COPPER-PLATED STAINLESS STEEL FOR BIPOLAR PLATES IN DIRECT-OXIDATION SOFC

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INTRODUCTION

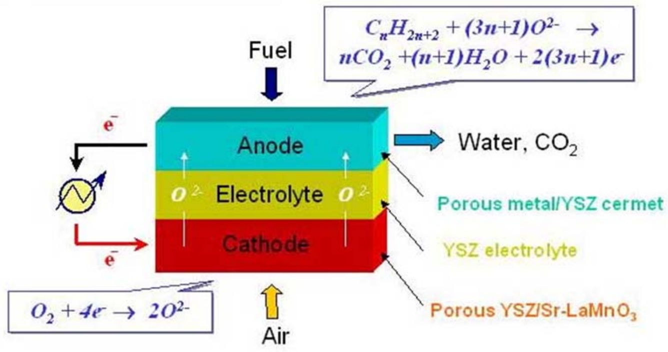
- Direct oxidation of dry hydrocarbon in SOFC
  - CeO_2, Cu catalyst in anode
  - 700^oC

- Gas-tight seals for an SOFC with a Cu-based anode in a stainless-steel bipolar plate

- Carbon formation is prevented when the steel is electroplated with a thin Cu film.

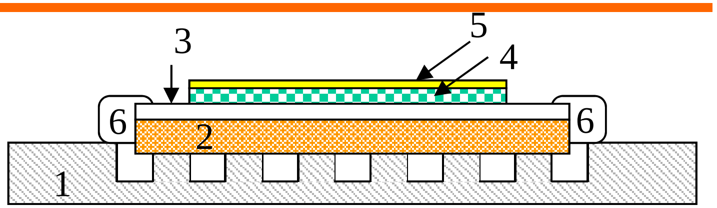
- Basic study for large scale stack and multi-stacking

SOFCs can theoretically operate on hydrocarbon fuels



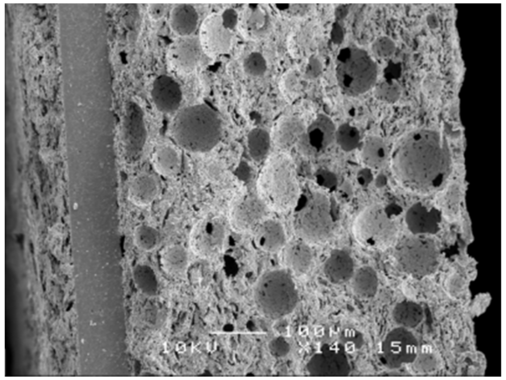
Experiment

- Double casting and calcined at 1550°C for;
  - Porous Anode:
    - 2.5 × 2.5 cm^2 , 600µm
    - 10 wt% Ceria, 20wt% Cu as catalyst
    - Poreformer : PMMA, Graphite
  - electrolyte: 90 µm
- Cathode: LSM ($La_{0.8}Sr_{0.2}MnO_3$) + YSZ calcined at 1250°C
  - 1~3 cm^2
- Cell holder: 430 Stainless steel
  - Fuel channel made by CNC machine
- sealing: Commercial Ceramic sealing
- Copper plating on fuel channel
  - by using copper Sulfate bath
  - To prevent catalytic carbon deposition formed by Ni, Fe in stainless steel
- Analysis for carbon deposition
  - GCMS
- Series connection of fuel between two cell for high conversion



1: Stainless steel stack
2: Cu-cermet anode
3: Electrolyte
4: Cathode
5: Pt current collector
6: Ceramic seal

Schematic diagram of the SOFC mount used in this study.



