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High temperature electrolysers based on protonic and ionic conducting ceramics, differences in operation conditions and cell materials

The use of high temperature electrolysers (HTE) of steam offers high efficiency of conversion of renewable and peak electricity to H_2. In solid oxide electrolysers (SOECs), that use oxide ion conducting electrolytes and operate at around 800 °C, the hydrogen is produced on the steam feed side. However, in proton conducting electrolysers (PCECs) a high temperature proton conducting electrolyte is used instead and protons are pumped and form dry H_2, leaving O_2 on the steam side. These PCECs can produce pressurised dry H_2 directly.
Concerning SOECs cells, different electrolytes materials were tested in order to compare the cell performance at the operation temperature (700-500 ºC). Gadolinium doped ceria (GDC), Scandium stabilized zirconia (ScSZ) and Yttrium stabilized zirconia (YSZ) were used. Results showed the electrons leakage in the GDC electrolyte due to the electronic conductivity in hydrogen containing atmospheres, reducing the electrolysis efficiency.
In addition, different cathode (steam chamber) materials were studied and catalytic improvement was performed by means of different nanomaterials infiltration.
Finally, electrolysis and co-electrolysis measurement were performed in order to check the cell overpotential. Hydrogen and carbon monoxide production were also followed in continuous operation with a gas chromatographer and gas mass spectrometer.
Regarding PCECs, $BaCe_{0.2}Zr_{0.7}Y_{0.1}O_{3-\delta}$ (BCZY27) was selected as electrolyte for high temperature protonic electrolyser. Thus this study is focused on the study of compatible anodes for this electrolyte.
The compatibility of different proposed phases with the BCZY was tested upon a heat treatment together with the electrolyte and under high temperature and high steam pressure conditions (700 ºC, 1.5 bars of steam in 2 bars of total pressure). First selected phases were $La_{0.8}Sr_{0.2}MnO_3$ (LSM), $Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_3$ (BSCF) and $La_{0.6}Sr_{0.4}Co_{0.2}Fe_{0.8}O_3$ (LSCF). The anodes were prepared as composites by mixing one of these phases with the BCZY electrolyte.
Composite anodes were tested by impedance spectroscopy on BCZY27 electrolytes as symmetrical cells as a function of the temperature (800-500 ºC) under air with 1.5 bar of steam, with a total pressure of 2 bars. First screening was performed by using 50-50 vol.% of each phase and LSCF based anode showed the best properties. Then the performance was improved by (1) changing the ratio of the different phases and (2) improving the microstructure.