# Solid Oxide Fuel Cells


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## Introduction

With the continually increasing demand of fuel in modern times and the long-term goal of sustainability, fuel cell technology has become important and vital to further advancement in energy production. Solid oxide fuel cells (SOFCs) are of great interest because of their ability to generate energy using different fuel sources such as: hydrogen, carbon monoxide, hydrocarbons, and alcohols. SOFCs readily convert chemical energy from these fuels to electricity in an energy-efficient and environmentally-friendly manner.

## Operation Principle

A SOFC consists of two chambers: the anode chamber for fuel oxidation and the cathode chamber for oxygen reduction. The chambers are divided by a thin layer of electrolyte, which transports ions in addition to keeping the fuel and oxygen separate. From the reactions occurring in the two chambers, the fuel cell is able to accumulate power via current collectors such as silver paste and silver wires. This type of SOFC has a high power density and a high efficiency.

## Method

### Fabricating Fuel Cell Powders

*Step 1 - Synthesize electrolyte powder*

$Sm_{0.2}Ce_{0.8}O_{1.9}$

*Step 2 - Fabricate anode powder*

Nickel Oxide + Electrolyte

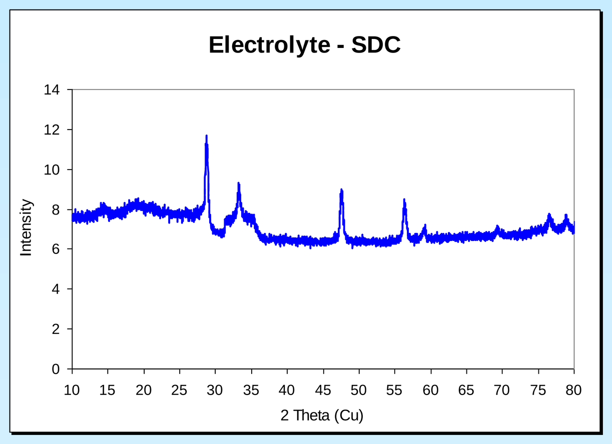
*Step 3 - Synthesize cathode powder*

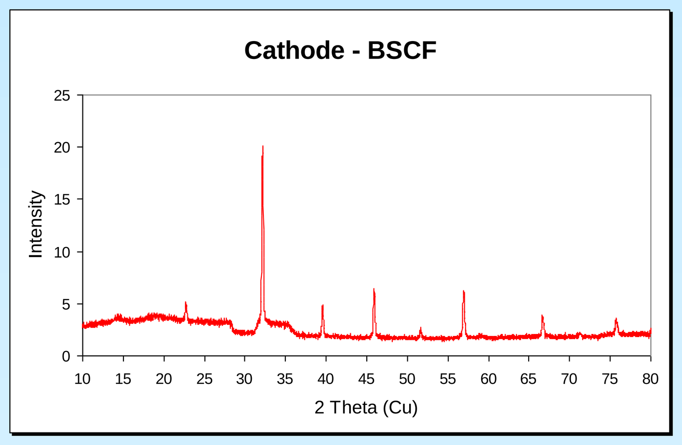
$Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$ (Low-Temperature SOFCs)
$La_{0.8}Sr_{0.2}MnO_3$ (High-Temperature SOFCs)

For steps 1-3, each powder was mixed with EDTA ($C_{10}H_{16}N_2O_8$), CA ($C_6H_8O_7$), and Ammonium Hydroxide ($NH_4OH$) in the following proportions to help produce nanoparticles:

Molar Ratio of EDTA:CA:Metal is 1:2:1
Molar Ratio of $NH_4OH$:EDTA is 4:1
Molar Ratio of $NH_4OH$:CA is 3:1

*Step 4 - X-Ray Diffraction Analysis*




These XRD results indicate that the electrolyte and cathode materials were successfully synthesized.

### Dry Pressing Fuel Cells

*Step 5 - Laboratory Press*

A layer of anode powder was evenly pressed. Electrolyte powder was added to the surface of the pressed anode and subsequently pressed.

