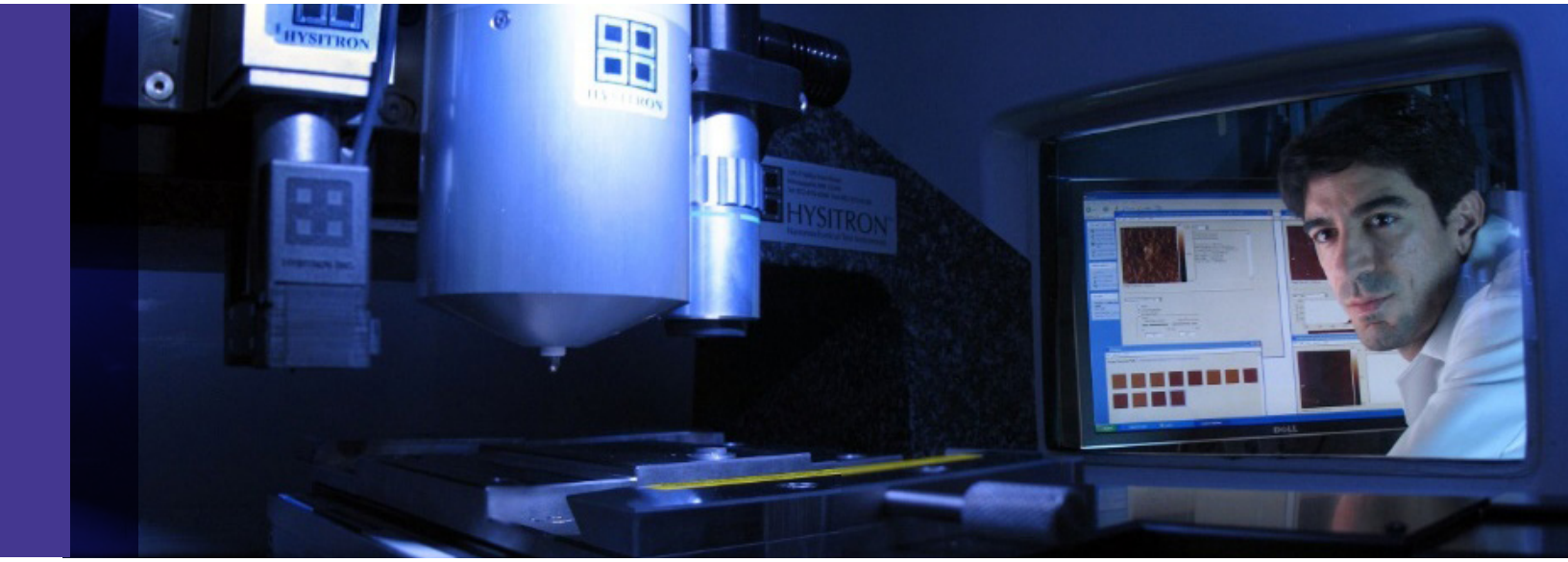
Argonne NATIONAL LABORATORY

# SLIDE: SURFACES AND LUBRICATION INTERACTION DISCOVERY AND ENGINEERING




**Argonne's Nick Demas uses SLIDE's nanoindentation and surface characterization instrument to obtain measurements of thin-film and bulk materials on the nanometer and micrometer levels.**

Argonne researchers are tasked with providing the fundamental science breakthroughs necessary to ensure a clean, secure energy future. And few scientific arenas hold the promise for increasing efficiency across a range of energy technologies, from wind turbines to internal combustion engines, as does tribology, or the study of interacting surfaces in motion.

Argonne turns to its SLIDE—or, Surfaces and Lubrication Interaction Discovery and Engineering—program to unlock hidden efficiency gains across the energy spectrum by reducing the friction inherent in the interactions of moving parts.

SLIDE researchers apply tailored scientific approaches aimed at minimizing the friction in transportation, increasing longevity in energy production, addressing tribological issues in medical applications and increasing material performance to ensure that American industry remains competitive in the global marketplace.

