

Analysis of potential materials for single component fuel cells

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ABSTRACT

The following paper summarizes the results of systematic analysis on single component fuel cell. This recent technology in the solid oxide fuel cell field consists of a unique layer in place of the conventional three-layers structure. The single layer is a mixture of ionic and semi-conductor material. Surprisingly, the expected short circuit has not shown up. On the contrary, the performance is even higher, as reported in literature [1]. This work aims to compare different combinations of materials in terms of performance. $\text{La}_{0.6}\text{Sr}_{0.4}\text{Co}_{0.2}\text{Fe}_{0.8}\text{O}_{3-\delta}$ (LSCF), $\text{LiNi}_{0.8}\text{Co}_{0.15}\text{Al}_{0.05}\text{O}_2$ (NCAL), $\text{La}_{0.8}\text{Sr}_{0.2}\text{CoO}_3$ (LSC), LiNiZn oxide (LNZ) and a new kind of material, CuFe_2O_4 are analysed as semi-conductor material. As ionic conductor, CeO_2/Gd (GDC) is mainly utilised. Also, CeO_2/Sm (SDC) and $\text{CeO}_2/\text{Sm}/\text{Ca}$ SCDC are considered too.

I. INTRODUCTION

Defined from the Nature Nanotechnology (2011) as *three in one* technology [2], single component fuel cells (SCFC) or electrolyte-separator-free fuel cell (EFFC) is an emerging technology born from the downsides of solid oxide fuel cell (SOFC). The problems arisen from high operative temperature as thermal expansion mismatching, chemical and mechanical issues for the material. These critical points are overcome with a single layer of material, which accomplishes both the role of electrode and electrolyte. The simplicity of this system allows to lower the fabrication cost and to fasten the commercialization of fuel cells [3].

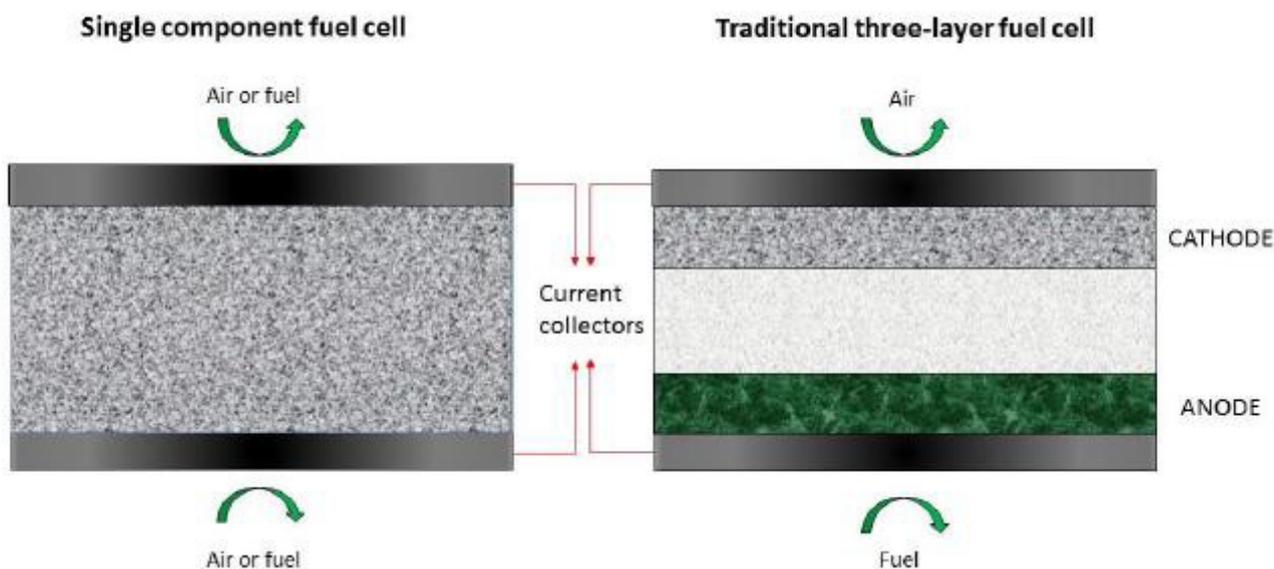


Figure 1 Scheme of SCFC compared to a traditional solid oxide fuel cell, notice that with SCFC the fuel and air sides are interchangeable.

II. MATERIAL AND PELLET SYNTHESIS

LSCF, NCAL, LSC, CuFe_2O_4 , GDC and SCD were purchased from Sigma Aldrich, USA. LNZ has been prepared by mixing Li_2CO_3 , $\text{NiCO}_3 \cdot 2\text{Ni(OH)}_2 \cdot x\text{H}_2\text{O}$ and $\text{Zn(NO}_3)_2 \cdot 6\text{H}_2\text{O}$ with molar ratio of 3:9:8 and calcinated at 800 °C for 1 h. SCDC has been prepared with solid dry method. All the pellets have been prepared by mixing 60 wt% of the ionic conductor material and 40 wt% of the semi-conductor material. All the pellets have been pressed under 250 MPa for 13 mm of diameter and then sintered at 650/690 °C for 1 h after 6 hours of temperature rump up. The thickness is 1 mm and the active area is 0.12 cm² for sample 4 and 5, 0.32 cm² for sample 3 and 0.55 cm² for sample 1 and 2. The number of the samples are listed in *Table 1*.

