Technology Brief: *Fabrication of Quasicrystalline Coatings on Conventional Engineering Materials*

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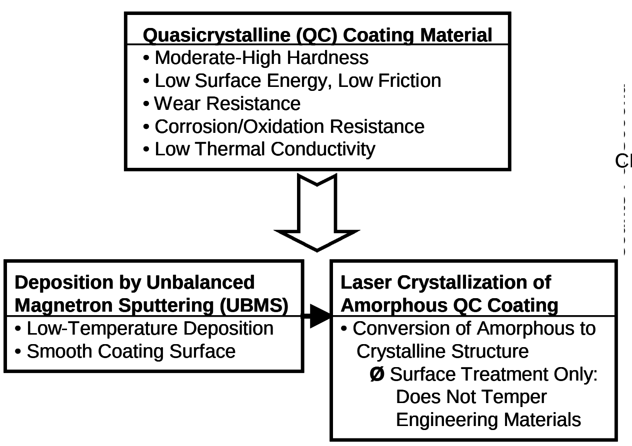
Technology Overview

Engineered Coatings, Inc. (ECI) is developing thin-film protective coatings, based on novel quasicrystalline (QC) Al-Cu-Fe-Cr materials, that offer a unique combination of low surface energy (non-wetting and low friction), corrosion /oxidation resistance, and low thermal conductivity. These coating materials cannot be fabricated on conventional engineering materials, such as Al, Ti, and bearing steel alloys, due to the requirement for high-temperature (e.g., 700°C) heat treatment to crystallize the QC material. Engineered Coatings, with Iowa State University and DOE-Ames Laboratory, have developed a process consisting of low-temperature physical vapor deposition (PVD) of amorphous (a) QC coatings, followed by localized laser crystallization to induce the formation of the crystalline form of the ternary alloy. These coatings offer protective surfaces for gears, bearings, and other components of moving mechanical assemblies. In addition, the thermal resistance of these coating materials are beneficial for engine applications, where higher operating temperatures increase energy efficiency.



Process Key Attributes
- Net-Shape, No Part Growth
- Low-Temperature Deposition and Surface Crystallization; Will Not Temper or Distort Parts

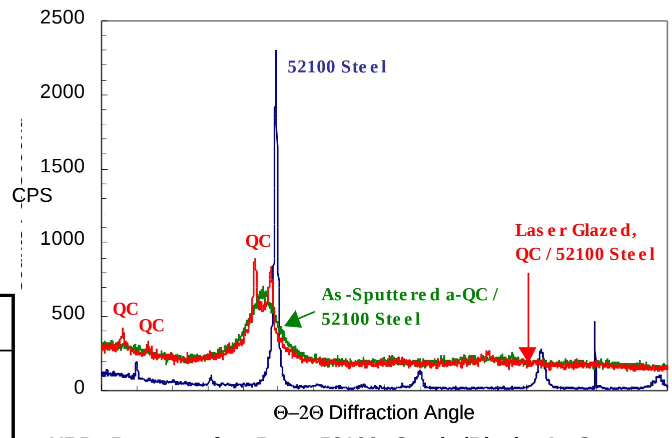
Applications
- Engine Components
- Gear, Bearing Surfaces
- Shafts

Benefits
- Thermal Insulation
- Increased Durability, Life
- Reduced Maintenance
- Reduced Costs / Increased Profits

The ECI-developed coating process includes low-temperature, net-shape PVD deposition of a-QC coatings onto thermally-sensitive engineering materials, followed by laser crystallization surface treatment to convert the coating from an amorphous to crystalline material. Key features of the coating design, attributes, applications, and benefits are shown below.

Performance Results

Optimization of both PVD deposition and laser crystallization treatment parameters has been conducted to ensure: 1) good coating adhesion and relative toughness, 2) coating crystallization without reduction in the substrate hardness, and 3) reduction in coefficient of friction and wear damage for non-lubricated wear couples. Best adhesion has been obtained using moderate substrate heating during sputter deposition of amorphous QC material. Laser crystallization using a pulse energy level of >50-56 mJ resulted in conversion of the amorphous to a crystalline icosahedral structure (see Figure below), without reducing the hardness of the underlying substrate.



XRD Patterns for Bare 52100 Steel (Blue), As-Sputtered Amorphous QC Coating (Green), and Laser Treated c-QC Coating (Red) Showing Characteristic Icosahedral Peaks (QC) for Laser Treated Coating.

