Scalable Ceramic Protonic Membranes for Intermediate Temperature Steam Electrolysis

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Abstract

Intermediate temperature (400–600 °C) steam electrolysis using ceramics proton conducting electrolytes (PC-SOECs) might offer a solution to high electrical energy consumption associated with conventional water electrolyzers through a combination of favorable thermodynamics and kinetics. This class of electrolytes is particularly favored for their relatively high ionic conductivities within this operating regime. There has been an increased interest towards such a technology in recent years, aimed at reducing the cost of electrolytic hydrogen. Although progress has been made with small scale type PC-SOECs devices, a significant challenge has been upscaling robust and affordable planar type devices. The fabrication of such multilayered devices usually via a tape casting process requires careful control of shrinkages of individual layers to prevent warping, cracking during sintering.

Aiming to realize a highly efficient electrolysis technology based proton conducting ceramics, a sequential tape casting approach for processing 50 mm square proton conducting ceramic half-cells was successful developed. The present work describes recent promising results obtained in terms of performance and new strategies for the scalability of PC-SOECs, through a facile cathode-support assisted densification of our state-of–the-art Ba-based electrolyte ($BaZr_{0.44}Ce_{0.36}Y_{0.2}O_{3-\delta}$). An excessive shrinkage force driven from NiO-$SrZr_{0.5}Ce_{0.4}Y_{0.1}O_{3-\delta}$ cathode functional layer uniformly promotes densification at a much lower temperature than that required for the electrolyte alone. All three layers casted, green-on-green yielded suitably dense, warp free and gas-tight $Ba(Zr_{0.5}Ce_{0.4})_{8/9}Y_{0.2}O_{2.9}$ electrolyte after co firing at 1350 °C/5h. Current-voltage characteristics and hydrogen evolution rates measured in the temperature range 500-600 °C (Fig.1), demonstrate excellent performance and durability. A typical $Ba_{0.5}La_{0.5}CoO_{3-\delta}$/$BaZr_{0.44}Ce_{0.36}Y_{0.2}O_{2.9}$(20µm) /NiO-$SZr_{0.5}Ce_{0.4}Y_{0.1}O_{2.95}$ cell at 600 ºC with 80% steam in the anode compartment reached reproducible terminal voltages of 1.45V @ 500 mAcm^{-2}, achieving ~86 % current efficiency which is among the best PC-SOECs performance reported in literature. Further improvements in efficiency can be expected by a further reduction in film thickness and better optimization of the anode.

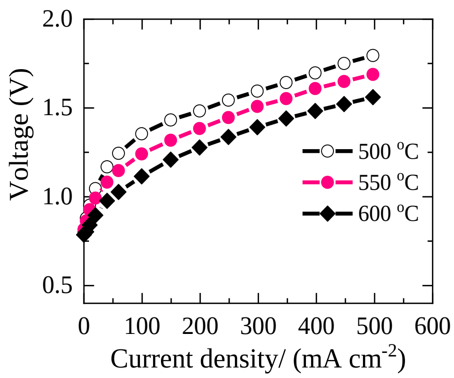

Fig.1. steam electrolysis I–V curve performance with ~20 µm thick $BaZr_{0.44}Ce_{0.36}Y_{0.2}O_{2.9}$ electrolyte