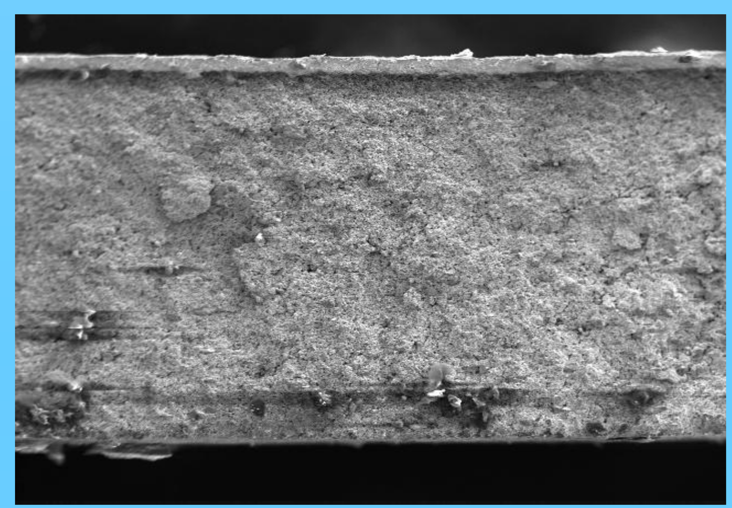
### Sintering the Fuel Cells

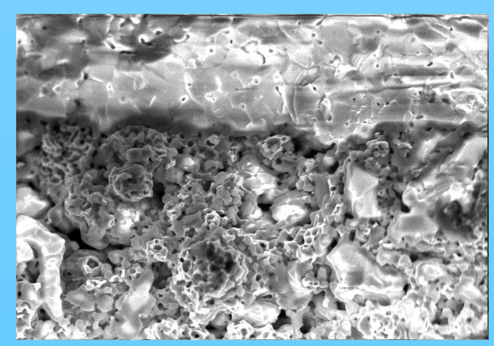
*Step 6 - Furnace*

The pressed fuel cells were placed in a high temperature muffle furnace at 1350°C for five hours for electrolyte densification.

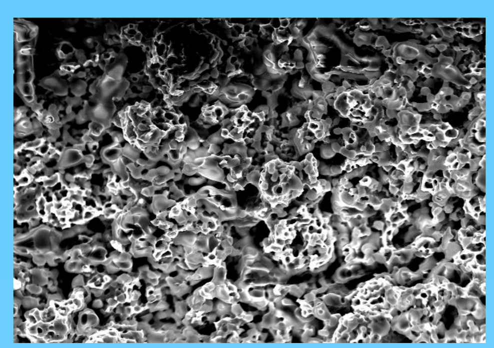
### Analyzing Fuel Cell Quality

*Step 7 - Scanning Electron Microscope Analysis*





Dense Electrolyte Layer

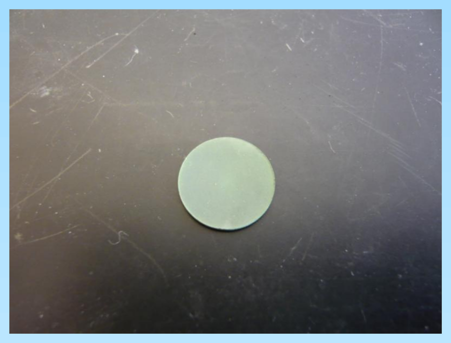


Porous Anode Layer

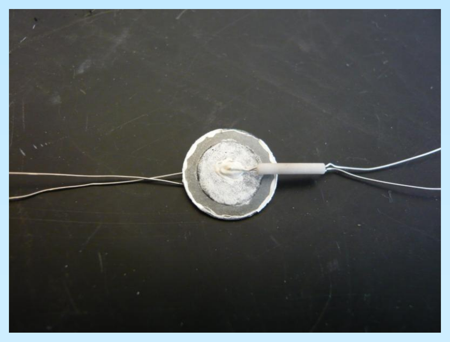
*Step 8 - Attach Current Collectors*

A cathode layer was sprayed onto the electrolyte and then coated with a thin layer of silver paint. Once dried, silver conductive ink was applied over it, holding two silver wires that were current collectors. The sintered fuel cells were tightly sealed to a quartz reaction chamber using silver conductive ink. The anode was exposed to the fuel inside the chamber, while the cathode was exposed to the air in the ambient lab environment.

Sintered Fuel Cell With Cathode and Silver Paint



Sintered Anode



Fuel Cell With Current Collectors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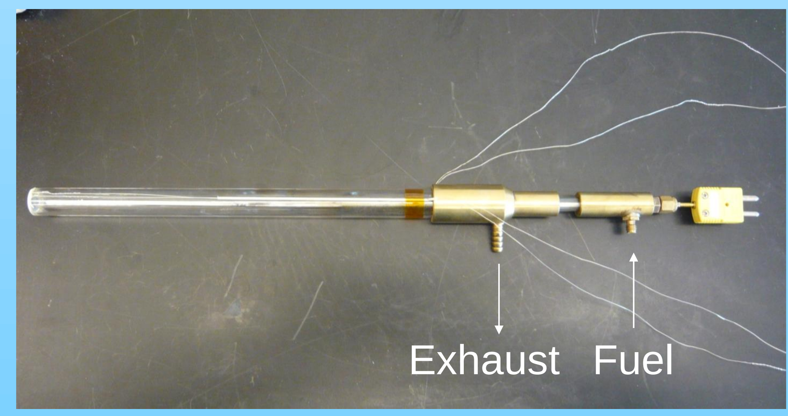
*Step 9 - Test Power Density*

