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Smart composite electrode for reversible solid oxide cells (RSOCs)

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Reversible solid oxide cells (RSOCs) represent a promising technology for the efficient exploitation of intrinsically intermittent renewable energy sources. RSOCs allow to derive fuel and chemicals from power (power-to-gas technology, P2G) and power from fuel and chemicals (gas-to-power technology, GTP) and can be interchangeably operated either as a solid oxide fuel cell (SOFC) or as a solid oxide electrolyzer cell (SOEC).

A key aspect to render these devices competitive on a market scale is the development of multi-tasking, reliable, cost-effective, and long-lasting electrodes. Besides, to overcome the issues related to hydrogen production, storage and distribution, the fuel-electrode of RSOCs should ensure high catalytic activity and coking resistance toward carbon-containing species [1].

Using a hydrocarbon-tolerant fuel electrode, energy can be obtained by natural gas and biogas (SOFC-mode), with useful recovery of CO_2 in the exhausts (carbon capture and storage, CCS). Besides, if the electrode is also active towards CO_2 electrolysis (SOEC mode), CO_2 is reduced to CO and O_2 (carbon capture and utilization, CCU).

Ni-YSZ is the reference fuel-electrode material for both H_2 fed SOFC and for CO_2 electrolysis in SOEC. Nevertheless, Ni-based cermet cannot be used in SOFCs fed with methane-containing fuels, as it suffers from two main drawbacks: mechanical instability upon NiO-Ni redox cycles and passivation due to coking, being Ni a catalyst for methane cracking [1]. Moreover, during Ni-YSZ operation in CO_2-SOEC mode, ZrO_2 reduction can occur at high cathodic potential, resulting in Ni-Zr compounds formation.

In our work, a recently developed composite material containing $La_{0.6}Sr_{0.4}Fe_{0.8}Mn_{0.2}O_{3-\delta}$ (LSFMn) and 5wt% Ni-containing $Ce_{0.85}Sm_{0.15}O_{2-\delta}$ (NiSDC) is tested as fuel electrode for LSGM-electrolyte supported cells. In reducing conditions, Fe exsolved from the LSFMn perovskite forms a Fe-Ni alloy with Ni present on SDC [2,3].

LSFMn+NiSDC was tested in SOFC-mode for hydrogen, dry methane, and carbon monoxide oxidation, showing MPD of 657, 668 and 527 mW/cm^2, respectively, with a redox stable behavior and coking resistance for over 120 h. LSFMn+NiSDC in SOEC-mode delivered 2.66 A/cm^2 at 2 V in 95:5 CO_2:CO mixture, keeping 1 A/cm^2 for over 40 h.

[1] *M. Mogensen et al., Clean Energy 3.3 (2019) 175-201.*
[2] *L. Duranti, et al., Journal of the European Ceramic Society, 40.12 (2020) 4076-4083.*
[3] *L. Duranti et al., Electrochimica Acta 362 (2020) 137116.*