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Versatility of Solid Oxide Reactors

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An electrochemical device such as the solid oxide fuel cell (SOFC) may possess configurations that will make it suitable to different applications, as a function of the important variety of materials developed for its fabrication [1].

The main objective for SOFC utilization is the electrochemical conversion of energy contained in a fuel, usually hydrogen, into electricity, generating water vapor as byproduct.

The SOFC evolution in the last decades began with fuel cells supported by the electrolyte, on top of which the anode is deposited on one side and the cathode on the other side. The conventional electrolyte is usually made of yttria stabilized zirconia, YSZ, to guarantee structural stability without phase changes until the elevated operating temperatures that are used, in the range of 850 to 1000ºC. The conventional anode is made of a mixture of YSZ and nickel oxide, which is reduced to metallic nickel under the anode's reducing atmosphere to act as an electrocatalyst of the electrochemical reaction of interest. The conventional cathode is composed of lanthanum manganite, frequently doped with other chemical elements to improve electronic and ionic conductivities and to control its coefficient of thermal expansion. Electrolyte supported SOFCs possess thick electrolytes, with thicknesses usually greater than 150 µm. This causes important ohmic losses related to the conduction of O^{2-} ions from the cathode to the anode throughout the electrolyte and limits the magnitude of the power density that can be reached.

The next step, still utilizing similar materials, had the objective to decrease operation temperatures below 850ºC, which was achieved fabricating cells supported either by the anode or by the cathode, for which the supporting electrode possessed thicknesses between 300 µm and 1 mm, and a thin electrolyte, with thicknesses ranging from 5 to 50 µm. The use of a thinner electrolyte decreased the ohmic loss in the electrolyte, which has allowed operation in temperatures in the range of 700 to 850ºC. This procedure created the intermediate temperature solid oxide fuel cells, IT-SOFC [2]. The present development step, representing the third generation of solid oxide fuel cells, is the metal supported cells, MS-SOFC. Furthermore, metallic supports were developed to allow the deposition of all elements that constitute the fuel cell in a controlled way and bearing dimensions suitable for the specific requirements, once a metallic alloy assumed the cell-supporting role. Ferritic steels are frequently used for such application that includes the following iron-based alloys: ITM, with 26 wt% Cr; CROFER 22APU, with 20 to 24 wt% Cr; Sandvik Sanergy, with 22 wt% Cr and type 430 stainless steel, with 22 wt% Cr [3-5]. The MS-SOFC presented important advantages such as to facilitate the fabrication procedures, now associated with a metallic support, gaining robustness, but requiring an electrolyte better adapted in terms of coefficient of thermal expansion with the metals above mentioned and with better ionic conductivity at the lower operation temperatures. Because of that, the YSZ gave place to ceria and other ceria-based mixed ceramic materials.

The versatility of such a chemical reactor represented by the SOFC was further unveiled when it assumed configuration and operation modes associated to new functions for which the production of electric energy either does not take place or is considered a sub-product of other reactions. This ocurred by utilizing it for hydrogen production, consuming electric energy to make high temperature water electrolysis, being denoted solid oxide electrolysis cell, SOEC [6]. In such a case, the device may operate reversibly, either as a SOFC or as a SOEC. Still, a new and recent configuration was proposed for which a SOFC is not used with the main objective of generating electric energy, since the production of electricity and heat became subproducts of a device that makes the electrochemical conversion of methane into C2 type hydrocarbons, such as ethylene and ethane [7]. This unveils the utilization of the C-SOFC, a solid oxide fuel cell that has the main objective of making the electrochemical conversion of hydrocarbons.

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