Current Collection at the Anode in Tubular Solid Oxide Fuel Cells

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Introduction

- Solid Oxide Fuel Cells (SOFCs) are ceramic-based devices which convert chemical energy from hydrogen fuel to electricity and water[1] (Fig. 1).

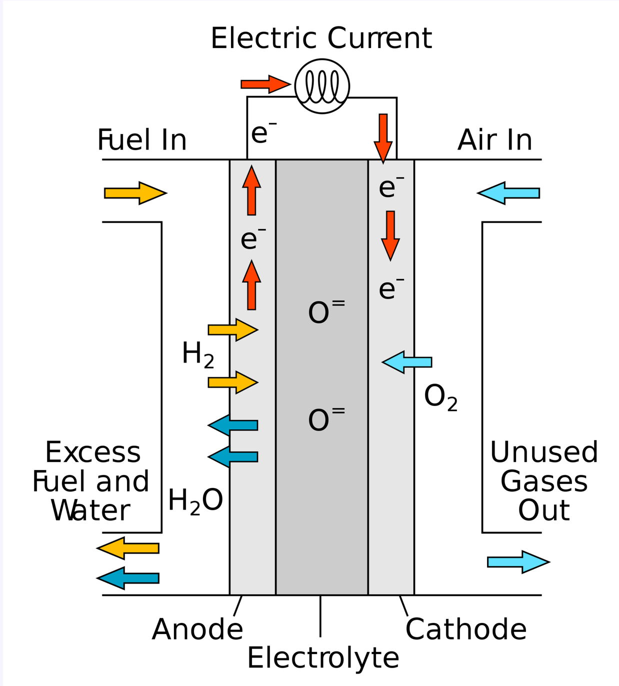

Fig. 1 (SOFC mechanism)[3, 4]

- Our lab is working with tubular cells, which are advantageous as they do not require sealing in stack formation, have better thermochemical properties, and are more applicable to large-scale power generation[2].
- However, the tubular cells have lower power density than planar SOFCs, in part because some efficiency of the cell is lost at the anode current collection point, where it is difficult to make a strong connection with the cell to complete the circuit.
- It is important to continue increasing the efficiency of fuel cells as they hold great potential as an environmentally-friendly, reliable, and long-lasting energy source, from small devices to power plants[1].

Purpose

To increase the efficiency and power output of tubular SOFCs through better methods and materials of anode current collection.

Methods

- The anode support was made of a NiO-YSZ (Yttria-Stabilized Zirconia) cermet with graphite powder and water, pH adjusted to 4.
- This material was slip casted in gypsum molds (Fig. 2), forming porous tubes with high conductivity and strong mechanical properties after 1000°C sintering.


