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Inorganic proton conducting membrane based membrane reactors

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Abstract

Inorganic proton conducting membranes enable membrane reactors in which hydrogen can be removed from the reaction zone via electrochemical proton pumping. This enables deep removal of hydrogen as well as the production of pressurized pure hydrogen in a single device.

Such reactors can be used for the production of high pressure hydrogen in (small, forecourt scale) integrated steam methane reformers for hydrogen mobility, but also for efficient steam electrolysis for the production of green hydrogen. Other applications include ammonia cracking, dehydrogenation of hydrocarbons as well as co-electrolysis of water and CO2 to syngas (and further to higher hydrocarbons).

The cells' architectures are tailored for each application. This work is guided by systematic experimental work on modelled electrodes and parameterization of cell's performance as function of operating conditions. The experimental work is steered by multi-scale multi-physics modelling establishing correlations and functions between atomistic, electrode, cell, reactor and system levels. The resulting technology platform is shown to provide new paths towards the viable production, extraction, purification and compression of hydrogen combined with other useful products.

For steam electrolysis, existing steam electrolyser designs utilize the high packing density of planar stacks, but the hot seal and vulnerability to single cell breakdown give high stack rejection rate and questionable durability. Recently, we demonstrated an innovative proton conducting electrolysis technology utilizing tubular proton conducting ceramic cells and their inherent advantages: lower operating temperature than traditional solid oxide ion conducting electrolysis cells; increased safety as the pressurized hydrogen is balanced by a mixture of steam and oxygen; reduced sealing areas and increased robustness in particular, when exposed to pressure differentials, compared to planar stacks.

The tubular cells consist of a porous $Ni\text{-}BaZr_{0.7}Ce_{0.2}Y_{0.1}O_{3-\delta}$ (BZCY) cathode for the H_2 side, a dense BZCY-based electrolyte, and a porous $Ba_{1-x}Gd_{0.8}La_{0.2+x}Co_2O_{6-\delta}$ (BGLC)-BZCY composite anode for the H_2O+O_2 side. Extensive characterization of the cells' performance as function of temperature, pressure (up to 10 bar) and steam content has been carried out showing positive impact of pressure and steam on the Faradaic efficiency and hydrogen production rate of the cells, as will be reported here.

Shell is working together with a number of key partners to further develop this technology in a range of different EU projects. The projects (GAMER, WINNER, PROTOSTACK) are supported by the Clean Hydrogen Partnership and its members Hydrogen Europe and Hydrogen Europe Research. The eCOCO2 project has received European Union's Horizon 2020 research and innovation funding under grant agreement N 838077. The presentation will provide an overview of the various developments in these projects