

New solutions and materials for Molten Carbonate Fuel Cells

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Introduction

This paper deals with an investigation on new materials, treatments and procedures suitable for Molten Carbonate Fuel Cells (MCFC). Investigation was carried out by manufacturing a single cell facility (SCF) which was used as test bench. SCF is constituted by:

- a single MCFC;
- exhaust and inlet manifolds;
- a frame for cell elements stacking;
- a heating system.

Cell frame was covered by thermal insulation material. High temperatures sensors were installed into heating system, cathodic and anodic sections. By means of SCF the following components were tested:

- electrolyte matrices based on tape-casting and injection moulding formation procedures;
- cathodes and anodes obtained by tape-casting formation procedures;
- new materials for electrodes mechanical support.

Results showed that:

- dewaxing is quicker and less carbonic residues occur on matrices obtained by injection moulding.
- the proposed original materials for electrodes support provide high mechanical resistance.

The experimental facility

An experimental facility (SCF) was built (see Fig.1). SCF allowed to:

- test innovative materials for small size cylindrical MCFCs (Patent PG2003A0019, IPASS, 2003) [1];
- individuate the optimum treatment procedures for MCFC elements;
- optimize the MCFC start-up procedure.

The facility is constituted by:

1. a single MCFC (a nickel-oxide porous cathode, a lithium aluminate porous matrix, a nickel-chrome porous anode, gases distribution plates and electrical current manifolds) [2];
2. a mechanical system for the cell elements stacking;
3. a heating system for the cell elements and inlet gases.

Distribution plates are AISI 310S inox steel disks. Flared holes plates are mounted between each distribution plate and the corresponding electrode. Flared holes plates are used as current manifolds. Gases inlets are created on the distribution plates; gases pass through the flared holes and lick the electrodes. The electrodes were built by tape-casting; this procedure allowed to create channels for exhaust gases. Exhaust gases exit by two circular section inox steel pipes. Gases retaining is obtained by a matrix the dimensions of which are greater than the electrodes ones. The frame is constituted by two steel plates which keep compressed the distributors and the single cell elements by four springs and steel ties. Four steel spacers keep the springs at a 10 cm distance from the single cell in order to avoid springs damage due to high temperatures. Alumina rings are placed on the superior plate in order to avoid short circuits due to the contact between spacers and ties.

The cell heating system is constituted by silicon carbide disks (diffuser) and a bunsen burner. The system provides the start-up procedure and the inlet gases heating. The disks enhance heat diffusion in order to reduce temperature disuniformities. The diffuser is positioned into an inox steel box which contains also an AISI 316L steel winding for the cathodic inlet gases heating. Two cylindrical chambers for gas heating are engraved on the cell-side of each stacking plate: the inferior chamber is used for the anodic inlet gases heating and is directly fed by the burner; the superior one is used for the cathodic inlet gases heating and is fed by the burner through the

winding pipe. Temperature regulation is obtained by an automatic system constituted by thermocouple sensors which allow to regulate the burner fuel and air flow rate. The single cell and the heating system thermal insulation was obtained by ceramic fibers the efficacy of which was verified by a measurement campaign. In particular, the insulation material superficial temperature is lower than 50°C when the cell temperature is 650°C.

