Tailoring high entropy perovskites for green hydrogen production via solid oxide electrolysis

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Introduction & Motivation

Solid oxide electrolysis cells (SOECs) represent a tremendous opportunity for green hydrogen production, as it utilizes high-temperature electrolysis to efficiently split water molecules into hydrogen and oxygen, with the added benefit of utilizing renewable energy sources. This technology holds immense promise for a sustainable future, enabling the large-scale production of clean hydrogen as a versatile and environmentally friendly energy carrier. The present work deals with a promising novel material class for the air electrode of solid oxide cells, which is high entropy perovskites (HEPs). The results show that HEP could be a promising choice for air electrodes for SOEC as well as fuel cell (SOFC) applications.

Theory

$$S_{config.} = -R\left[\left(\sum_{a=1}^{n} x_a \ln x_a\right)_A + \left(\sum_{b=1}^{n} x_b \ln x_b\right)_B + 3\left(\sum_{c=1}^{n} x_c \ln x_c\right)_O\right]$$

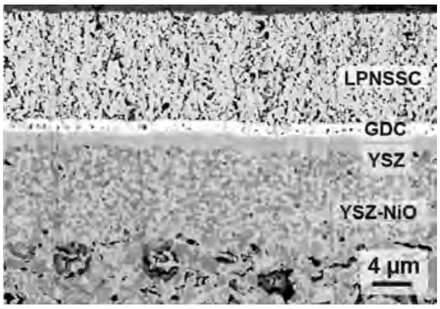
- At least 5 different cations at A or B site increase configurational entropy
- The high dispersity of several different cations in A-site may cause lattice distortion which might suppress strontium diffusion [1]
- Cocktail effect may be induced: properties can differ significantly from related elemental compositions

Synthesis

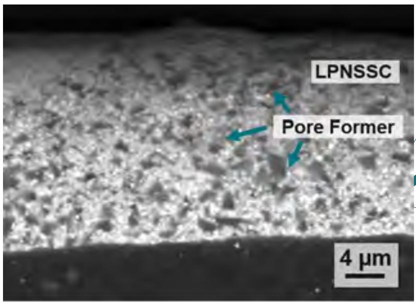
- $La_{0.2}Pr_{0.2}Nd_{0.2}Sm_{0.2}Sr_{0.2}CoO_{3-\delta}$ (LPNSSC) was investigated
- LPNSSC powder was synthesized by the citric acid – ethylenediaminetetraacetate (CA-EDTA) sol-gel method
- The powder was homogenized and calcined for 4h at 1,000°C

Cell Microstructure and Microstructural Tailoring

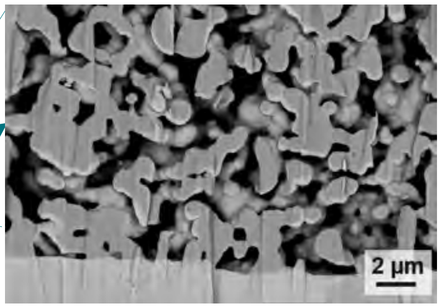
Simulating SOEC with different kinds of microstructure attributes, indicate a favorable porosity of more than 30% with grain size down to 0.1µm of most efficient hydrogen production. The images below show a way how to influence microstructural parameters [2].



FESEM cross section images of a fresh 5 x 5 cm² full cell. The screen printed LPNSSC air electrode shows homogeneous thickness (14 µm ± 0.3 µm) and a uniform, rather dense microstructure.



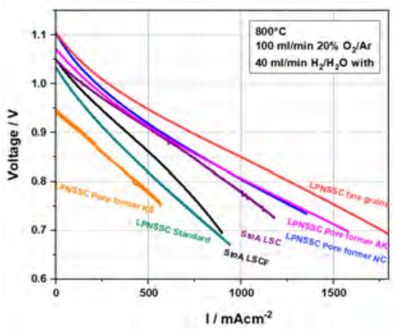
SEM image of the cross section of a screen printed, LPNSSC air electrode, containing carbon particles as pore formers, with a diameter that varies from approx. 0.8 µm to 1.8 µm.

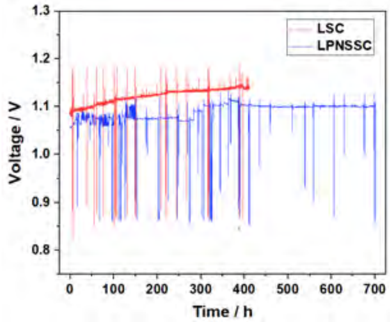


FESEM image of the cross section of a screen printed LPNSSC air electrode after sintering, containing carbon particles. Carbon was oxidized resulting in a more porous microstructure.

Electrochemical Characterization

- Left image: Superior cell performance in SOFC mode for LPNSSC and different pore formers compared to state of the art air electrodes (KS = ~30µm potatoes starch, NC = ~0.1 µm nano carbon, AK ~1.5 µm active carbon)
- Right image: Better long term stability of LPNSSC in SOEC mode compared with $La_{0.6}Sr_{0.4}CoO_{3-\delta}$. Constant voltage over a wide range means hardly any degradation





References

[1] Yang, Y., et al., A novel facile strategy to suppress Sr segregation for high-entropy stabilized $La_{0.8}Sr_{0.2}MnO_{3-\delta}$ cathode. Journal of Power Sources, 2021. 482: p. 228959

[2] Wenying, Li, et al., Theoretical modeling of air electrode operating in SOFC mode and SOEC mode: The effects of microstructure and thickness. International Journal of Hydrogen Energy, 2014. 39: p. 13738-1375

This research activity has received funding from Montanuniversität Leoben and is part of the Strategic Core Research Area SCoRe A+ Hydrogen and Carbon

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