Fig. 2

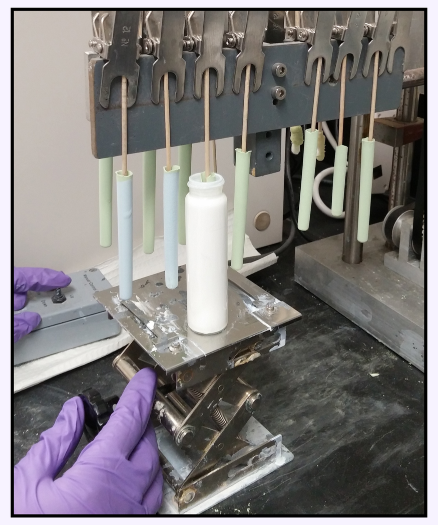
Fig. 3

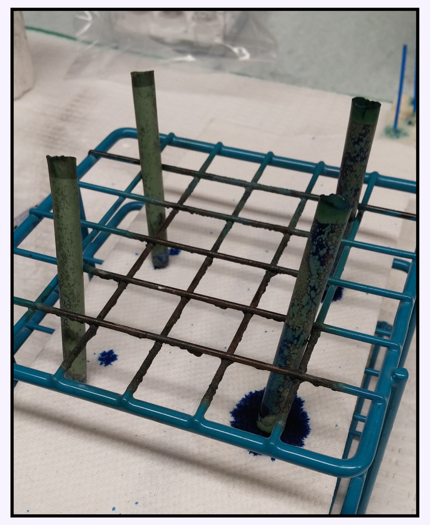
Fig. 4

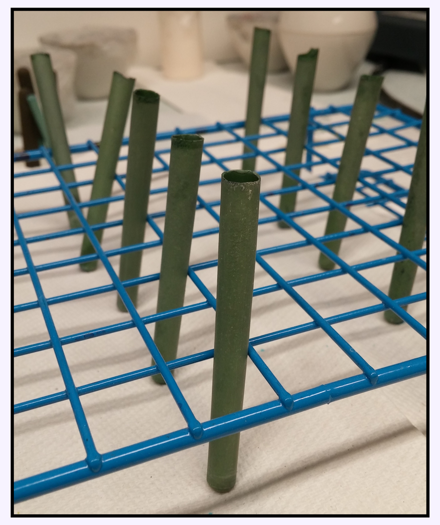
Fig. 5

- The anode was coated in an ethanol-YSZ electrolyte through dip coating (Fig. 3).
- Each tube was filled with methylene blue dye as a leakage test to see if more electrolyte needed to be applied (Fig. 4, 5).
- A 1cm wide section of each was dipped in TPL (Thin Porous Layer) as a framework for the cathode, then infiltrated with Nd-Ni to form the conductive and porous cathode layer (Fig. 6).

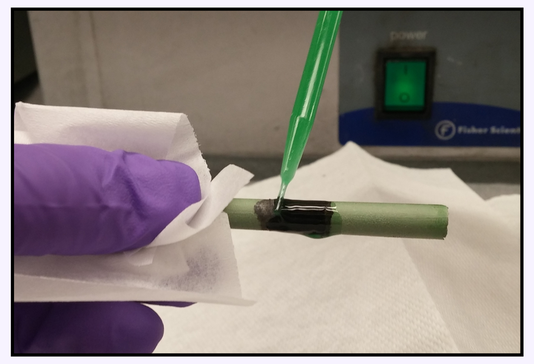
Fig. 6

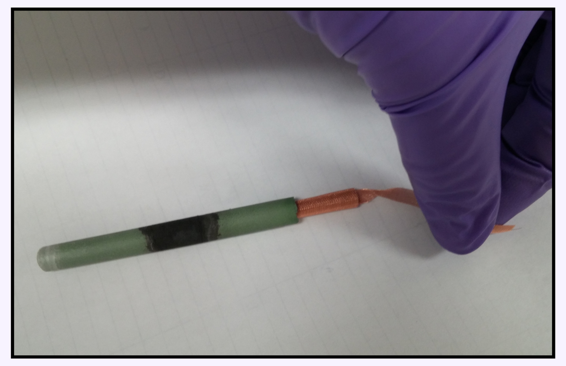
Fig. 7

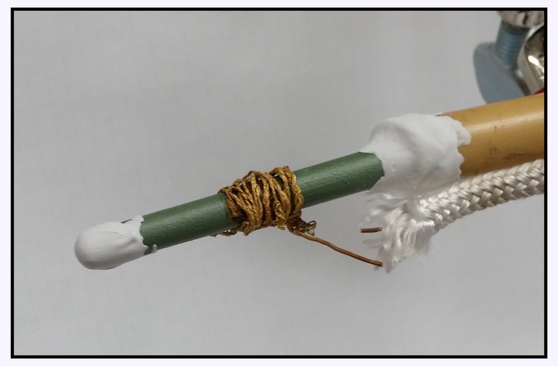
Fig. 8

- Each cell was set up with a different anode current collector (Fig. 7).
  - cell 1: copper mesh
  - cell 2: copper mesh with CuO/PMMA (50 volume% each) paste - PMMA is used as a pore former
- For our testing, each cell used gold wire and paste as the cathode current collector (Fig. 8).
- Cells were tested at 600, 650, and 700°C under H_2 carrying 3 vol% moisture at the anode and air at the cathode. Voltage and power were measured and graphed over time with increasing current.