Crystalline QC coatings exhibit a hardness of about 11-15 GPa (harder than non-coated bearing steel, 11 GPa), 2) a low dry coefficient of friction (COF), which reduces with time (see Figure below) and specific counterface materials (e.g.,

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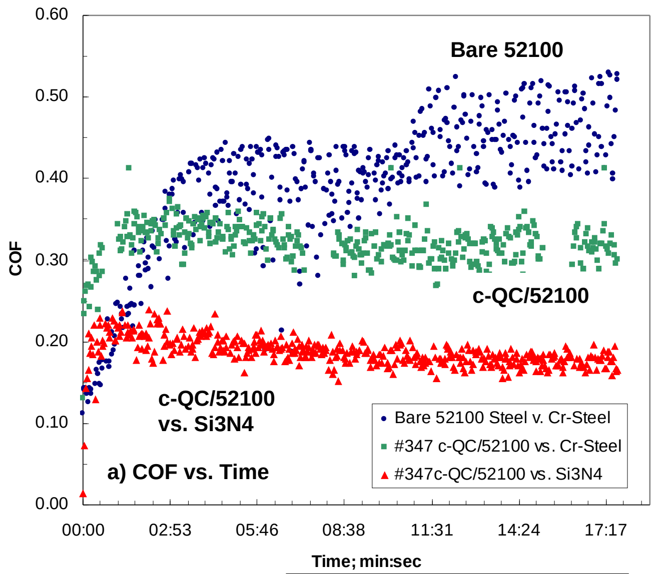
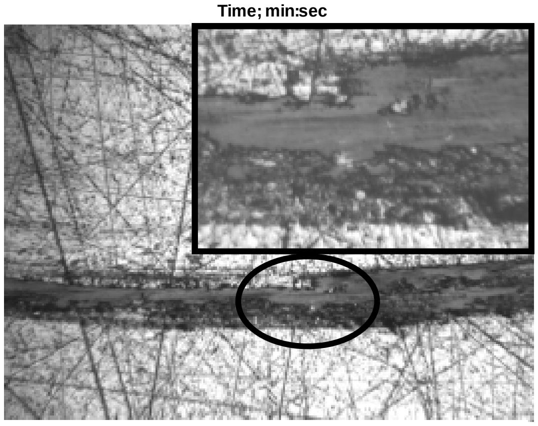
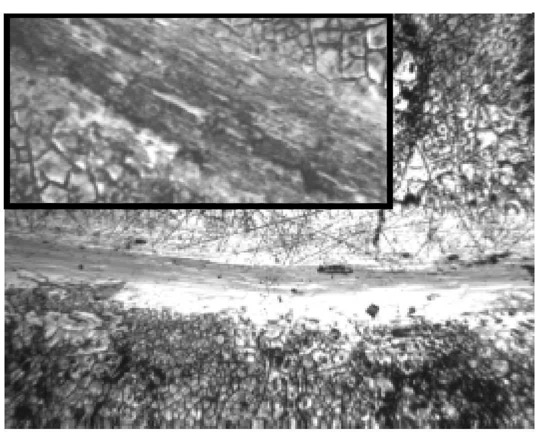




b) Significant Wear Damage for Non-coated 52100



c) Reduced Wear for c-QC Coated 52100

COF vs. Time (a) and Wear Scars for Bare 52100 (b) and c-QC Coated 52100 (c) Showing Lower Friction (Green and Red Traces) and Reduced Wear for c-QC Coating.

silicon nitride) , and 3) minor wear damage.

Technology Status

The quasicrystalline coating technology is currently under development by ECI under a Small Business Innovative Research (SBIR) program sponsored by the National Science Foundation (NSF). The anticipated Phase II effort will consist of integration of a laser within a PVD vacuum chamber and further coating and laser parameter optimization. This equipment integration will enable laser crystallization immediately after sputtering, without vacuum break, which will reduce processing time and cost.

Industry tests/evaluations of both amorphous and crystalline QC coating technology are being conducted by a coating toll service vendor and a major transportation company. The diesel engine manufacturer is conducting evaluations of the QC coating for non-wetting applications.

Technology Evaluation Opportunities

Engineered Coatings welcomes and encourages mechanical system designers to consider evaluation of this unique quasicrystalline lubricant coating technology. Our materials scientists/engineers will assist in coating materials recommendations and processing approaches to solve your surface-related problems.

Engineered Coatings routinely conducts small-scale coating feasibility trials for customers. If required, we can also perform coating screening tests, including ball-on-disk wear, galling, and simulated fretting wear evaluations.

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