Boride-carbon hybrid technology to produce ultra-wear and corrosion resistant surfaces for applications in harsh conditions

EE0008320

Michigan State University, Argonne National Laboratory & Fraunhofer USA, Inc.

05/16/2018 – 11/15/2019

Thomas Schuelke, Michigan State University

Nina Baule, Fraunhofer USA, Inc.

U.S. DOE Advanced Manufacturing Office Program Review Meeting

Washington, D.C.

June 11-12, 2019

This presentation does not contain any proprietary, confidential, or otherwise restricted information.

Overview

Timeline

- Project start date: 05/16/2018
- Project end date: 11/15/2019

Budget	DOE Share	Cost Share	Total	Cost Share %
Overall Budget	$550,000	$200,000	$750,000	26.7%
Costs as of 3/31/19	$219,444	$154,977	$374,420	41.4%

Barriers

- Develop a **commercially feasible** treatment for making extremely durable low-friction wear and corrosion resistant surfaces.

AMO MYPP

- Materials for Harsh Service Conditions

Partners

- Michigan State University (project management, coating technology)
- Argonne National Laboratory (boriding technology)
- Fraunhofer USA Inc. (coating technology)
- Industry partners (application specification and testing)

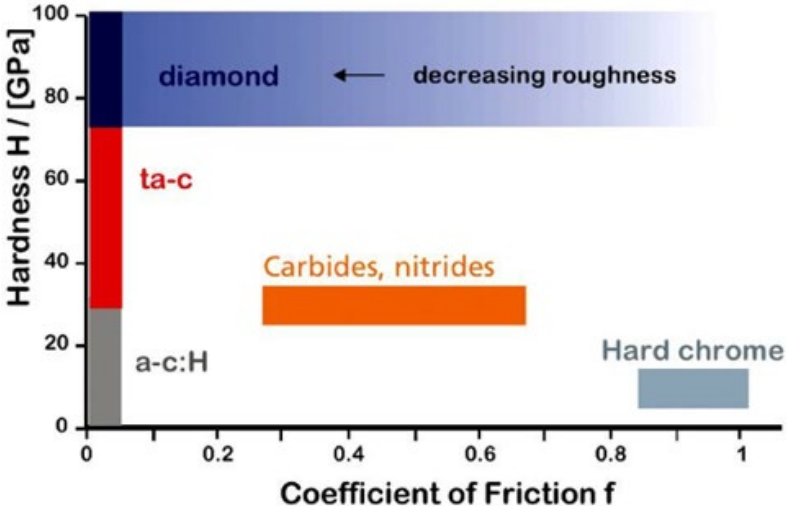
(Boride-carbon hybrid technology to produce ultra-wear and corrosion resistant surfaces for applications in harsh conditions)

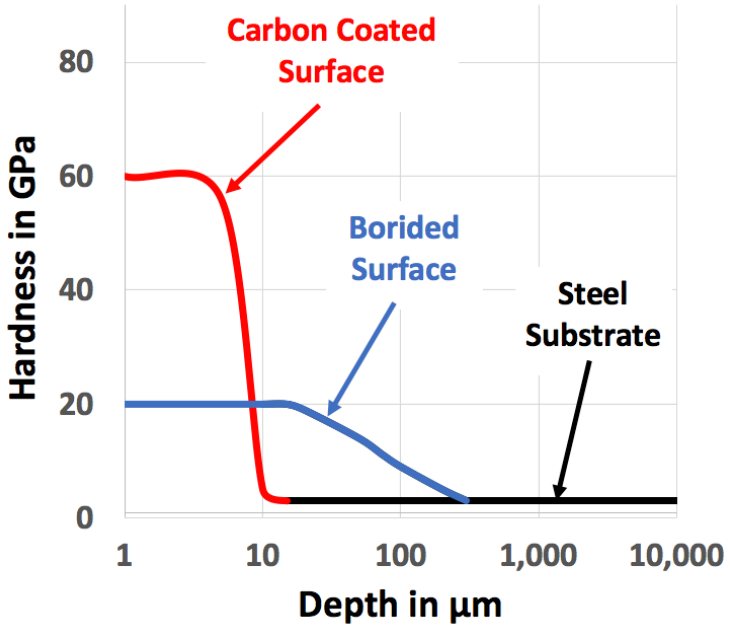
Project Objectives

- **Mechanical assemblies** (engines, transmissions, complex tools) experience ever **harsher operating conditions** (extreme contact loads, corrosive environments), while **durability** has to increase and **costs** have to decrease. Therefore this project aims:
  - To develop a hybrid process for creating **extremely durable low friction, wear and corrosion protective engineered surfaces** for tribological components in harsh conditions.
  - To **demonstrate the performance** of such surfaces on the laboratory scale.
  - To **demonstrate a commercialization path** via industry engagement and cost-benefit analysis to enable deployment across **transportation**, **renewable power** and **manufacturing** industries to reduce energy consumption and increase service life.

