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PRODUCTION AND CONVERSION OF HYDROGEN INTO ELECTRICITY: TECHNOLOGICAL ACHIEVEMENTS AND REMAINING CHALLENGES

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Summary: Using renewable energies is mandatory to solve the question of global warming and recent acceleration of global CO₂ emissions. Nevertheless, renewable energy is inherently intermittent, costly, and location-dependent, and hydrogen may be used as a decarbonized carrier. Indeed, hydrogen can be produced by water electrolysis when renewable electricity is available, stored, and converted later into electricity via fuel cells. Development of the hydrogen sector has begun, and numerous applications exist today around the world. Nevertheless, some important challenges remain in the fields of production of hydrogen by electrolysis, its storage, and the conversion of hydrogen into electricity, and are the subject of France's national low-carbon hydrogen strategy, organized in Priority Research Programmes and Equipments. Due to recent work carried out in our group, IMN is involved in three of the programmes, respectively devoted to the development of innovative materials and processes for the manufacture of High Temperature Water Vapour Electrolysis (CELCER project), to electrochemical cells based on protonic conduction ceramics and operating in intermediate temperature in the 400-600°C range (PROTEC project), and to the development of a flexible oxide fuel cell, capable of working with various liquid or gaseous mixtures (syngas, biogas, etc.), or in the presence of pollutants that can act as a catalyst poison (FLEXISOC project).

In a first part, the search for new high-performance materials, by exploring new innovative, environmentally-friendly synthesis techniques, such as cold sintering process, will be presented. Indeed, this new technique enables the acceleration of the densification BaCe_{0.8}Zr_{0.1}Y_{0.1}O_{3-δ}, resulting in a more compacted microstructure with a relatively high theoretical density of 83% at only 180°C. Subsequent annealing at temperature lower than that of the traditional sintering (1200°C instead of 1400°C) further improves the relative density which reaches 94%, and remarkably increases the total conductivity at 700°C to 4 10⁻² S.cm⁻¹, by mostly increasing the grain boundary conductivity^[1].

While developing new materials, we must take into account that the expected large production of fuel cells and electrolyzers will generate mass production of raw materials, dependence on commercial products, and production of waste for the environment. The second part of this talk will be devoted to our first successful recycling and recovery of anode supported Solid Oxide Fuel Cell (SOFC) ceramic components^[2], and our future work scheduled in the NOUVEAU European project in which we are involved. The last part of the talk will be devoted to the extension of the conditions of use of fuel cells, allowing them to be supplied with various fuels, particularly from gaseous mixtures issued from biomass, or from marine and/or polluted air. Results obtained during the two projects VALORPAC and DEBHAT, coordinated by our group, and illustrated in Figure 1, with a gas issued from a gasifier, will be presented. and emphasize issues linked to pollutants such as HCl or H₂S^[3]. Strategies used to enlarge conditions of SOC operation, both in modifying cell composition, but also in adapting current collection or gas purification, are also presented.

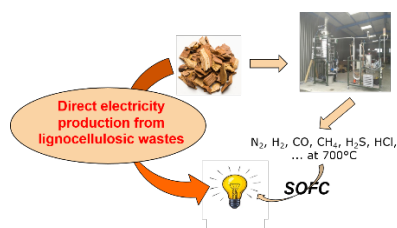


Fig. 1 Schematic representation of the direct electricity production from biomass using a SOFC

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