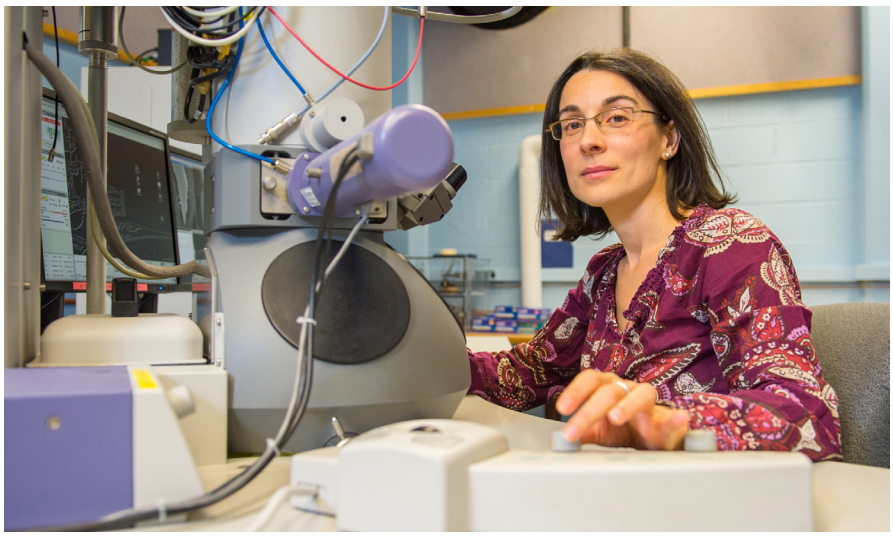
With a staff of 10 PhDs and a suite of cutting-edge analysis and validation tools, SLIDE builds on Argonne's rich history of tribological innovation by partnering with American industry and research institutions to push the innovation envelope in materials and friction reduction. At its nexus SLIDE represents the only place in the world where cutting-edge scientific tools, national user facilities such as the Advanced Photon Source and multidisciplinary expertise exist to tackle tribology's most challenging problems.

SLIDE achieves tribology breakthroughs via three distinct yet overlapping research platforms: tribological lab-scale testing, the technological development of coatings and lubricants, and materials characterization.

## TRIBOLOGICAL LAB-SCALE TESTING

SLIDE employs a suite of state-of-the-art, customizable equipment, including 15 bench-top tribometers, to achieve a fundamental understanding of tribological phenomena by:

- Conducting tests in extreme environments to emulate real-world conditions
- Identifying critical test parameters to replicate various sliding conditions
- Pairing materials with lubricants and coatings for optimum performance



**SLIDE's Cinta Lorenzo Martin uses the group's transmission electron microscope to gain an enhanced understanding of structural and chemical characterizations of materials and surface interactions.**

## MATERIALS CHARACTERIZATION

The interaction of surfaces in motion introduces unique changes at their interface; modeling these changes has enormous implications for evaluating and optimizing materials performance. SLIDE researchers achieve an enhanced understanding of surface structure and performance by:

- Conducting mechanistic modeling to understand and predict tribological behavior
- Predicting the formation, structure and behavior of tribofilms
- Quantifying changes in surface morphology and mechanical properties

## TECHNOLOGY DEVELOPMENT

Over the last few decades performance demands have increased while the size of components has largely decreased, creating the need for novel coatings and lubricants to unlock remaining efficiencies. Through advanced testing and materials characterization SLIDE researchers are:

- Optimizing and validating next-generation lubricants and additive combinations to increase efficiency
- Engineering surfaces for a wide range of applications
- Integrating ideal lubricants and coatings with materials to increase efficiency and component life

## PARTNER WITH SLIDE

SLIDE's unique combination of cutting-edge tools, facilities and unparalleled expertise make Argonne the premier one-stop shop for friction reduction and tribological innovation.

Since its inception in 1983, Argonne's tribology program has authored more than 300 peer-reviewed journal articles and won six *R&D 100 Awards*.

