DEMO:H2 FUEL CELLS REALIZED BY PCB (PRINTED CIRCUIT BOARD) TECHNOLOGY

ST MICROELETTRONICS S.R.L.

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GENESI develops structural health monitoring systems for critical infrastructures such as tunnels, bridges, dams, private and public buildings, providing cutting edge green wireless sensor networks technology

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Introduction

The present article pertains to the realization of fuel cells, for the production of electric energy, realized with technology PCB (Printed Circuit Board). The increasing energetic application from portable electronic systems, because of the elevated number more and more of functions and performances that such devices introduce, has strongly contributed to the search of new solutions to feed such systems, with the purpose to increase the performances and the density of energy stored into the batteries

The fuel cells at polymeric electrolyte fed with hydrogen and air, seem to be a good harvesting method to store electric energy in tandem with "traditional" batteries, thanks to some exclusive functional characteristics, that are: raised theoretical output of conversion (80%), absence of polluting (water and heat) by-products, management of the energetic production only by the feeding of the reagents.

The deceleration of the development on this kind of system is related mainly to two factors: the elevated cost of production of the same, and some issue concerning the feeding of the fuel. In the following article it will be showed how to resolve the first described aspect introducing the technology PCB for the realization of the bipolar dishes and the package. As it regards the second aspect instead, greatest problem list are individualized in the necessity to furnish hydrogen and therefore to store the fuel to make fuel cells as portable system, involving the aspects of the safety of the application. However, in this field, a great effort has been developed through the usage of hydride materials (chemical hydride like for example $NaBH4$, metal hydride like LiH, or alloy like $LiNa5$) that have the great property to store good amount of hydrogen in a secure and easy way. So the usage of metal hydride tank to feed hydrogen to the anode of a fuel cell, results of great interested to answer to the issue of fuel storage for fuel cells application especially where a trade-off between energy density constraints and endurance of the system is required.

The choice of PCB technology to manufacture fuel cells, is due to its low cost, and maturity in machining. The workmanship of PCB materials through techniques of rapid prototyping it allows to realize complexes crossed three-dimensional voters, buried channels and holes.

II. GENERALITY ON PEMs FUEL CELLS

In general a FC [1] (Fuel Cell) is an electrochemical system that converts the chemical energy, by the reaction between a fuel (typically hydrogen) and a combustive, (oxygen) in electric energy and heat. A fuel cell is constituted by two electrodes, anode and cathode, on which the reactions of oxidation and

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reduction respectively happen, and by an electrolytic membrane.

Particularly, in the cells described in the present job, the electrolytic membrane is a polymer whose characteristics are those to easily absorb the water, to be conductor of ions H+, but not of electrons, and to prevent that the gases of feeding come to direct contact. The MEA (Membranes Electrode Assembly) is a sort of sandwich composed by the protonic exchange membrane (PEM: Proton Exchange Membranes) and of two catalytic layers, that are the ones in which reactions occur.

The two GDLs (Gas Diffusion Layers), externally attached to the electrodes, increase the efficiency of the system guaranteeing a direct and uniform access of the fuel (H2), and of the combustive (O2) one. The bipolar elements, where the electrons produced by the reaction are driven versus external circuit, are constituted by metallised semi cells realized in PCB . These semi cells are separately worked and assembled through processes of heat gluing. Using such materials (that is the typical machined by PCB technology) is possible to realize compact systems, alternative to the bipolar dishes usually realized in metal or in carbon. In figure n. 1 is represented a scheme of operation of a PEM Fuel Cell fed with hydrogen.

Following the fundamental reactions, of oxidation to the anode and of reduction to the cathode, that take place inside a PEM Fuel Cell [2], are described.

$$
\begin{aligned}
&\text{Anode: } H_2 \rightarrow 2H^+ + 2e^- \\
&\text{Cathode: } \tfrac{1}{2}O_2 + 2e^- + 2H^+ \rightarrow H_2O \qquad (1) \\
&\text{Full reaction: } H_2 + \tfrac{1}{2}O_2 \rightarrow H_2O
\end{aligned}
$$

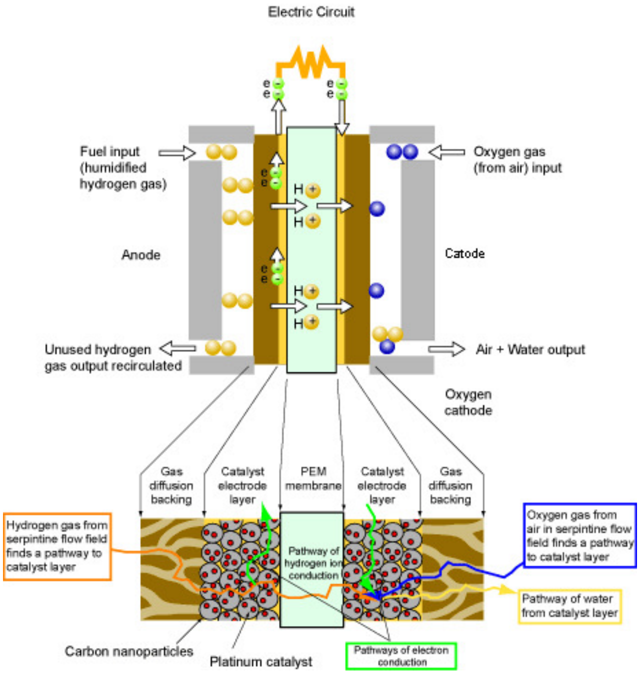

Figure 1. Schematic of H2 Fuel Cell working.

