Application 2023

Electrochemical properties evaluation of multi-layered thermal spray coatings for Solid Oxide Fuel Cells

Nicolaie Markocsan, Mohit Gupta

University West, Trollhättan, Sweden

INTRODUCTION

This application is related to a project carried out at University West that focuses on the development of new SOFCs which outperform (lower cost and better durability) and are better suited for large scale production than the current state-of-the-art. This will be mainly achieved by developing multilayered coating systems with nano-structured morphology using emerging thermal spray methods such as Plasma Spray - Thin Film (PS-TF) and Axial Suspension Plasma Spraying (A-SPS). Development of thin and dense electrolyte layers together with highly porous anode layers with a high density of triple boundary phases, sprayed on thin metallic substrates, are the main goals of our project.

OBJECTIVE

The objective of this application is to test the functional performance of the developed single cells as well as to study the degradation mechanism of the cells under high temperature and current loads.

BACKGROUND

Of all types of fuel cells, Solid Oxide Fuel Cells (SOFC's) deliver the highest electrical efficiency. However, high production costs and poor durability are key barriers to the widespread commercialization of SOFCs. An approach to reduce costs and improve durability that was introduced in this research was to use a thin and cost-effective metal supported cell structure. The inclusion of metallic supports brings the advantage of high electrical and thermal conductivity, superior toughness, better thermal shock resistance, and good workability which are highly attractive attributes for SOFCs. The most common technique for fabricating anode-supported SOFC's is wet ceramic powder slurries, which are solidified by sintering at high temperatures. However, it may be difficult to apply these wet ceramic fabrication methods to metal-supported SOFCs because the electrolyte sintering process could rapidly oxidize or densify the porous metallic supports. Therefore commercialization of SOFC on a broad scale depends, to a large extent, on thermal sprayed coatings, which improve the lifetime and efficiency of SOFCs. Thermal spraying is also better suited for large scale production of metal-supported SOFC's. Plasma sprayings high flexibility permits deposition of coatings with various microstructures and different thicknesses. Moreover the latest developments in plasma spraying (suspension and plasma spray thin film) bring unprecedented improvements in terms of possibilities to produce coatings with low thickness (from few to tenths of microns) and/or coatings with very low porosity (gastight), characteristics which were not available only few years ago and which are of key importance for high performance SOFC's. Suspension plasma spraying (SPS) is a modification of the traditional plasma spray process in which the feedstock powders are suspended in liquid for feeding to the plasma rather than being fed as dry powders with the use of carrier gas. The suspension permits the use of smaller feedstock powders (in the range of nano- and sub-micrometric size), why SPS can potentially produce much thinner and denser coating layers and more refined microstructural features than standard plasma spraying. It is also possible to mix in the liquid suspension two or more powder materials (e.g. Ni and YSZ) and then to produce homogenous and finely inter-dispersed anode layers with high density of triple boundary phases, which is a key issue in a high performance anode layer. A-SPS is the next generation of SPS methods that brings improvements such higher process flexibility, higher deposition efficiency and improved process stability. Plasma spray thin film (PS-TF) is another technology that was recently developed. It is a low pressure plasma spray technology to deposit coatings out of the vapor phase. The vaporized coating material is transported in a hot and supersonic gas stream (2000-4000 m/s, 6000-10000 K) which is expanding in a 1 mbar chamber controlled atmosphere. This leads to high growth rates and the possibility to create homogeneous and gas tight coatings with thicknesses of 2 ‘ 50 µm.

The above mentioned technologies have been evaluated in our previous work and they showed very promising results, as they enable nano-sized feedstock material. However the evaluation of the functional layers, nano-structured coatings and fabricated single cells is at an early stage. A detailed electrochemical analysis is required to evaluate bottlenecks and to adapt the above mentioned technologies to the specific needs of metal supported SOFC's.

ACTIVITIES

In this application we apply for an access to the SOFC testing facilities at KIT (SOFC, KIT04) to test the cells developed at University West. As KIT has already gathered a lot of experience in testing of metal supported cells in the previous years (European projects METSOFC, METSAPP, national funded projects NextGen-MSC, cooperation with FZ Jülich on MS-SOFC, contracts with industry) their experience will be highly valuable for performing the tests (i.e. adaptation of test setup, sealing of the cells, testing procedures), analyzing the testing results and drawing conclusions how to improve cell performance and durability.

It is planned to perform the tests within 3 testing campaigns for 3 generations of cells:

1. G0 cells which are already available
2. G1 cells with an improved performance due to optimized electrolyte and electrodes
3. G2 cells with an improved durability

Each campaign consists of two single cell tests (20 days of testing). In these tests the following cell properties will be evaluated:

1. OCV test - this test provides information about the gas tightness of the electrolyte as well as a possible short circuiting of the cell due to an insufficient coverage of anode / MS by the electrolyte
2. DC-performance test - by measuring CV-characteristics at different temperatures (550 - 850 °C) the cell performance will be evaluated

3. AC impedance spectroscopy test - electrochemical impedance spectroscopy will be applied to evaluate the different loss contributions, i.e. ohmic losses of the electrolyte and polarization losses of cathode and anode
4. Durability test - in a first step the durability of the cell is rated by comparing the cell performance (OCV, DC-performance, ohmic and polarization resistance) before and after the testing procedure (DC-performance test, AC impedance spectroscopy test). In case of a stable cell performance, G1 and G2 cells will be tested for a longer period of time (500 - 1000 h) at aggravated testing conditions (high temperature, current density and fuel utilization).

The expected technical results of this application are:

1. Evaluation of bottlenecks of the cells
2. Iterative improvement of the cells by eliminating these bottlenecks
3. Strengthening of University West's research capability and knowledge within the field of thermal spray coatings for high temperature applications

Furthermore the results of this application will be published in international journals and presented at conferences.

TIME PLAN

Since the experimental work of producing and optimizing the functional characteristics of the cells has an iterative character, several electrochemical testing campaigns as described above are required. After each campaign about 2 - 3 month are required for data analysis and post test analysis of the tested cells (SEM, TEM, carried out at University West). Based on the results of these analyses, an improvement and further development process will be started to eliminate the existing bottlenecks. The modification of the individual layers in the cell will required a timeframe of several weeks to months.