy efficiency. Preliminary analyses show industrial hydraulics and tooling combined energy savings of 30 trillion Btu per year by 2030 and an associated energy cost savings of $187 million per year.

Applications in Our Nation's Industry

The advanced coatings will be initially deployed on hydraulic system components and machining tool inserts, but can also be applied in other high-performance, high-stress environments.

Project Description

The goal of this project is to develop degradation-resistant nano-coatings of $AlMgB_{14}$ and $AlMgB_{14}–TiB_2$ that result in improved surface hardness and reduced friction for industrial hydraulic and tooling systems.

Barriers

Major barriers to be overcome include:

- Failure of existing coating solutions to combine durability with reduction in friction losses needed to improve energy efficiency in hydraulic pump components and tooling systems;
- High friction, low wear resistance, and over-specification of pump size, which lead to excessive energy use in industrial hydraulic systems: Wear of the active components can decrease volumetric and mechanical efficiency by as much as 10% over the lifetime of a typical hydraulic pump;
- Lack of long-term performance data to predict operating lifetime of the coatings under typical operating conditions; and
- Insufficient information on the correlation between vapor deposition processing method and surface properties.

Pathways

The objectives of the project will be achieved through (1) establishing the mechanical and tribological properties of single-phase and composite boride thin films; (2) developing and optimizing various vapor deposition techniques for coating application;(3)verifying the energy efficiency advantage of boride thin film over baseline performance metrics; (4) assessing lifetime energy savings in industrial hydraulic and tooling systems; and (5) scaling up deposition technology for large scale applications, complex shapes, and industrial commercialization.

Progress and Milestones

- Confirm improved friction and wear characteristics of boride coatings (Complete)
- Achieve deposition on complex geometries while retaining elevated performance
- Optimize composition and deposition parameters to reduce torque-to-turn ratio of hydraulic systems and nose and flank wear of machine tooling systems each by 50% from incumbent performance
- Develop large scale deposition methods for various high volume products
- Verify energy savings based on product performance and durability testing

Commercialization

A strong industry/national lab partnership well positions the project team for widespread adoption of the new technology. Eaton and Greenleaf Corporations both command leadership positions in their respective industrial market segments. The high-performance materials involved in this project will enhance both companies' competitive position, and will find easy introduction in both arenas.

Project Partners

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Ending FY10
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