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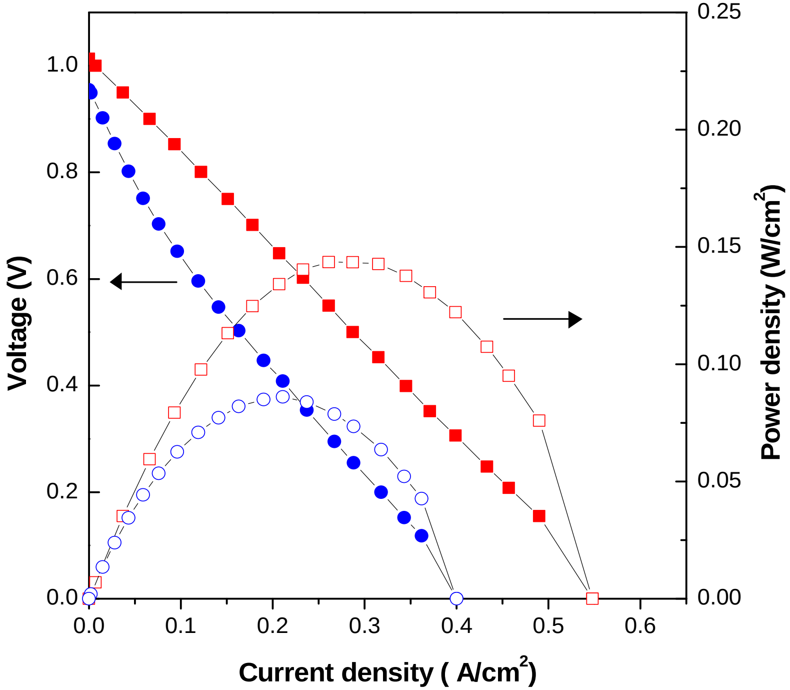
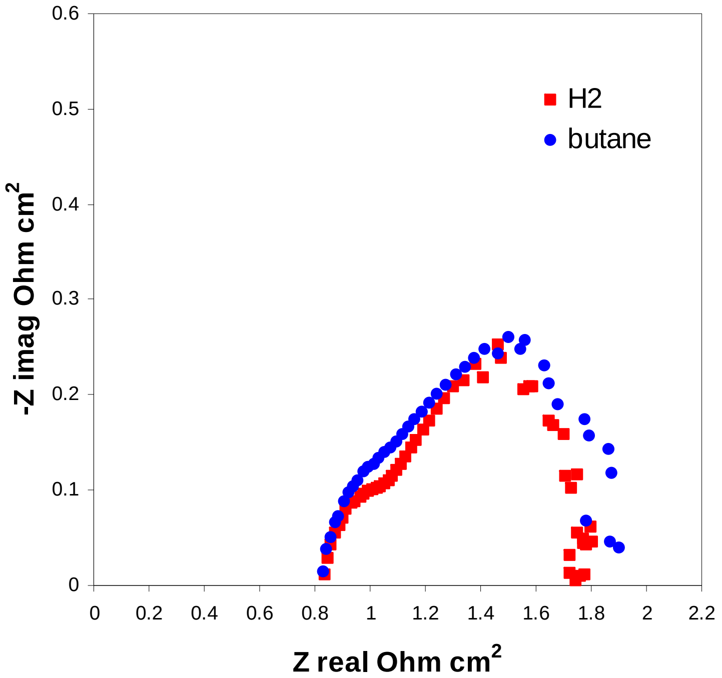
V-i Curves & AC-Impedance Analysis





Cell potential and power density *vs*. current density while running on H_2 and n-butane at 973 K. The squares are for H_2 and the circles for n-butane.

Power density : **0.16 W/cm^2 for H_2,**
0.09 W/cm^2 for butane

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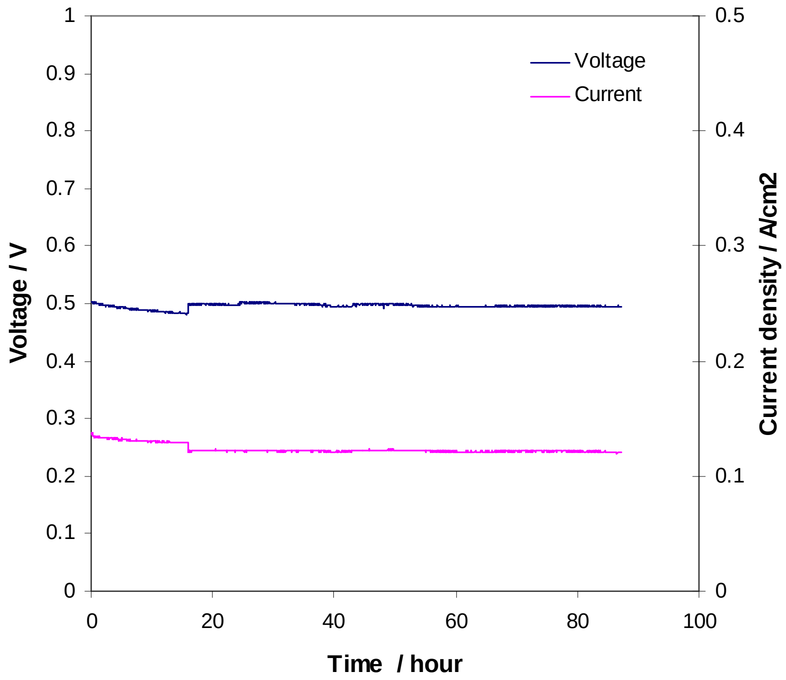
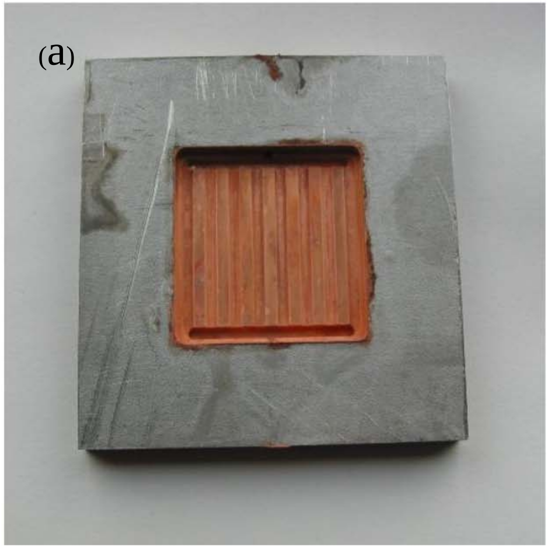
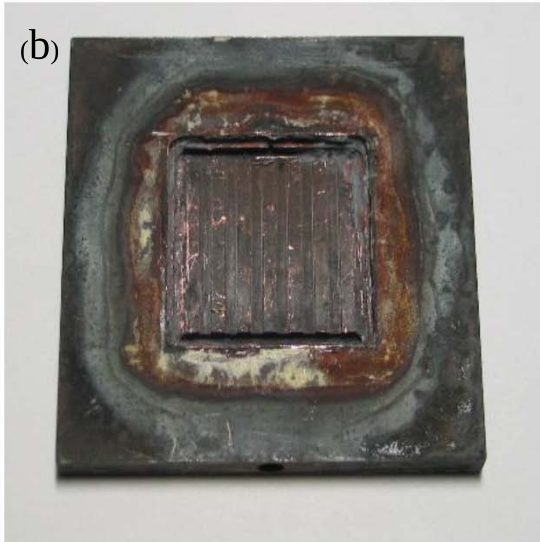
Long Run Test for Hydrocarbon