Technical Innovation – State-of-the-Art

- Today's Surface Engineering:
  - Hard carbon coatings
  - Fast boriding
- Issues:
  - Insufficient mechanical **substrate support for** the hard **coating**
  - **Insufficient hardness** of borided layers for extreme applications
  - **Corrosive attack of substrate through pinholes in thin coating**

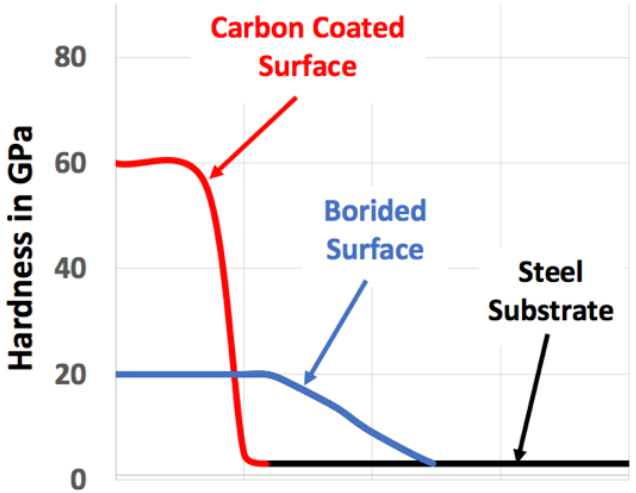


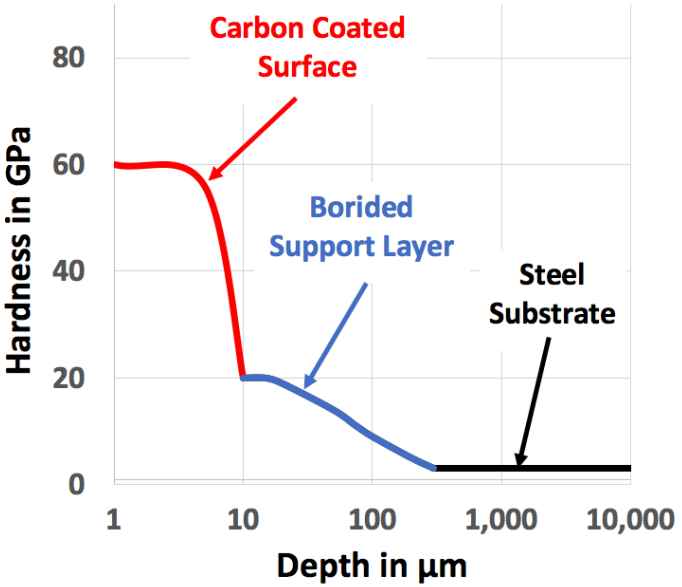


(Boride-carbon hybrid technology to produce ultra-wear and corrosion resistant surfaces for applications in harsh conditions)

Technical Innovation – New Approach

- **Hybrid Treatment**: Fast Boriding + Hard Carbon Coatings
- Advantages:
  - Tailored **mechanical substrate** support for the hard coating by thicker boride support layer
  - **Corrosion protection** by thicker boride support layer
  - **Economical** due to ultra fast electrochemical boriding process