This rich history, when combined with the group's unique range of expertise and suite of customizable equipment, allows SLIDE to provide complete solutions for today's most complex tribological research questions.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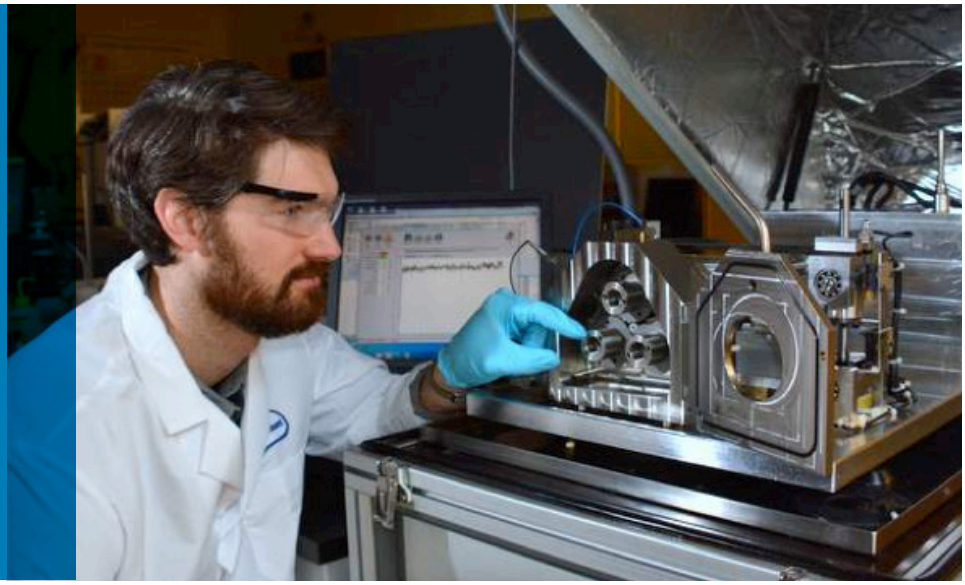
# ENHANCED LAB-SCALE TESTING

*SLIDE brings real-world conditions to laboratory*



**SLIDE researcher Aaron Greco uses a micro-pitting rig to replicate failure in a wind turbine bearing. The rig can also be used to test macro-pitting, scuffing and wear for different material combinations, coatings/surface treatments and lubricants.**

In order to test a wider range of technologies and bring innovation to the marketplace more rapidly, tribologists often rely on lab-scale rigs that simulate engine conditions as closely as possible. From these initial R&D experiments researchers can identify the most promising candidates for system-level validation.

Lab-scale testing rigs offer a variety of options for creating testing conditions. However, differences between rigs can greatly affect research outcomes, making the prediction of system performance in the real world exceptionally difficult. In order to extract meaningful data researchers must select the most useful platform and the best conditions for each experiment.

To match industrial environments as closely as possible and eliminate weaker technologies, tribologists at Argonne National Laboratory have formed the Surfaces and Lubrication Interaction Discovery and Engineering (SLIDE) program, which employs a comprehensive suite of customizable equipment, including 15 bench-top tribometers, for:

- Conducting tests in extreme environments to emulate real-world conditions
- Identifying critical test parameters to replicate various sliding conditions
- Pairing materials with lubricants and coatings for optimum performance

## EXTREME ENVIRONMENTS

Tribological phenomena occur in a wide range of extreme environments, such as the heat inherent in the operation of internal combustion engines. SLIDE testing capabilities can replicate a broad spectrum of temperatures, from -20 to 850°C, and stresses over six orders of magnitude.

## TESTING PARAMETERS

SLIDE's assortment of lab-scale analysis tools can also quantify numerous phenomena including simple wear, abrasive wear, scuffing and contact fatigue across a range of inert environments—from dry to sliding to liquid to gas.

## MATERIALS, COATINGS, AND LUBRICANTS

The pairing of materials with the proper lubricants and coatings requires the ability to test a range of combinations. The SLIDE program's lab-scale rigs enable the rapid evaluation and validation of lubricants, coatings and materials across unique motions and geometries.

These evolving testing platforms, along with SLIDE expertise across the tribological spectrum—from transportation to energy production to medical devices—make Argonne the perfect setting in which to tackle today's most difficult friction-related research questions.