- **Cell performance in n-butane as a function of time at 973 K while holding the cell potential at 0.5 V.**
- **Very stable performance during 90 hours**

Before and After Test





- **Photograph of cell mount before (a) and after (b) exposure to n-butane at 973 K for 24 hrs.**
- **Copper plating on Fuel Channel for reducing the catalytic carbon deposition enduced by Ni, Fe in stainless steel**
- **Thin carbon deposition on Copper layer after test**
  - **Easily removed by toluene and analyzed by GCMS**

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Analysis for Carbon Deposition

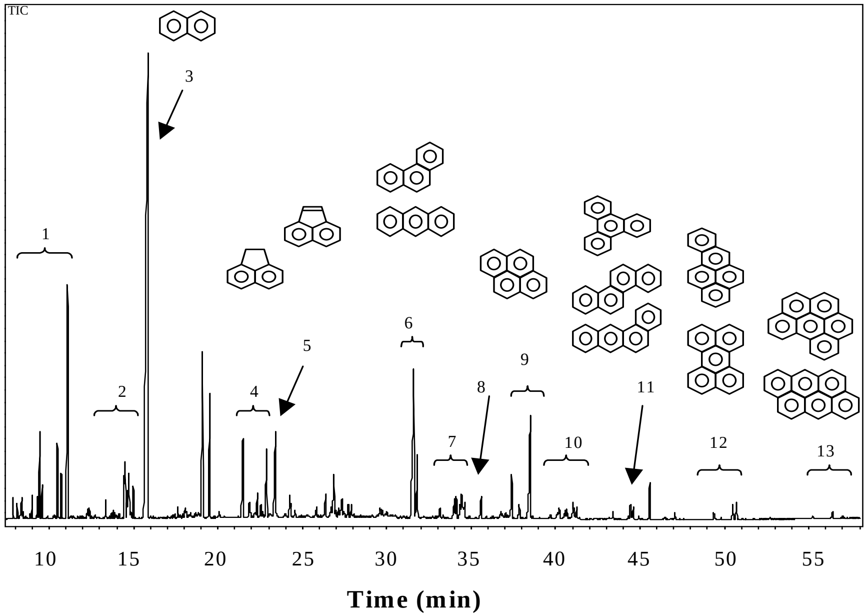

Table 1. Names and molecular weights for selected products that are shown in Figure