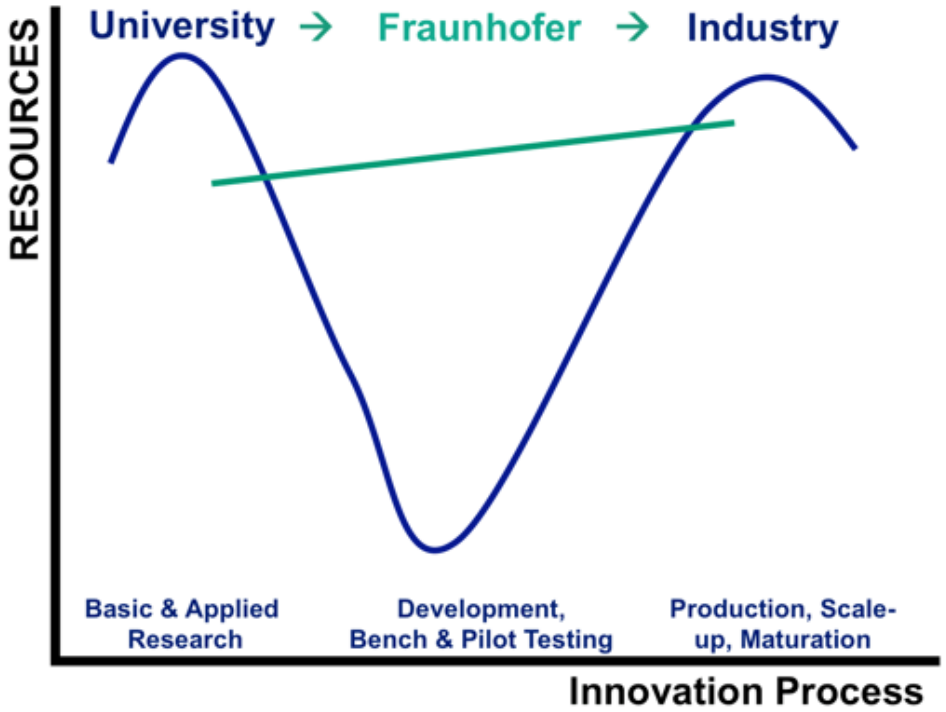




(Boride-carbon hybrid technology to produce ultra-wear and corrosion resistant surfaces for applications in harsh conditions)

Technical Approach – Unique Attributes

- Unique collaboration to **bridge the innovation gap**:
  - University,
  - National Laboratory,
  - Fraunhofer,
  - Industry.
- **Risk reduction** through existing
  - Translational experience,
  - Equipment, infrastructure,
  - Precompetitive and cross-industrial approach.



MICHIGAN STATE UNIVERSITY

Argonne NATIONAL LABORATORY

Fraunhofer

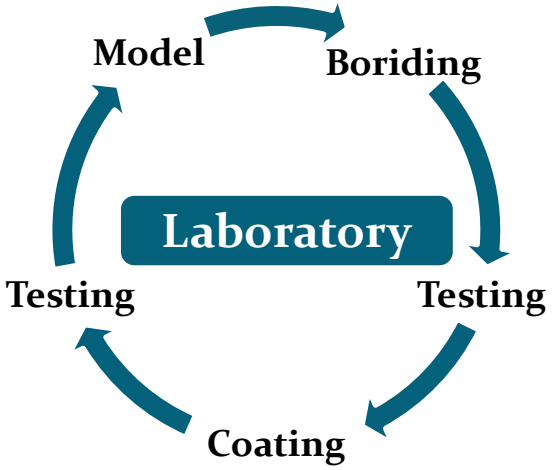
Cummins Fuel Systems

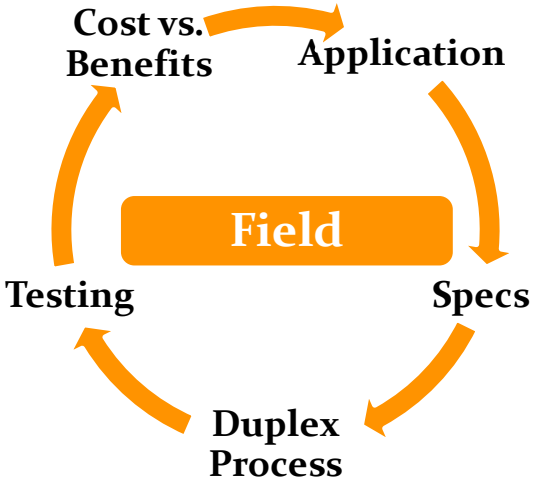
USA MERITOR

(Boride-carbon hybrid technology to produce ultra-wear and corrosion resistant surfaces for applications in harsh conditions)

Technical Approach – Team Roles

Boriding	Argonne NATIONAL LABORATORY
Coating	MICHIGAN STATE UNIVERSITY; Fraunhofer USA
Lab Testing	Argonne NATIONAL LABORATORY; Fraunhofer USA
Appl. Specs	Cummins Fuel Systems; MERITOR
Duplex Process	Argonne NATIONAL LABORATORY; Fraunhofer USA
Field Testing	Cummins Fuel Systems; MERITOR





