Improving The Performance of Anode Supported Tubular Solid Oxide Fuel Cells

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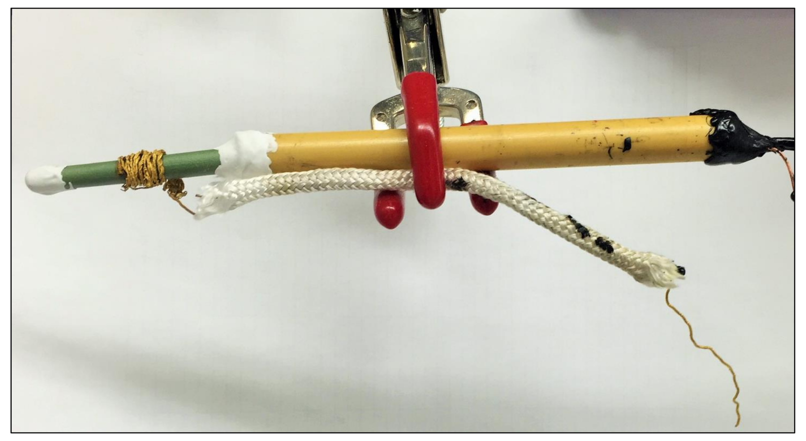
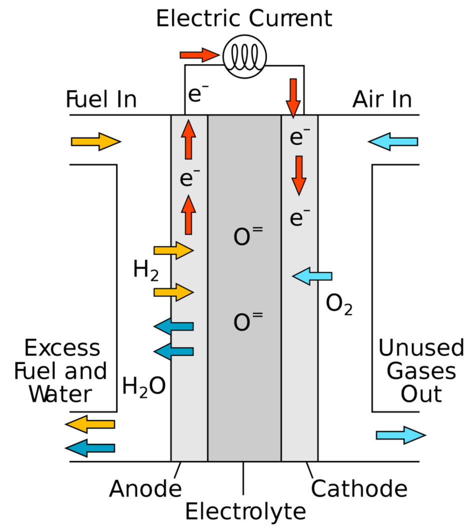
Introduction

A fuel cell is a device that produces electricity, water, and heat by converting an energy source (fuel) into a flow of electrons. This device has no moving parts, meaning that it is a long-lasting system that works silently and produces zero or near zero greenhouse emissions.





Solid Oxide Fuel Cells (SOFCs) are one of the five types of fuel cells; they are composed from a porous cermet (anode), solid ceramic electrolyte, and a porous mixed conducting oxide (cathode). They convert hydrogen and oxygen (the fuels) into water, and this process generates electricity.

The main advantages of SOFCs are that they are designed to be run on more than one fuel (fuel flexibility). They produce high quality waste heat that can be used for cogeneration application, and have a good power performance.

Electrode infiltration is known to be an efficient way to enhance the electrochemical performance of fuel cells by the introduction of nano-sized particles into the electrode structure. Depending on the type of infiltrates, they can enhance the electrical or ionic conductivities as well as improve the electrode catalytic activity.

Purpose

Improving the performance of tubular solid oxide fuel cells through infiltration of the anode. $Pr_{0.5}Ba_{0.5}MnO_3$(PBMO) is a new material which shows a great mixed electronic and ionic conductivities and excellent catalytic activity.

Experimental Procedure

1. Compose a mold by using gypsum and water in a weight ratio of 3:2 (Figure 1).

2. Prepare the anode support by combining 65:35 weight ratio of Nickel(II) Oxide (NiO) and Yttria-stabilized zirconia (YSZ) with deionized water in a bottle. Mix the solution for 72 hours in the ball mill. Correct the pH of the slurry to approximately 4 with diluted hydrogen chloride. Add graphite in order to make the anode support porous.

Figure 1

Figure 2

Figure 3

a) Pour the anode support slip into the mold. The slip in the mold will be dried after a set amount of time. Remove the dried tubular anode support from the mold, and place it in the furnace at 1000ºC for sintering.

b) Dip the tubular anode support into the YSZ electrolyte solution. Leave each anode tube in the electrolyte solution for 10 seconds, and repeat the process 5 times. Place the anode tubes in the furnace to sinter at 1400ºC for 3 hours.

c) Fill each of the anode supports with methanol blue for the leak test. If the blue dye is visible on the outside of the tubes, more electrolyte coats are required (Figure 2).

3. Apply thin porous layer (TPL) on 1cm length of the tube by dip coating, and sinter at 1350ºC for 3 hours (Figure 3).

4. Infiltrate the tubular anode support by filling the tube with PBMO. Place the tube inside the vacuum chamber; allow the solution to bubble to the top of the tube. Be careful not to overflow. Turn off the vacuum, and repeat the process 4 times. Then place it in the oven, and transfer the tube in the furnace at 350ºC. This procedure is completed 5 times at the end of which the tube is heat treated at 950ºC (Figure 4).