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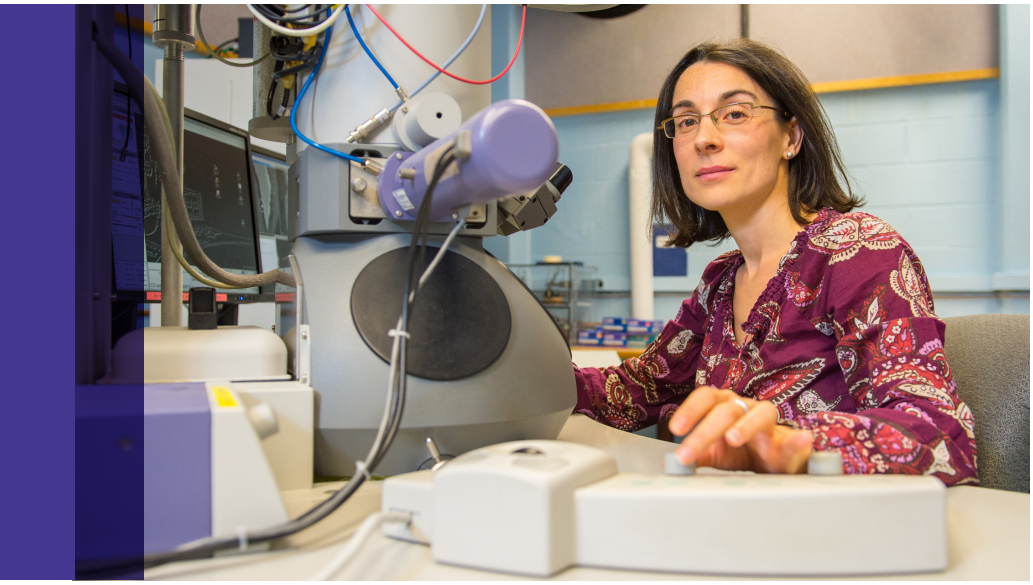
# DEVELOPING PREDICTIVE SURFACE MODELS

*Characterization at core of SLIDE mission*



**SLIDE's Cinta Lorenzo Martin uses the group's transmission electron microscope to gain an enhanced understanding of structural and chemical characterizations of materials and surface interactions.**

As surfaces in motion come into contact, their properties—such as microstucture, chemistry, roughness and hardness—change. Understanding how these surface interactions alter a material's properties over time is critical for predicting performance across a range of energy-related technologies.

In their efforts to reduce friction and increase efficiency, tribologists at Argonne National Laboratory have formed the Surfaces and Lubrication Interaction Discovery and Engineering (SLIDE) program to develop unique methods for characterizing surfaces with predictive fidelity in order to bring novel coatings and lubricants to market faster and cheaper.

SLIDE researchers apply tailored scientific approaches to advance the state-of-the-art in surface characterization by:

- Conducting mechanistic modeling to understand and predict tribological behavior
- Predicting the formation, structure and behavior of tribofilms
- Quantifying changes in surface morphology and mechanical properties

## MECHANISTIC MODELING

Useful models need data, and lots of it. SLIDE's unique combination of expertise and state-of-the-art equipment enables the collection of data to predict and quantify both performance and failure, providing partners with a critical roadmap to optimization for their most pressing tribological problems.

## TRIBOFILM FORMATION, STRUCTURE AND BEHAVIOR

With Argonne's advanced materials characterization tools, SLIDE researchers are able to measure critical tribofilm properties such as thickness and engineer novel surface layers by correlating tribofilm structure with friction and wear.

## QUANTIFYING SURFACE MORPHOLOGY

The interactions of surfaces lead to significant changes in material morphologies and mechanical properties. By quantifying the aging process and revealing how components grow over time, SLIDE researchers enable their partners to control surface properties for both improved component performance and prolonged life. SLIDE's characterization capabilities include:

- Electron microscopy for high-resolution images and chemical and structural mapping of tribofilms
- Nano-indenter tool for nano-mechanical properties of tribofilms and bulk materials

In their quest to model the interactions of surfaces with unprecedented accuracy, SLIDE researchers also use Argonne's Advanced Photon Source (APS), which offers several capabilities especially applicable to tribology including X-ray diffraction, microflourescence and absorption.