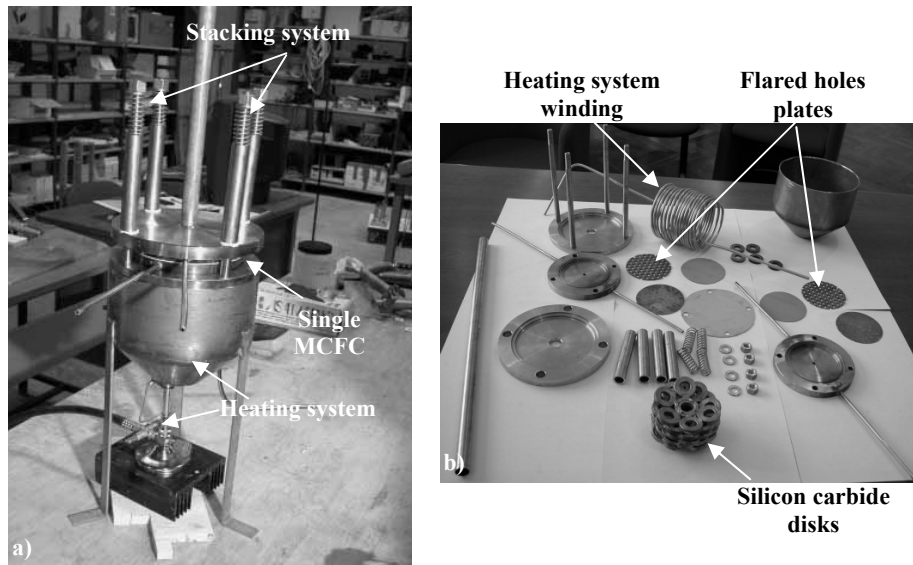


Figure 1 – a) the experimental facility; b) the elements of the experimental facility

Experimental Tests

Experimental tests were carried out in order to individuate the optimum treatment procedure for the cell elements (matrix dewaxing and impregnation with carbonates, cathode oxidization and lithiation). Two matrices were tested: the first is obtained by traditional tape-casting [3, 4]; the second by injection moulding. The second one showed better behavior in eliminating the organic bindings. In particular:

- matrix dewaxing is quicker than the first matrix;
- less carbonic residues occur at the end of the dewaxing phase.

Start-up procedures were optimized by numerous tests. Finally, tests were carried out in order to individuate the voltage-current curve relative to the single cell characterized by the novel matrix (see Fig. 3, without support plates curve). Results showed that the cell electric efficiency is 0.29, a low value but the tests are mainly carried out in order to optimize materials and treatment procedures.

Development of new materials for electrodes support

Electrodes surfaces are distorted near the flared holes just after ten working days; this fact shows that distribution plates support is not sufficient for electrodes support which is very weak at high temperatures. Thus, original support plates were designed and built in order to avoid cell damages (see Fig. 2).

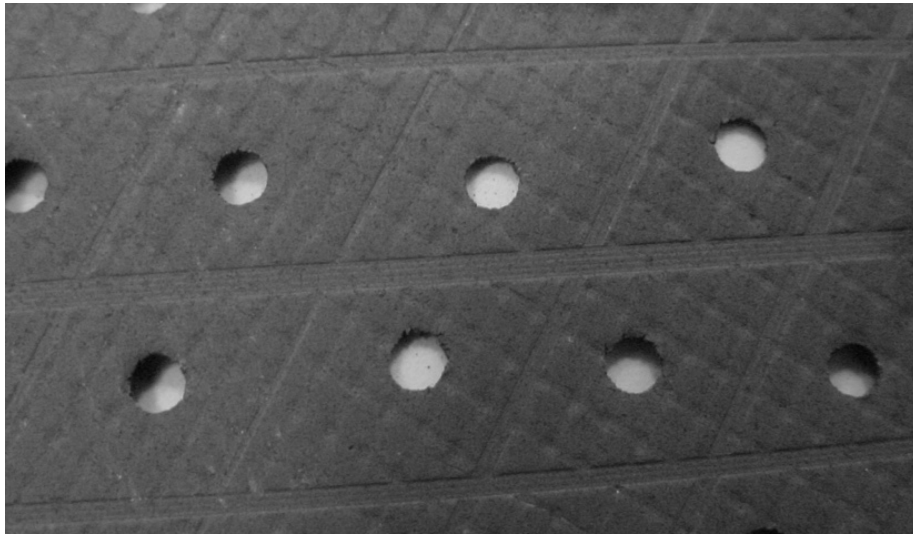


Figure 2 –picture of support plates

Such plates are constituted by nickel and particular additives: nickel is the base component of the electrodes; additives allow to improve the plates mechanical resistance and the structural stability at high temperatures. Thus, creep and sinterization problems may be avoided. Numerous channels were created on the plates side which contacts the electrodes. The channels network allows a correct distribution of the process gases which have to lick the electrodes surface. Holes were created on the support plates surface in order to allow the exhaust and feeding gases passage. Electrodes were created by tape-casting. Thus, tape-casting was chosen also as the support plates formation technique. Channels were created by a calendar system in order to optimize the industrialization process. The final product is a porous structure which is also used to store carbonates on the anodic side.