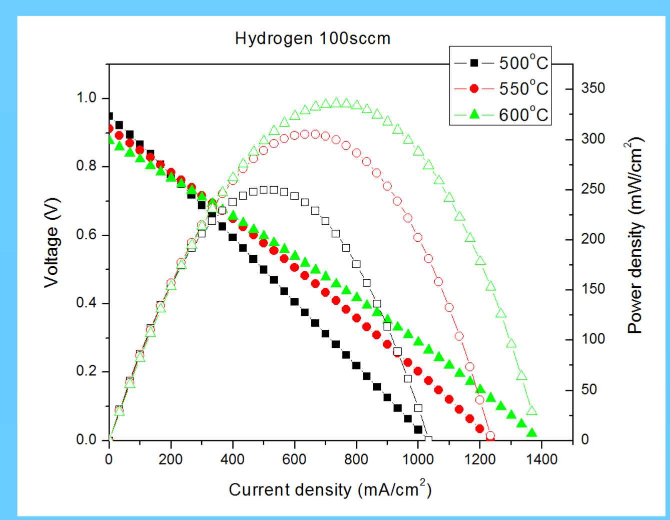
The silver wires were connected to a Keithley 2420 SourceMeter. The reactor was put in a vertical furnace with the following fuel inputs: ethanol at 0.8 mL/hr and hydrogen at 80 mL/min. The fuel cell was tested at three different temperatures: 500°C, 550°C, and 600°C. The SourceMeter measured current and voltage readings and plotted them in LabVIEW.

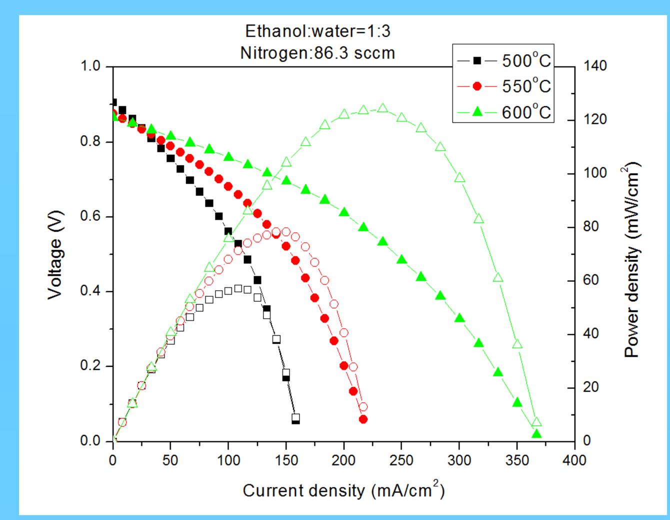
Current Collectors
Fuel Cell
Thermocouple




Fuel Cell Reactor

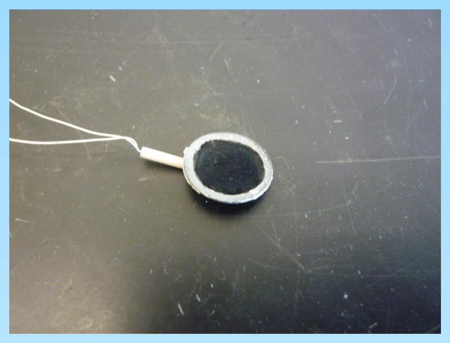
## Results




## Conclusions

Analysis of the powders by X-ray Diffraction revealed that the correct materials were synthesized. Furthermore, examination by a Scanning Electron Microscope of dry-pressed SOFCs indicated that they were successfully fabricated with porous anode and cathode layers and a dense electrolyte layer. Through testing the SOFCs in a dual-chamber reactor consisting of hydrogen and ethanol as fuel sources, the power densities were analyzed and the results indicated that the fuel cells were functioning properly.



Coking on Anode

## Future Work

Because fuel cell technology is still developing, future work on this project is necessary. Some areas of work are: synthesizing nanoparticle-sized powders; varying the thickness of compounds used in the anode, cathode, and electrolyte layers to find the most efficient composition; and further experimenting with different fuel types to find the optimal fuel source. Additionally, it is necessary to eliminate coking problems; one method of accomplishing this is adding a catalyst layer, such as ruthenium, on the anode.