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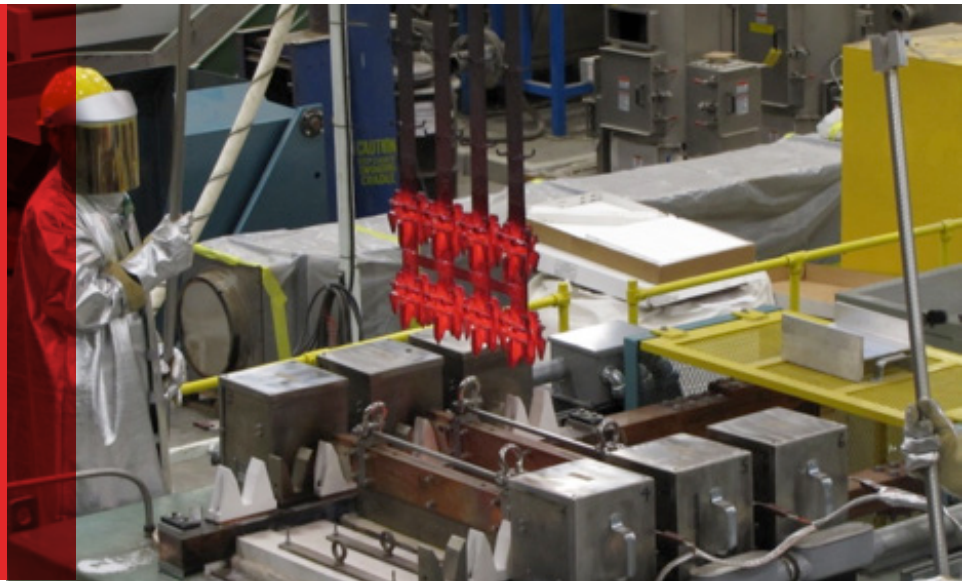
# ADVANCING TECHNOLOGY DEVELOPMENT FOR TRIBOLOGY

*Coatings and lubricants critical to friction reduction*



**Argonne researcher Osman Eryilmaz recovers industrial parts from the large-scale ultra-fast boriding furnace after a successful boriding treatment. The furnace uses an electrochemical process similar to that of batteries to deposit boron on metal workpieces.** (Photo credit: Osman Eryilmaz)

Argonne tribologists work to increase efficiency across a range of technologies by reducing friction inherent in the interactions of moving parts.

However, this mission has become increasingly difficult in the last few decades as performance demands have increased while the size of moving components has greatly decreased in nearly every major industry, from energy production to manufacturing to medical devices.

In order to achieve the desired efficiency gains, Argonne tribology researchers have formed the Surfaces and Lubrication Interaction Discovery and Engineering (SLIDE) program. Among the program's many objectives is the design of novel lubricants and coatings that—when paired with the right materials—not only increase efficiency but also extend component life.

Through advanced testing and materials characterization techniques, SLIDE researchers:

- Optimize and validate next-generation lubricants and additive combinations to increase efficiency
- Engineer coatings for a wide range of applications
- Integrate ideal lubricants and coatings with materials to increase efficiency and component life

## LUBRICANTS

Lubricants typically contain performance-enhancing additives with by-products that often compete with one another and react negatively with other materials and coatings. SLIDE testing capabilities reveal new approaches to achieving the desired properties of conventional additives with more environmentally friendly alternatives. SLIDE researchers also apply Argonne's advanced testing and characterization capabilities to develop advanced lubricants that exceed the performance of today's lubricants without their negative side effects.

## COATINGS

The discovery of new coatings for friction management lies at the core of the SLIDE mission— because many traditional coatings designed for manufacturing applications are not compatible with some of today's most common performance-enhancing additives, SLIDE researchers must design novel coatings that complement newer additives under a wide range of conditions.

## PAIRING LUBRICANTS AND COATINGS

The proper pairing of lubricants and coatings can unlock hidden efficiency gains across a range of technologies. By developing coatings for use with advanced lubricants, SLIDE researchers help industry partners to both increase efficiency and extend the life of valuable machinery.

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