Table 1. List of the material combinations

Sample	Ionic conductor	Semi-conductor
1	GDC	NCAL
2	GDC	LSCF
3	SDC	LSC
4	GDC	LNZ
5	SCDC	CuFe_2O_4

III. EXPERIMENTAL SETTINGS

The equipment used for the measurements of sample 3, 4 and 5 is shown in *Figure 2*. For the first two samples, Probostat from Norecs is instead used. Before to be measured all the pellets are coated with gold paste on both sides and sintered at 600 °C for 20 min after 6 hours of temperature rump up. In addition sample 1 and 2 have also NCAL coated nickel foams on both sides. The experiments are conducted at 550 °C with hydrogen supplied at 41-82 ml/min and air at 104-208 l/min under 5 bar pressure. Electrochemical impedance spectroscopy has been performed with Zahner IM6.

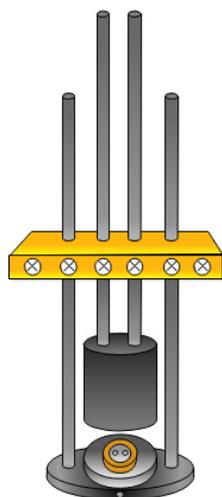


Figure 2 Representation of the setup for performance measurements.

IV. RESULTS

The outputs of the measurements are shown in *Figure 3*. The most promising combination is sample 4 which gives 110 mW/cm² as power density. From the results, LSC does not seem a promising semi-conductor material. Only with LNZ some considerable output has been detected, although the open circuit voltage is still not very high. A new material has been tested with SCDC as electrolyte but its performance is still not remarkable. Sample 1 and 2 have similar performance. The limiting factors are extrapolated from EIS measurements in *Figure 4*. Sample 3 has the highest high frequency intercept (bulk resistance) which makes very low the ionic conductivity. Its EIS spectra is a condensed spot which suggests that it behaves as a pure electronic conductor. Instead, sample 4 has the lowest polarization resistance. In paper [4], they reported higher ionic conductivity 1.1 S/cm than our result, 0.24 S/cm. Also, the performance is higher in [4] i.e. 600 mW/cm². Our cell has high current density but low voltage. This means that the conductivity is good while the catalytic activity should be improved. Also, in [5] higher performance has been achieved with the same electrode (CuFe_2O_4) but with better electrolyte. In sample 1 and 2 there are two semicircles which is mainly due to the the presence of

NCAL coated nickel foams which could be also the cause of bad performance. Further analysis of the material should be done without the NCAL coated nickel foam. Sample 3, 4 and 5 are characterized by one semicircle since they have only gold paste. Sample 1 has a tail at low frequency typical for diffusive problem.

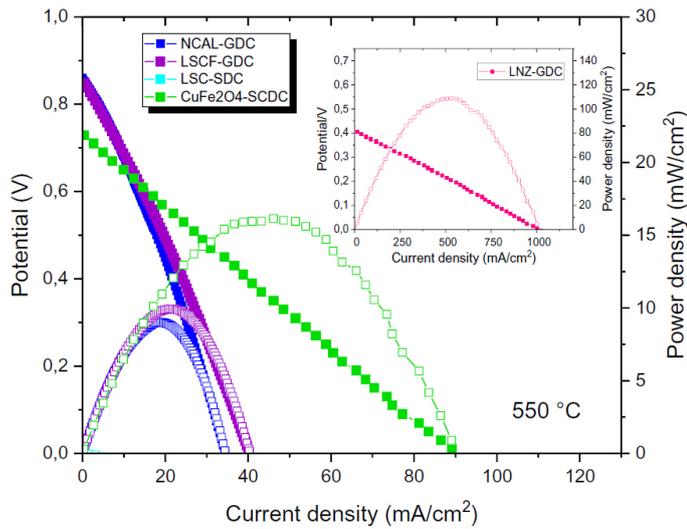


Figure 3 j-V and j-P curve for the different combinations of materials.

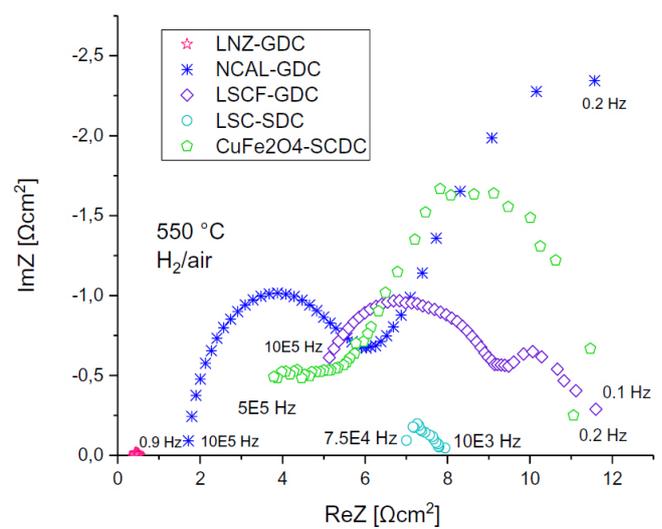


Figure 4 EIS results for the different combinations of material measured at 550 °C under H₂ and air supply.

V. RESULTS

The performances obtained in this work are not as high as reported in literature. From EIS analysis, some possible explanations are extrapolated: for sample 1 and 2 the catalytic activity is good but the ionic conductivity is not very good, probably due to the NCAL coated nickel foams. Sample 3 seems not working at all. It has bad catalytic and ionic conductivity activity. Sample 4 is the promising combination although it should be improved in voltage. One suggestion could be the increasing of the porosity and consequently of the triple phase boundary. The ionic conductivity is the limiting factor for sample 5.

VI. REFERENCES

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