Peak no.	Name	MW
1	Ethyl methyl benzene, Propenyl benzene etc.	118
2	1,4-Dihydronaphthalene	130
3	Naphthalene: $C_{10}H_8$	128
4	Acenaphthene: $C_{12}H_{10}$	154
5	Acenaphthylene: $C_{12}H_8$	152
6	Phenanthrene, Anthracene : $C_{14}H_{10}$	178
7	2-methy-phenanthrene, 1-methyl-anthracene: $C_{15}H_{12}$	192
8	2Phenylnaphthalene: $C_{16}H_{12}$	204
9	Pyrene: $C_{16}H_{10}$	202
10	Benzo[a]fluorine, Benzo[b]fluorine: $C_{17}H_{12}$	216
11	Benzo[a]anthracene, Chrysene, Triphenylene: $C_{18}H_{12}$	228
12	Benzo-fluoranthene, Benzo-pyrene, Perylene: $C_{20}H_{12}$	252
13	Benzo[ghi]perylene, Anthanthrene : $C_{22}H_{12}$	276

- **The GC trace obtained from the carbonaceous deposits formed on Cu-plated stainless steel following exposure to n-butane at 973 K for 24 hours.**
- **The structures of selected species are given, along with numbers corresponding to the compounds in Table 1.**
- **Poly-Aromatic Hydrocarbons (PAHs) with 2~6 benzene rings**

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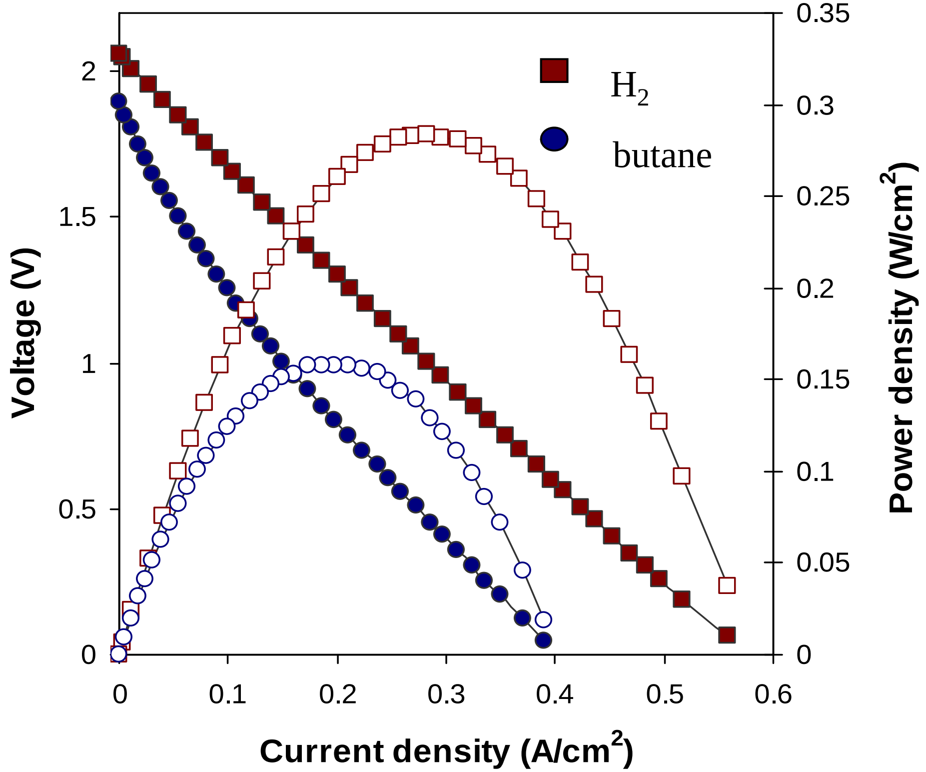
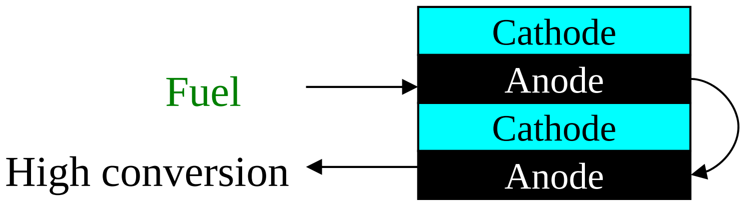
Multi-Stage Connection for High Conversion





- 2-series connection
- High conversion of fuel
- OCV
  - 2.1V for H_2
  - 1.9V for butane
- Power density
  - 0.29 W/cm^2 for H_2
  - 0.16 W/cm^2 for butane

Conclusion

- **It is possible to obtain gas-tight seals for an SOFC with a Cu-based anode in a stainless-steel bipolar plate**

- **The tar-like substances on Cu plating analyzed by GC-MS consist primarily of poly-aromatic hydrocarbons having between 2~6 aromatic rings. These compounds are probably form as a result of gas-phase, free-radical reactions. It is important to note that these deposits are very different from what is formed in the presence of a metal catalyst such as Ni or Fe.**

- **The series-fuel providing to multi-stage cells can increase the conversion and efficiency of fuel.**

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