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PROJECT FACTS

Hydrogen Turbines

An Alternative Low-Cost Process for Deposition of MCrAlY Bond Coats for Advanced Syngas/Hydrogen Turbine Applications—Tennessee Technological University

Background

One of the material needs for the advancement of integrated gasification combined cycle (IGCC) power plants is the development of low-cost effective manufacturing processes for application of coating architectures with enhanced performance and durability in coal derived synthesis gas (syngas)/hydrogen environments. Thermal spray technologies such as air plasma spray (APS) and high-velocity oxy-fuel (HVOF) are currently used to fabricate thermal barrier coating (TBC) systems for large land-based turbine components. In this research Tennessee Technological University (TTU) will develop metal chromium-aluminum-yttrium (MCrAlY; where M = nickel [Ni], cobalt [Co] or a mixture of Ni and Co) bond coats via an alternative low-cost electrolytic codeposition process. In contrast to thermal spray processes, the electro-codeposition process offers advantages such as non-line-of-sight deposition and the capability of producing dense and oxide-free coatings.

This project was competitively selected under the University Turbine Systems Research (UTSR) Program that permits academic research and student fellowships between participating universities and gas turbine manufacturers. Both are 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.

Project Description

The proposed MCrAlY bond coats will be synthesized via an electrolytic codeposition process, followed by a post-plating heat treatment. Figures 1 and 2 are schematics of the laboratory electro-codeposition process and the targeted microstructure of the as-deposited coating, respectively. In contrast to traditional electro-codeposition processes where sulfate or sulfamate bath is used for Ni/Co deposition, a sulfur-free electrolyte will be employed to control the impurity levels in the MCrAlY coatings. The reduced sulfur

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PARTNERS

None

PROJECT DURATION

Start Date	**End Date**
09/12/2011	09/11/2014

COST

Total Project Value
$466,515

DOE/Non-DOE Share
$371,288/$95,227

AWARD NUMBER

FE0007332

U.S. DEPARTMENT OF ENERGY

(S) levels will be expected to improve oxide scale adhesion. The amounts of Cr, Al, and particularly the Y reservoir, in the MCrAlY bond coat will be optimized to extend the lifetime of the TBC system. Reactive elements such as Y + hafnium (Hf) or Y + zirconium (Zr) will be co-doped into the MCrAlY coatings by modifying the composition of the CrAlY alloy powder. The composition of the CrAlY+ alloy (where "+" equals Hf or Zr, etc.) will be carefully designed, based on the literature data for model MCrAlY alloys and other types of MCrAlY coatings. Other parameters of the electrolytic codeposition process will be systematically studied using a design-of-experiment approach to provide a fundamental understanding of their synergistic effects and to optimize the coating composition and microstructure.

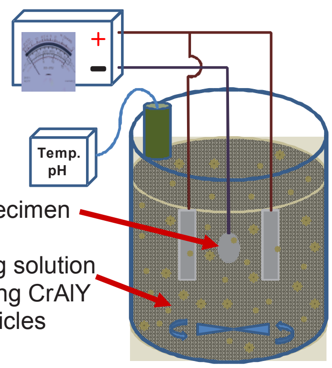

Figure 1. Laboratory electro-codeposition process.

Goals and Objectives

The goal of this project is to develop and optimize MCrAlY bond coats for syngas/hydrogen turbine applications using a low-cost electrolytic codeposition process. The coating performance will be improved by reducing the impurity levels in the coating and by employing reactive-element co-doping. The oxidation resistance of the new bond coat will be assessed in water vapor environments with various water levels. The failure mechanism of the new TBC/bond coat architecture will be studied to provide a knowledge base needed for further extending the TBC lifetime.

Specific objectives include:

- Exploring a sulfur-free plating solution (to replace conventional sulfate or sulfamate plating bath) with the aim of reducing impurity levels (particularly sulfur) in the MCrAlY coatings. This is expected to improve the oxidation resistance.
- Co-doping reactive elements (e.g., Y+Hf or Y+Zr) into the bond coats via engineering the composition of the CrAlY-based powders to further enhance their oxidation performance.
- Optimizing the electro-codeposition parameters using a design-of-experiment approach to provide a fundamental understanding of the synergistic effect of multiple variables on coating microstructure/composition and coating quality.

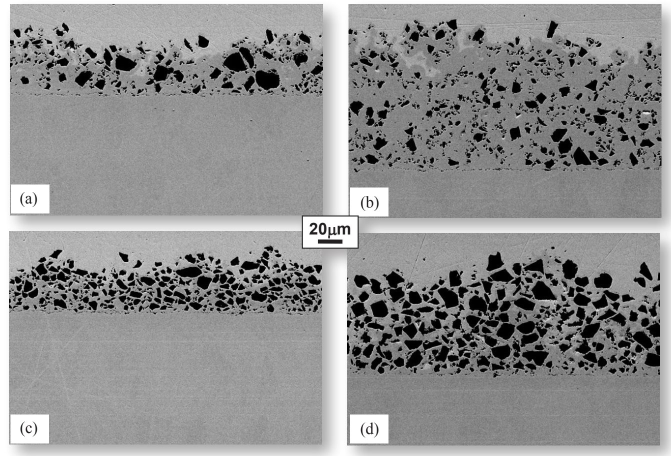

Figure 2. SEM cross-sectional images of the coatings codeposited with 10 g/L Cr-Al-Y particles in the solution. The current density and stirring speed were: (a) 20 mA/cm2, Stir #3, (b) 60 mA/cm2, Stir #3, (c) 20 mA/cm2, Stir #7, and (d) 60 mA/cm2, Stir #7.

Accomplishments

- Established a well-controlled laboratory process of fabricating Cr-Al-Y powder using arc melting followed by ball milling.
- Employed two electro-codeposition configurations, i.e., vertical and horizontal (also known as sediment codeposition) arrangements in synthesis of composite coatings consisting of the Ni matrix and the embedded Cr-Al-Y particles.
- Studied the effects of electro-codeposition parameters on Cr-Al-Y particle incorporation in the coating using a Design-of-Experiment approach.
- Investigated the potential of using a sulfur-free fluoborate-based nickel plating solution for electro-codeposition of MCrAlY coatings

Benefits

This UTSR 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. Successful application of the proposed electrolytic codeposition process will offer an alternative, economical fabrication route, with advantages such as non-line-of-sight deposition and capabilities for producing dense and oxide-free coatings, as compared with current low-cost thermal spray processes.

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