Processing Ceramic Proton Conductors by Inverse Tape Casting for use in Steam Electrolysis

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Abstract

Steam electrolysis using proton conducting electrolytes (PC-SOECs) are potentially the most efficient and cost-effective option for hydrogen production at intermediate temperatures (400–600 °C) from renewable sources. These classes of electrolytes are particularly favored for their relatively high ionic conductivities within this regime. Although significant progress has been made with small scale laboratory type PC-SOECs devices, a significant challenge has been upscaling robust and affordable planar type devices for commercialization. The fabrication of such multilayered devices *via* a tape casting process requires careful control of shrinkages of individual layers to prevent warping, cracking or even delaminating during sintering.

Cathode supported planar protonic solid oxide electrolysis cell (P-SOEC) with large dimension (50×50×0.5mm³) were successfully prepared by a sequential tape casting and co-firing technique and allow for the creation of a thin $BaZr_{0.44}Ce_{0.36}Y_{0.2}O_{2.9}$ electrolyte layer on a high shrinkage NiO-$SZr_{0.5}Ce_{0.4}Y_{0.1}O_{2.95}$ cathode functional layers. Suitably high densification (1350 °C/5h) is achieved without the addition of sintering aids, which is unprecedented with this state-of-the-art composition. The low sintering behavior of the green tapes as well as the obtained final microstructure are direct results of careful control over casting parameters, such as slurry viscosities, thicknesses of individual layers, temperature and time scheme for firing. A substantial amount of strontium was detected in the $BaZr_{0.44}Ce_{0.36}Y_{0.2}O_{2.9}$ electrolyte layer of the half-cell using EDS mapping whereas no significant amount of Ni was detected. High–angle annular dark-field imaging also indicate yttrium oxide accumulation in the vicinity of NiO grain when the half-cells are co-fired above 1450°C. 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. This work also present substantial progress in upscaling leakage free P-SOEC and also provide new insight into designing new cathode functional layers.

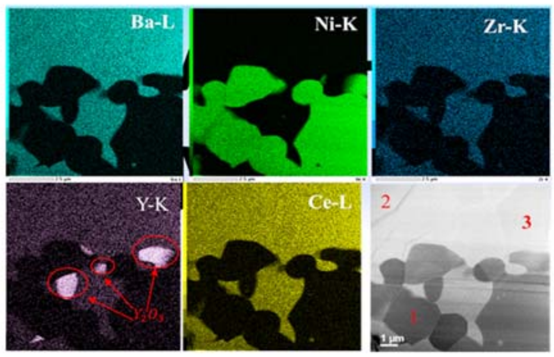

Fig.1 HADDF micrograph and EDS maps at the Ni-$SZr_{0.5}Ce_{0.4}Y_{0.1}O_{2.95}$/$BaZr_{0.44}Ce_{0.36}Y_{0.2}O_{2.9}$ electrolyte interface of the half-cell (1500°C)