(Boride-carbon hybrid technology to produce ultra-wear and corrosion resistant surfaces for applications in harsh conditions)

Results and Accomplishments

Milestones

- Diamond and ta-C coatings with good adhesion on borided parts made from industry relevant steels

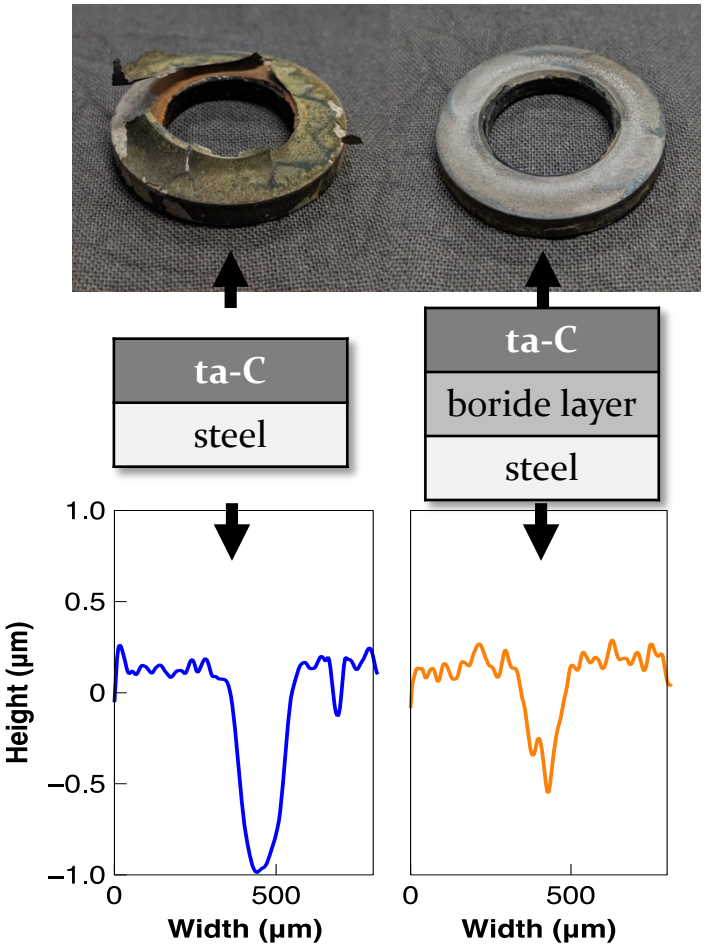
Accomplishments

- Duplex layers have better wear and corrosion resistance than single layers
- In contact with end-users

Future Work

- Fatigue Performance
- End-user specifications
- Cost-benefit model

After corrosion test, 15 % HCl for 3 h

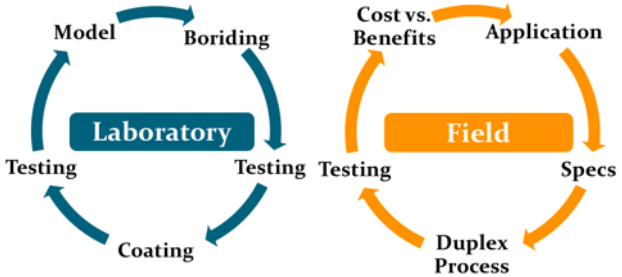


Wear profiles for ball-on-disk experiments (ta-C vs. ta-C)

(Boride-carbon hybrid technology to produce ultra-wear and corrosion resistant surfaces for applications in harsh conditions)

Transition

EERE Project → **Additional Application Development** → **Transfer & Implementation with Service Providers**



MICHIGAN STATE UNIVERSITY

Argonne NATIONAL LABORATORY

Fraunhofer USA

Cummins Fuel Systems

MERITOR

Who cares?

- Oil & gas,
- Mining,
- Rail vehicles,
- Heavy duty trucks,
- Cement and mineral processing,
- Hydro, wind and tidal energy,
- Automotive,
- …


Service provider facility

- **Component manufacturers** will work with **service providers** to treat parts adding value for the **end user**.
- If **benefits outweigh costs** for all, the technology will succeed as previous surface engineering technologies have demonstrated (e.g. coated cutting tools).

(Boride-carbon hybrid technology to produce ultra-wear and corrosion resistant surfaces for applications in harsh conditions)