Results

- Figure 9 shows the impedance of each cell. The cell with paste applied shows much greater impedance; fuel did not fully diffuse through the cell, limiting the reaction.
- The cell with a copper mesh current collector (Fig. 12) reached a power density of 442mW/cm² at 700°C, whereas the cell with copper paste (Fig. 13) reached 156mW/cm².
- Figure 11 shows the cell's internal structure
  - anode: 431.0 microns
  - dense electrolyte: 15.4 microns
  - cathode: 33.5 microns
- Figure 10 shows a section of copper paste, which has low porosity.

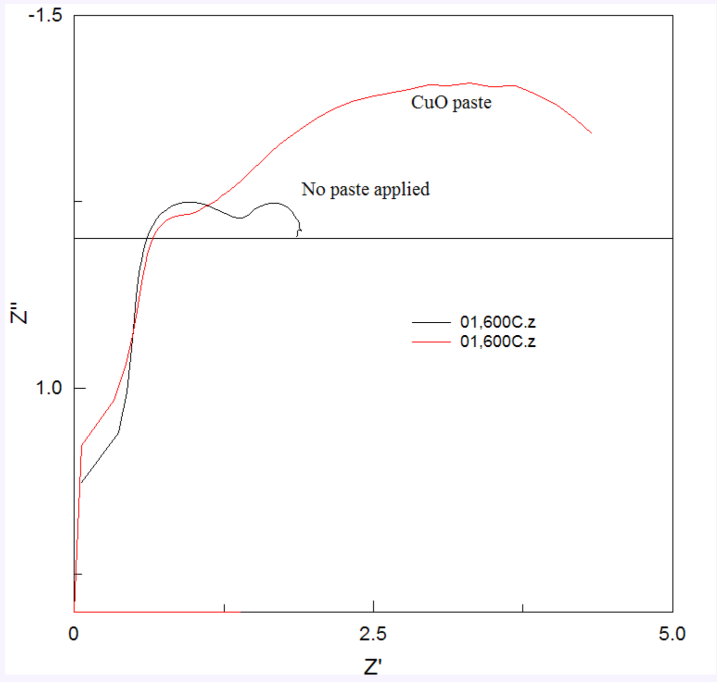

Fig. 9

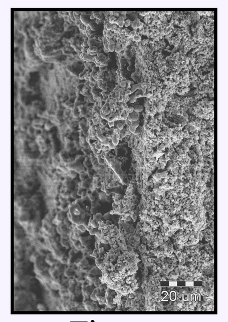
Fig. 10

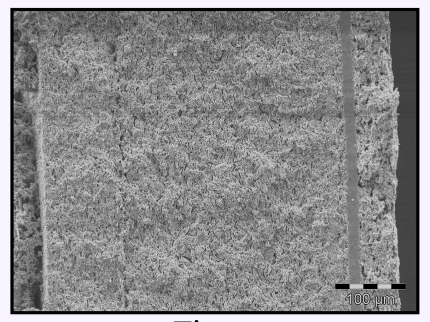
Fig. 11

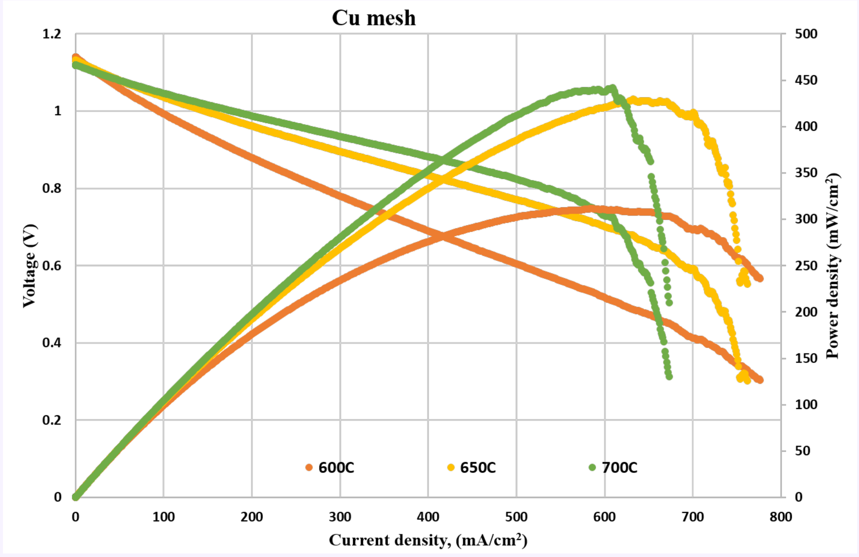

Fig. 12 (performance of SOFC with Cu mesh)

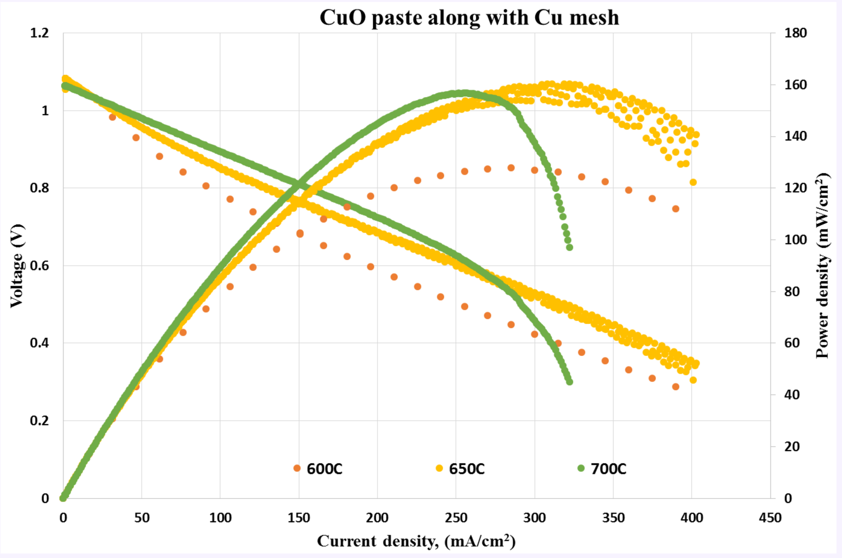

Fig. 13 (performance of SOFC with Cu mesh and paste)

Discussion

- From these results it can be concluded that the cell with copper paste as a current collector blocked gas diffusion due to its low porosity.
- The paste may still be a viable option to increase current collection, but it can only be effective while allowing for gas diffusion.
- The low porosity of the paste is most likely due to the high temperatures causing reduction and subsequent agglomeration of the fine copper particles.
- In future testing, we plan to create a higher porosity paste by using coarser copper oxide particles which are less likely to agglomerate.We will also test different materials such as silver and nickel.

References and Acknowledgments

1. O'Hayre, R., Cha, S., Colella, W., & Prinz, F. (2006). Fuel Cell Fundamentals. Hoboken, NJ: John Wiley & Sons.
2. Hanifi, A., Torabi, A., Shinbine, A., Etsell, T., & Sarkar, P. (2011). Fabrication of thin porous electrolyte-supported tubular fuel cells using slip casting. Journal of Ceramic Processing Research, 12(3), 336-342.
3. Public Domain image: Solid oxide fuel cell. (n.d.). Retrieved August 6, 2015, from https://en.wikipedia.org/wiki/Solid_oxide_fuel_cell
4. Based on image from: U. S. Department of Energy. (n.d.). Types of Fuel Cells. Retrieved July 25, 2015

The methods section of this poster was mainly derived from the SOFC Fabrication Standard Operating Procedure from the fuel cell lab.

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