Development of advanced proton conductor membranes for electrochemical devices by sequential tape casting

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Abstract

Electrochemical devices such as solid oxide fuel cells (SOFCs) and solid oxide electrolysis cells (SOECs) are promising environmentally friendly alternative technologies for sustainable energy production. These devices generally consist of two porous electrodes separated by a dense electrolyte and are generally classified by the type of electrolyte used. Traditionally oxide ion conducting electrolytes have been favored for such devices, although proton conducting electrolytes have also been attracting growing interest especially for operation at intermediate temperature (600 ~ 400 °C). In addition, such proton conducting electrolytes are very promising for steam electrolysis. In this case, as protons are the conducting ion, hydrogen is produced separate from the supplied steam, which is an important advantage. One of the significant challenges for proton conducting SOECs is the creation of robust, durable, and affordable cells. While the search for new materials remains an important research activity, the role of process development for fabrication and manufacture is equally very important. Indeed better understanding between materials, processing, and the resulting microstructure is vital for improving cell performance.

In the present work, quality Y-doped $BaZrO_3$-$BaCeO_3$ ($BaZr_{0.44}Ce_{0.36}Y_{0.2}O_{2.9}$) thin films were successfully prepared by sequential tape casting on a high shrinkage NiO-$SZr_{0.5}Ce_{0.5}Y_{0.1}O_{2.95}$ cathode (see Fig. 1.) Suitably high densification at 1350 °C was 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 result of the high quality of the slurry formulation in which $BaZr_{0.44}Ce_{0.36}Y_{0.2}O_{2.9}$ ceramic grains are electrostatically interacting with particles farthest away from each other and a viscosity with sufficient creep resistance to maintain its geometry. The fabrication process shows that each step is important, but that the formulation of the slurry is crucial for obtaining the final half-cell. We also present some aspects about co-sintering of the tri-layer components and provide some indications on how to circumvent difficulties in certain cases. In addition preliminary steam electrolysis results with typical $Ba_{0.5}La_{0.5}CoO_{3-\delta}$/$BaZr_{0.44}Ce_{0.36}Y_{0.2}O_{2.9}$(15µm)/NiO-$SZr_{0.5}Ce_{0.5}Y_{0.1}O_{2.95}$ cell measure at 600 ºC reached reproducible terminal voltage of 1.5V @ a current density of 500 $mAcm^{-2}$ with an ~86 % hydrogen production efficiency.

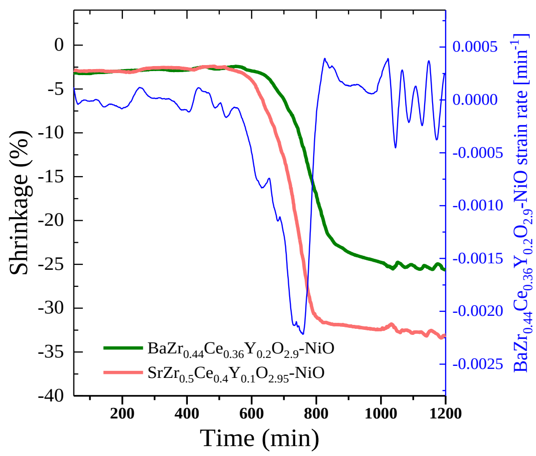

Fig. 1 Shrinkage of $BaZr_{0.44}Ce_{0.36}Y_{0.2}O_{2.9}$ –NiO and $SrZr_{0.5}Ce_{0.4}Y_{0.1}O_{2.9\,5}$ –NiO cylinders prepared from the substrate single layers.