Experimental tests for the support plates

The support plates efficacy was verified by a measurement campaign. Preliminary tests was carried out in order to determinate the optimum carbonates quantity and start-up procedure. The voltage-current characteristic was determined (see Fig. 3) by using the same fuel flow rate than the previous tests. Cell performances are slightly lower than the ones obtained without the support plates (cell electric efficiency is 0.26). This fact is due to the following reasons:

- cell electrical resistance increases due to the new two elements and their contact resistances;
- feeding gases paths towards electrodes surface are partially hindered by the support plates.

However, higher electrical performances may be obtained by increasing the fuel flow rate. The proposed solution allows the obtain high mechanical resistance: in fact, no deformations occurred at the electrodes surface in two months working days as verified by microscopy analyses after the experimental tests.

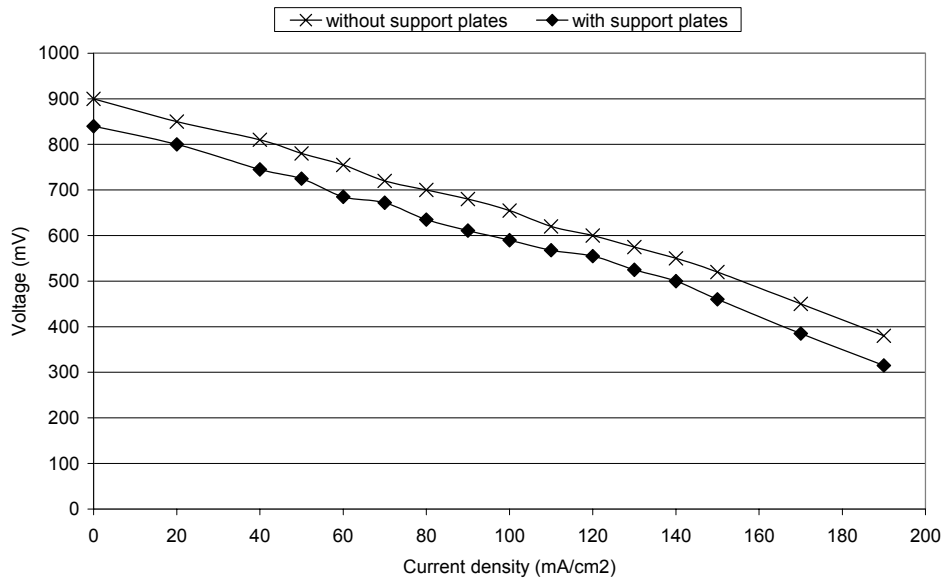


Figure 3 – Cell voltage/current characteristic curve

Conclusions

The experimental tests showed the versatility and the efficacy of the proposed facility for testing MCFCs materials and solutions. The measurement campaign and microscopy analyses confirmed the validity of the proposed solutions such as the gas distribution system, the stacking system and the heating system characterized by ceramic elements. Tests showed the following improvements when injection moulding matrices are used rather than the ones obtained by tape-casting:

- the novel matrices are more rigid (cell assembly procedures are quicker and simpler);
- dewaxing phases are quicker and characterized by lower carbonic residues.

The installation of electrodes support plates allowed to obtain strong improvement of cell mechanical resistance. Cell electrochemical performances are slightly lower than the ones obtained without the support plates; however, the gas distribution over the electrodes surface may be improved by increasing the cell working pressure. The proposed solutions were applied to a 1kW cylindrical geometry MCFC. Tests are actually going on in order to evaluate the cell performances.

References

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