the ENERGY lab

PROJECT FACTS

Hydrogen Turbines

FARADAYIC ElectroPhoretic Deposition of YSZ for Use in Thermal Barrier Coatings—Faraday Technology

Background

Thermal barrier coatings (TBCs) are employed to protect gas turbine engine components. These coating systems provide thermal, oxidation, and mechanical protection; reduce thermal gradients; and lower the metal substrate surface temperature, extending the life of the engine components.

Faraday Technology, Inc. (Faraday) is developing a new manufacturing process, the FARADAYIC Electrophoretic Deposition (EPD) process, for TBC deposition of yttria-stabilized zirconia (YSZ) onto gas turbine components. It should be further noted that the EPD coating process can deposit any material that can be manufactured into submicron powder form; thus it is not restricted to YSZ (which is a conventional and commercially available TBC) and would also be applicable for other advanced TBC material sets that have the desired low thermal conductivity and toughness necessary for increased turbine operating temperatures.

This project is managed by the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL). NETL is researching advanced turbine technology with the goal of producing reliable, affordable, and environmentally friendly electric power in response to the nation's increasing energy challenges. With the Hydrogen Turbine Program, NETL is leading the research, development, and demonstration of these technologies to achieve power production from high hydrogen content fuels derived from coal that is clean, efficient, and cost-effective, minimizes carbon dioxide (CO_2) emissions, and will help maintain the nation's leadership in the export of gas turbine equipment. This project was competitively selected under the Small Business Innovative Research (SBIR) Program.

Project Description

The FARADAYIC EPD process combines conventional EPD with pulsed electric fields to induce migration of charged particles in a suspension to uniformly deposit the TBCs onto the gas turbine components. Figure 1 shows a schematic drawing of a FARADAYIC pulse reverse electric field used to electrically mediate the applied electric field during the FARADAYIC EPD process. It is a non-line-of-sight process, making it suitable for coating complex shaped components with a TBC of controllable thickness and a microstructure that is sufficiently strain tolerant to survive in the turbine environment. Deposition experiments have been performed on substrate alloys currently used in turbine engines. Faraday is investigating thermal sintering as well as alternative techniques, such as directional heating and microwave and infrared sintering, for post processing of EPD coatings. Faraday also completed preparation for testing that will simulate the conditions experienced within a jet turbine engine. The most rigorous simulation, short of testing within an actual turbine engine, is to test the coating on a rig that uses burning jet fuel to heat the samples. Faraday is working with a partner who will use an interturbine burner rig to compare TBCs deposited by conventional coating technologies with TBCs deposited by the FARADAYIC EPD process.

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PARTNERS

University of Dayton Research Institute

PROJECT DURATION

Start Date	End Date
06/27/2005	08/06/2011

COST

Total Project Value
$1,099,992

DOE/Non-DOE Share
$1,099,992/$0

AWARD NUMBER

ER84202

U.S. DEPARTMENT OF ENERGY

Goals and Objectives

The goal is the optimization and validation of the FARADAYIC EPD process for deposition of TBCs with the appropriate microstructures to prevent coating failure during standard and accelerated turbine engine operation in natural and syngas environments. Fiscal year (FY) 2011 objectives are as follows:

- Optimization and validation of the FARADAYIC EPD process for deposition of TBCs with the appropriate microstructures to prevent coating failure during standard and accelerated turbine engine operation in natural and syngas environments.
- Development and validation of a post deposition thermal treatment for the EPD coatings to preserve the necessary microstructure to maintain coating durability and reliability during operation.
- Qualification of coating durability and reliability through appropriate tests of merit; for example, thermal stability, thermal cycling, thermal conductivity, etc.

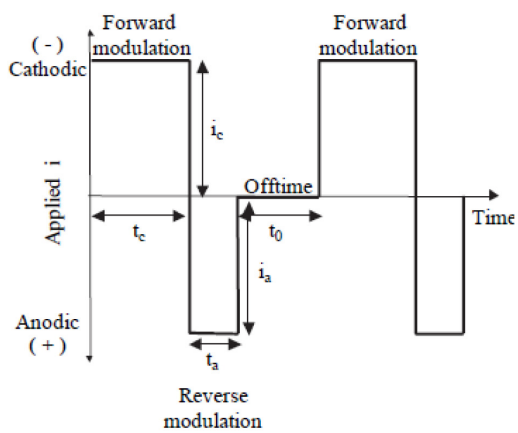
Accomplishments

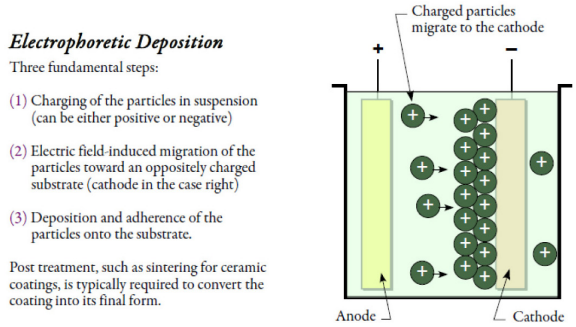
Program results have demonstrated that the TBCs deposited by the pulse/pulse reverse EPD process have a porous, laminar coating microstructure, exhibit decreased surface roughness and enhanced uniformity when compared with TBCs deposited by conventional EPD, provide favorable results in preliminary and long term thermal cycling tests, exhibit low thermal conductivity, and do not reduce cooling hole diameters during deposition. In addition to the technical benefits, the enabling manufacturing process equipment is expected to be affordable and relatively simple to operate. Specific FY 2011 accomplishments include the following:

- Demonstrated FARADAYIC EPD process for application of TBCs onto a turbine blade that can reduce surface roughness and hydrolysis related coating defects observed during conventional EPD.
- Completed construction of a deposition cell for testing components in a simulated turbine environment.

