the ENERGY lab

PROJECT FACTS

Fuel Cells

Low-Cost Alloys for High-Temperature SOFC Systems Components — QuesTek Innovations

Background

One of the key opportunities for cost reduction in a solid oxide fuel cell (SOFC) system is the set of balance of plant (BOP) components supporting the fuel cell itself, including the heat exchanger and air/fuel piping. These represent about half of the overall cost of the system. A major enabling technological breakthrough is to replace incumbent nickel-based superalloys in high-temperature BOP components with low-cost ferritic stainless steel. However, the ferritic alloys are unsuitable for SOFC application without additional coatings due to the inherent volatile nature of the alloy's chromium oxide (Cr_2O_3) element, which tends to poison the fuel cell's cathode and leads to per-formance degradation.

QuesTek Innovations LLC (QuesTek) will apply its computational alloy design methodology and experience with high-Cr stainless ferritic alloy and oxidation modeling to create a novel low-cost alloy for SOFC BOP applications. QuesTek will evaluate various approaches to develop weldable alloys with low Cr volatility and high oxidation resistance under typical SOFC high-temperature (700 to 900 degrees Celsius), oxygen-rich operating conditions.

This fuel cell project was competitively selected under the Small Business Innovative Research (SBIR) Program. It is managed by the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL). With the SOFCs program and systems coordination from the Solid State Energy Conversion Alliance (SECA), DOE/NETL is leading the research, development, and demonstration of SOFCs for both domestic coal and natural gas fueled central generation power systems that will enable low cost, high efficiency, near-zero emissions and water usage, and carbon dioxide (CO_2) capture.

Project Description

QuesTek is uniquely positioned to design a new material for SOFC BOP components using its advanced *Materials by Design*® stage-gate alloy development process. The process is based on computationally-implemented mechanistic models to predict process-structure and structure property relationships at length-scales ranging from inter-atomic bonding to macro-segregation during ingot solidification.

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PARTNERS

None

PROJECT DURATION

Start Date	End Date
06/28/2012	03/27/2013

COST

Total Project Value
$149,768

DOE/Non-DOE Share
$149,768 / $0

AWARD NUMBER

SC0008236

U.S. DEPARTMENT OF ENERGY

QuesTek has generated two unique alloy micro-structural concepts to achieve cost effectiveness, oxidation resistance and low Cr volatility in its new alloys. One is an alumia-forming ferritic alloy that develops a thermally grown oxide layer with slow growth kinetics that serves as a Cr diffusion barrier on the alloy substrate and provides additional oxidation resistance. One of the concerns of this approach is the reduced room-temperature toughness due to high aluminum content. The other is an in situ spinel-forming ferritic alloy (similar to custom alloys such as Crofer 22) that grows a spinel oxide layer on top of Cr_2O_3 to reduce the Cr vaporization rate. Spinel systems with minimal Cr solubility and diffusivity will be incorporated into the alloy designs.

Goals and Objectives

The goal of this project is to design prototype alloys using an integrated suite of material design models and demonstrate the feasibility of the initial design by producing and proto-typing ingots and evaluating them against program goals including low Cr volatility, oxidation resistance, creep resistance, weldability, and cost. Specific objectives are as follows:

- Extend existing thermodynamic databases and refine and validate mechanistic computational alloy design models to enable computational design.
- Investigate the potential of two well-defined microstructural concepts to achieve performance criteria required for cost effective oxidation resistant and non Cr-volatile alloys for SOFCs with a particular focus on the BOP components.
- Design and produce a series of sub-scale prototype alloys that explore different aspects of microstructural concept space. These prototypes will be tested to demonstrate concept feasibility.
- Refine the present models with data from the micro-structural and property characterization.

Accomplishments

QuesTek has demonstrated the feasibility of applying its *Materials by Design*® approach to computationally design new alloys to address the technical challenges related to SOFC components. During the Phase I SBIR, QuesTek designed and fabricated prototype austenitic stainless steels that exhibited:

- Stable, continuous aluminum oxide layer with suppressed aluminum nitride formation.
- Good high temperature moist-air oxidation resistance.
- Low Cr volatility at high temperature and under moist conditions.
- Improved high temperature strength over 310 stainless.

Image of a 30 lb prototype steel ingot designed and produced by QuesTek

The performance of these prototype alloys approaches that of much more costly nickel-based alloys, and they exceed the performance of existing steels considered leading candidate materials.

Benefits

QuesTek's SBIR project assists the SOFCs program in meeting its cost and performance targets by ensuring that SOFCs can achieve reliable operation over an extended operating life. The program will ultimately enable fuel cell-based near-zero emission coal and natural gas power plants with greatly reduced water requirements and the capability of capturing 97 percent or greater of carbon at costs not exceeding the typical cost of electricity available today. Achieving this goal will significantly impact the nation given the size of the market, the expected growth in energy demand, and the age of the existing power plant fleet. It will also provide the technology base to enable grid-independent distributed generation applications. Federal funding support of this research is appropriate given the game-changing nature of the technology accompanied by risks higher than the private sector initially can accept.

SC0008236, May 2013