5. To infiltrate the cathode, first heat the tube in the oven. Then use a fine tip plastic pipette and apply a thin layer of Neodymium-Nickelate **(**Nd-Ni) over the TPL. Place it in oven then transfer it in the furnace at 350ºC. This procedure is done 4 times.

6. Repeat steps 1 to 5 for NiO/calcined YSZ (CYSZ) batch. CYSZ is YSZ heat treated at 1500ºC.

7. The fabrication of the fuel cell is completed, and ready for testing (Figure 5).

Figure 4

Figure 5

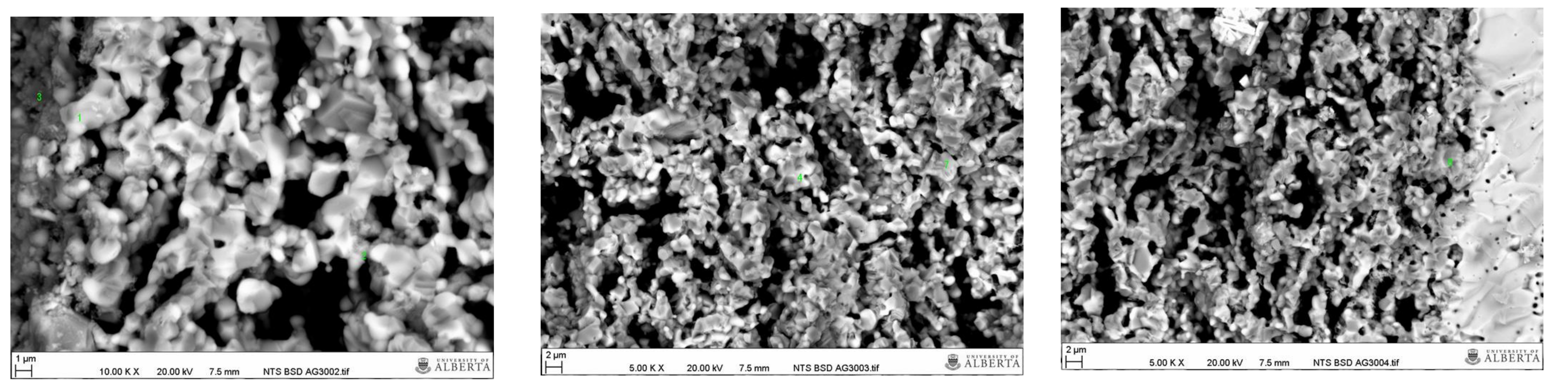
Results & Discussion

- The following metal salts were combined with water and the resulting solution was infiltrated: Manganese Nitrate ($MnNO_3$), Praseodymium Nitrate ($PrNO_3$), Barium Nitrate ($BaNO_3$).
- Higher the anode weight gain after each infiltration, higher the efficiency of the process.
- Objective: To achieve a minimum 5% weight increase after 5 infiltrations.

Anode Support Material	Actual weight gain after 5 infiltrations (%)
NiO/YSZ	0.3
NiO/CYSZ	2.12

- Porosity is an important factor in anode infiltration. Higher porosity leads to more effective infiltration.
- Porosity measurement was done for both the supports. As seen in the table below, the porosity for CYSZ support was almost twice the value for YSZ.

Anode Support Material	% Open Porosity	%Close Porosity
NiO/YSZ	22.31	5.42
NiO/CYSZ	42.51	6.51



Scanning Electron Microscope (SEM) images of Ni/CYSZ anode support infiltrated with PBMO. L to R: Energy Dispersive X-ray (EDX) analysis was done for quantitative measurement of elements at different points, marked on images.

Element	Point 3	Point 1	Point 2	Point 4	Point 7	Point 8
	Weight %					
Mn	5.99	1.09	1.33	0.96	0.70	0.80
Pr	12.79	1.05	2.95	1.24	0.21	0.44
Ba	12.67	0.46	0.36	0.28	0.00	0.49

As seen from EDX analysis given in table above :

- PBMO was successfully infiltrated throughout the cross section of anode.
- The concentration of Mn, Pr and Ba decreased with distance from the inside of the anode, which was directly in contact with the infiltrate solution.
- The concentration of the metal nitrates on the inside of anode made subsequent infiltration steps inefficient, leading to poor weight gain.

Future work

The future direction for this project is to:

- Increase the porosity of the anode support material.
- Manipulate the metal nitrate solution concentration and composition for improved infiltration.
- Electrochemical performance testing of a complete fuel cell

References

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- Scanning Electron Microscope lab in Biological Sciences

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