Benefits

This SBIR project supports DOE's Hydrogen Turbine Program that is striving to show that gas turbines can operate on coal-based hydrogen fuels, increase combined cycle efficiency by three to five percentage points over baseline, and reduce emissions.





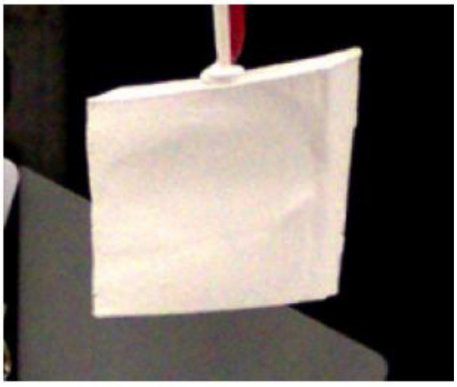
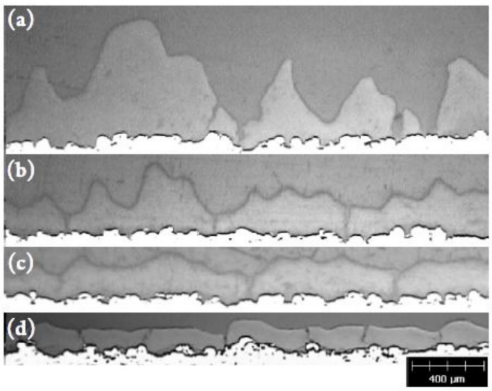
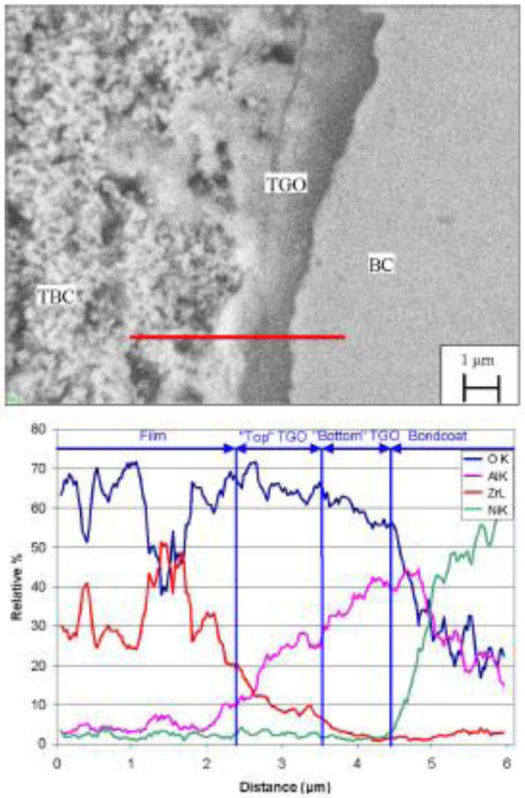


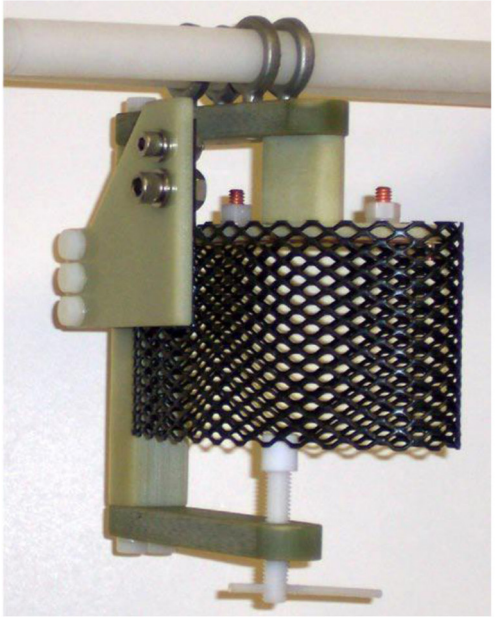
Illustration of FARADAYIC Electric Field Concept (top) and example photo of IN100 turbine blade coated by the FARADAYIC EPD Process (bottom).



Cross-section micrographs of (a) DC-EPD sample (295 µm) compared with FARADAYIC℠ EPD samples with (notation as duty cycle (γ)/frequency (f)) (b) high g/high f (185 µm), (c) medium γ/high f (190 µm), and (d) low γ/high f (102 µm). Notice a drastic decrease in peaks and valleys, leading to an overall better film quality.



Top: Characterization using scanning electron microscope/energy dispersive x ray spectroscopy (SEM/EDS) to examine the bond coat and substrate interfacial region subsequent to the post-deposition thermal treatment. The horizontal line depicts region scanned to determine compositions of layers and the diffusion of species throughout the TBC, thermal growth oxide (TGO), and bond coat (BC). Bottom: linear scan showing major constituents of the various layers. The TGO contains two distinct regions (an aluminum/zirconium-rich oxide phase and an aluminum-rich oxide phase) that are also evident in the picture.



Fixture for the ITB Rig Test Specimen, Includes the Tool (Counter Electrode).