$Sm_{0.5}Sr_{0.5}CoO_{3-\delta}$ - $Ce_{0.9}Sm_{0.1}O_{1.95}$ nanocomposites for reversible electrochemical cells

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The generation of electricity through environmentally friendly sources of energy has been one of the main challenges of our society in the last decades. The rapid growth of renewable energy has a large influence in the transport sector and industrial processes. Nevertheless, the irregular and seasonal disposition of renewable energy requires advanced devices for energy storage and conversion into electrical power. Reversible electrochemical cells can address this energy storage approach by operating as an electrolyser, when an excess of electricity is available, and as a fuel cell, when the electricity is needed afterwards. In electrolysis mode, the conversion of water into hydrogen molecules allows a chemical energy storage. Then, when electrical power is required, the reversible electrochemical cell can operate in fuel cell mode, converting back the hydrogen molecules into electricity. In this sense, reversible ceramic electrochemical cells appear as a promising alternative to store and produce electrical energy in a more efficient and eco-friendly way than the conventional batteries and generators, respectively [1].

An important aspect for increasing the efficiency of reversible ceramic electrochemical cells is the performance of the air electrode. Although the intrinsic properties of the ceramic material, such as electrical conductivity and electrochemical activity are of great importance, the real performance of the air electrode strongly depends on its microstructure: porosity, particle size, surface area and electrode-electrolyte adherence [2].

It is reported that the efficiency of air electrodes with poor ionic conductivity may be improved by adding a second phase with high ionic conductivity, i.e. CeO_2 and Bi_2O_3-based electrolytes, to obtain a composite electrode. Many studies have shown that composite electrodes have higher efficiency than the single-phase ones due to the increased active area [2]. Moreover, they are usually employed to reduce the mechanical stress between the electrode and the electrolyte layers, originated by the different thermal expansion coefficients (TEC), thus enhancing the mechanical stability of the cell.

Traditionally, composite electrodes are prepared by mechanically mixing the pristine materials but, unfortunately, it is difficult to control the composition distribution and architecture with this method. In order to overcome this drawback, nanocomposite powders may be synthesized by different co-synthesis methods, showing a more uniform distribution of nanosized crystals with high thermal stability and improved electrochemical properties.

$Sm_{0.5}Sr_{0.5}CoO_{3-\delta}$ present high ionic and electronic conductivity, but its elevated TEC, 21.5·10-6 K-1 makes its use incompatible with the electrolyte materials. In this work, $Sm_{0.5}Sr_{0.5}CoO_{3-\delta}$–$Ce_{0.9}Sm_{0.1}O_{1.95}$ (SSC–CSO) nanocomposite cathodes are successfully prepared in a single process by using the freeze-drying precursor method, in a single-step synthesis, from a precursor solution containing all cations in stoichiometric amounts. In this way, SSC and CSO are formed simultaneously, reducing drastically the preparation time, which is an important improvement for potential industrial application. Different percentages of SSC-CSO, ranging from 100 to 50% of SSC are investigated: 100-SSC, 80-SSC, 60-SSC and 50-SSC.

SSC and CSO are adequately refined in the orthorhombic perovskite *Pnma* (PDF 00-053-0112) and cubic fluorite *Fm-3m* (PDF 1-075-0157) space groups, respectively. No secondary phases are detected for any of the samples.

The electrode is composed of nanometric particles, providing high active area for the electrochemical reactions. The CGO addition suppresses the grain growth of the nanocomposite cathodes, rendering lower particle size, from 0.53 to 0.32 nm of diameter for 100-SSC to 50-SSC, respectively. This behavior is explained by the presence of CGO as secondary phase, which limits the cation diffusion and the grain growth rate.

A low polarization resistance of 0.088 Ω cm^2 is obtained at 700 °C for 50-SSC. The results suggest that this is a promising strategy to achieve high efficiency ceramic electrodes for reversible electrochemical cells in a single preparation step, simplifying notably the fabrication process compared to traditional methods.

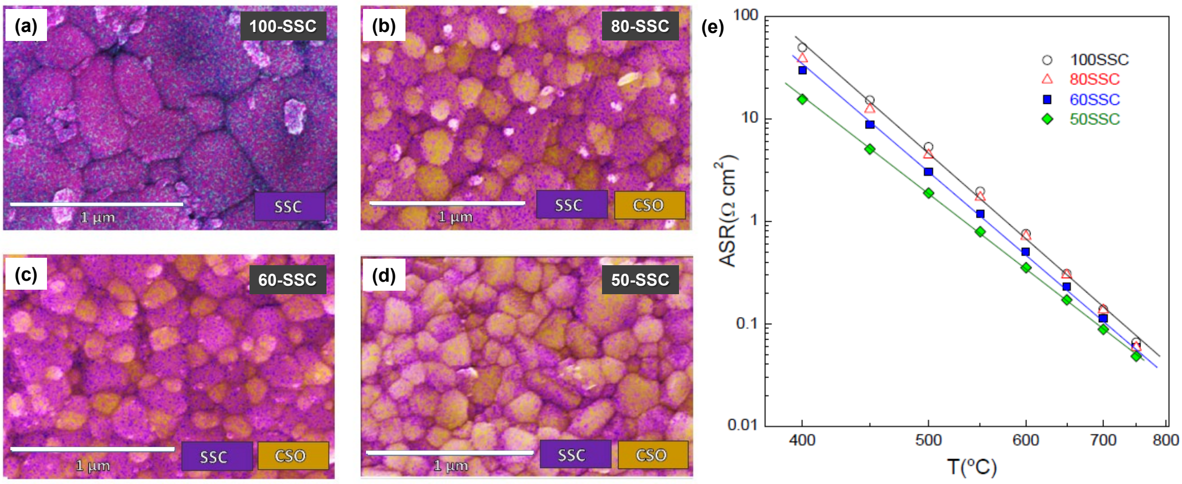

Figure 1. (a-d) EDX images and (e) polarization resistance values in air of the SSC-CSO nanocomposites prepared with different SSC ratio at 1100 ºC for 1 h.

References

[1] C. Duan et al., Nature Energy 4 (2019) 230.

[2] L. dos Santos-Gómez et al., Journal of Power Sources 507 (2021) 230277.