III. DESCRIPTION OF THE PROTOTYPE

The material used for the fabrication of the prototype described, is FR-4. The sheets of FR-4 are covered by a side (in the case of single-sided sheets) by an uniform layer of copper (usually 35 microns). The coppered card is worked therefore removing the copper film, only where the passage of a trace of the circuit is not anticipated. In such way it is possible to realize the necessary conductive runs for the extraction of the electric tide produced from the Fuel Cell and, through the workmanship of buried channels, the feeding of the reagents in correspondence of the MEA is ensured.

In this way are realized bipolar plates. The bipolar plates, act besides in the part exposed to the MEA, as diffusers of gas (Flow Field Plates). Finally upon the plates itself, it is possible to realize the control circuitry of the power produced by the Fuel Cell, so that a monolithic complete system, of the type SoP (System on Package) is realized.

Defined the layout, next step versus the realization of the prototype, consists in the elaboration of the project through software CAD / CAM, this allows to convert the geometric bi dimensional model content in a formed file standard (DWG, DXF, IGES) CAD, and finally in a list of instructions for the numerical control tool. The realized prototype is composed of three PCB parts: anode, cathode and room of diffusion. Both the anode and the cathode, are realized by single metallised PCB cards, they comprehend some passing loopholes for the outflow of the reagents toward the MEA. The room of diffusion is realized by two cards pre glued and it has the purpose to uniformly spread the hydrogen to the anode. The following image (figure n. 2), shows the described prototype.

The hydrogen is introduced in the diffusion room, through a passing hole with inserted a pneumatic quick-fitting. The general volume of the system assembled through heat gluing of the components, is of around 8 ccs.

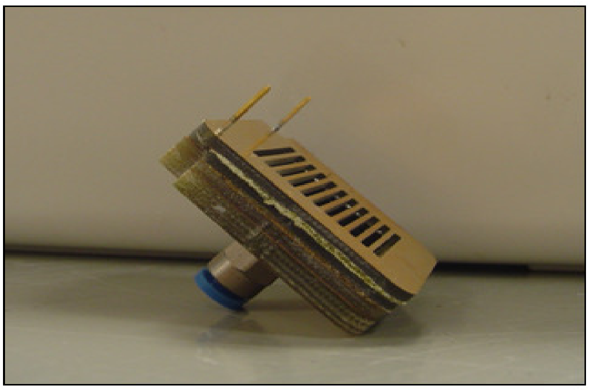

Figure 2. An image of the prototype realized.

IV. ELECTRICAL CHARACTERIZATION

Electrical characterization has been realized through a Station Test of the Arbin Instruments (FCTS, Fuel Cell Testing System).The purpose of the measures has been to underline the performances in terms of power density and reliability in the time of the fuel cell , submitting the same one to cycles of polarization. The tests have been conducted making to vary in the time, the ohmic load.

V. RESULTS

The described tests have been effected with commercial membranes furnished by the BASF Fuel Cell Technologies, serious ES12EP-W-5L with dimension of the active area 3,61 cm2s (19 mm x 19 mm) and dimensions of the membrane equal to 9 cm2s (30 mm x 30 mm) .Following (figure n. 3) a curve of measured polarization during the tests, is deduced that the maximum density of power gotten by the realized prototype is of 282,50 mW/cm2s. Subsequently tests of duration have been effected for verifying the decadence of the performances with the time, particularly it is seen that the realized system introduces a good reliability, the density of electric power, in fact, is maintained constant for over 135 hours (figure n. 4) above the 270 mWs / cm2.

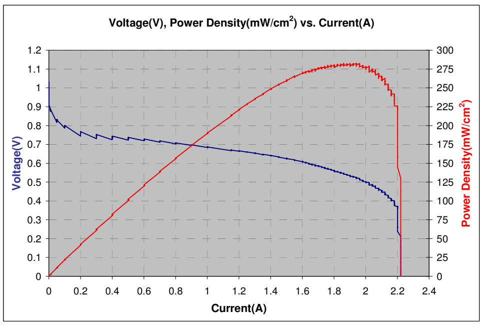

Figure 3.

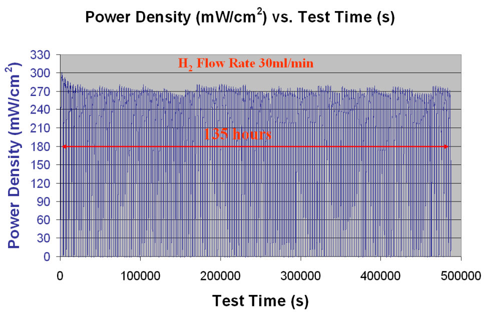

Figure 4.

Figures 3-4. Above (Figure 3) a polarization curve of the prototype of fuel cell realized. Below (Figure 4) The result of Test of Reliability on the same prototype.

CONCLUSIONS

The prototype presented has been realized by rapid prototype technique, and has been assembled tanks to dedicated gluing methods. The system presented has been tested with a fuel cell test station, reaching, at the specific conditions previously mentioned, a maximum power density of 282.50 mW/cm2. Besides, the prototype developed has showed good properties related to reliability, electrical results above mentioned, in fact, have been showed for more than 135 h. Thanks to the possibility to feed the fuel cells in an independent way by the usage of hydride materials from which necessary hydrogen may be extracted following different methodologies, systems of the kind presented, result in a very interesting energy harvesting source that may solve energy issue even when other harvesting sources have a failure.

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