Problem Statement

Cost is a key barrier to widespread commercialization of SOFCs. To make SOFC systems more manufacturable and reduce system costs, system developers, wherever possible, have substituted lower cost stainless steels into the stack design. However, for successful implementation of these stacks, protective coatings are necessary to prevent the air-facing metal surfaces from high temperature oxidation and to minimize chromium volatility from the metallic cell. Consequently, protective coatings must be evaluated to determine compatibility and degradation in cell performance.

For metallic interconnects the active area needs to be electrically conductive to minimize ohmic losses through the cell, whereas the primary functions of the non-active, seal area of the interconnect are to provide a sealing surface and to be chemically inert. Unfortunately chromium-forming steels interact with oxidative aluminate oxide residues, forming SiO2 and BaOx. These low TEC compositions lead to rapid failure during stack thermal cycling.

Interconnect Coating Solution

NexTech has developed multiple coating approaches to target the different functions associated with different areas of the interconnect.

For the cost-effective advantages offered by metallic interconnect designs, coating approaches must be size-scalable if and allow high volume throughput at low capital costs. NexTech has identified and developed a spray-deposition process (ASD) for depositing protective coatings on a range of substrates. The process is amenable to high-volume production and capable of providing low-cost coatings.

Cost-Effective Aluminization Coatings

Aluminate coatings oxidize to form self-repairing aluminate scales that enhance alloy corrosion resistance in high-temperature applications. Conventionally, aluminate coatings are produced by vapor deposition or plasma-spraying processes, which require controlled atmosphere bubbling of reactive gases to promote oxide formation. Two approaches, batch processes that require controlled environments. [7] Unfortunately, the high cost of these processes has restricted their limited applicability in SOFC applications.

For aluminate diffusion coatings to be commercially viable for SOFC applications, lower-cost coating processes are required. Researchers at Pacific Northwest National Laboratory (PNNL) have demonstrated a reactive aluminide (RAlA) process which does not require a controlled atmosphere heat treatment. [2,3]

Outside SOFCs, similar air-fired spray/sputter aluminate processes have been reported by the PARTICOAT consortium in Europe to deposit complete thermal barrier coatings (TBC) systems on nickel-based superalloys. [4,5]

Non-planar Components

A modified dip-coating process has been developed to allow both overall and diffusion-based coatings to be uniformly applied to non-planar components. The images below show an outer diameter Inconel 600 tube that has been successfully aluminate dip-coated. This will leverage NexTech’s commercial process technology for applying conventional oxide protective coatings to ferritic steels. The ASD process has been translated from the laboratory to pilot scale manufacturing at NexTech. It is anticipated that these approaches will expedite commercialization of the aluminate process.

Manufacturing Challenges

Manufacturing challenges that may limit the adoption of the coating technology are being identified and ranked and coating strategies to address them are being developed. Many of the challenges are associated with the wide-range of possible applications and environments the coating could be subjected to.

Aluminization Based SOFC Protective Coatings

Compatible non-active seal area coatings for interconnects

NexTech has developed two complementary coating products for protecting the non-active seal area. The first is based on mouluding oxide overlay coatings, the second on an aluminate diffusion coating. NexTech has evaluated interconnect seal-face overlay coatings in SOFC stacks and has demonstrated a significant improvement in both fuel utilization and stack power density. A cost analysis for the two coating scenarios indicates a significant cost-reduction is possible if the aluminate process can be substituted for the current overlay coating process.

Cost and Manufacturing Analysis

Translation of Pilot Scale Processing to High-Volume Production

Today, NexTech has the ability to cost approximately 10,000 interconnects per year. However, through collaboration with equipment manufacturers and industrial process integrators, we are designing a plant that will move our pilot’s line capabilities from small run prototypes to scale up to high-volume manufacturing where the coating process can cost up to 12 million interconnects per year.

Multiple Coatings Cost-Analysis

A detailed cost model has been developed for a range of interconnect coatings.

- MCO cathode active area coatings
- Aluminization based, non-active seal area coatings
- Dual MCO/aluminaulation based coatings.

Cost curves for annual production volume from 100,000 to 4 M have been shown. Parts are assumed to be: 15 cm to 15 cm with a 10 cm active area, 20 cm high and MCO and alumination based coatings are assumed. Various manufacturing scenarios are built into the model including:

- Batch versus continuous production
- Incorporation of automated part handling/transfer and integration as production volume increases
- Integrated spray coating systems

The contribution of the different process steps to the overall coating cost for the different coating scenarios is shown below. The significant savings in combining the two coating processes (MCO and alumination) is driven by a reduction in overhead expenses. In addition, work is in progress to optimize the capability of the MCO and alumination processes for further cost reduction.

Cost breakdown at annual volume production of 1 M parts for NexTech’s ASD-based interconnect coating process as follows:

- MCO coating: 15% of overall coating cost
- Alumination: 35% of overall coating cost
- Diffusion Coating and Transfer: 45% of overall coating cost
- Alumination/Preparation: 5% of overall coating cost

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Footnotes:


Figure 1: Schematic of proposed high-volume manufacturing plant for NexTech’s interconnect coating products.