Summary of the PhD thesis

Solid oxide cells (SOCs) represent a promising solution for the conversion and storage of clean energy from renewable power sources. The SOC devices can operate reversibly both in electrolysis mode (SOEC), producing hydrogen from the steam by using renewable electricity, and in fuel cell mode (SOFC), converting chemical energy of a fuel into electricity.

In a SOC stack, interconnects (ICs) provide electrical connection between the cells and act as a physical barrier to prevent direct combination of the fuel and the oxidant. Chromia-forming ferritic stainless-steels are widely employed as interconnects. However, the introduction of a metallic component raises issues that can potentially affect the durability of the device. Indeed, the continuous oxidation of the interconnect progressively reduces the electrical conductivity, while the chromium volatilization degrades the electrochemical performances of the cells. Moreover, in the common planar stack configuration, the integration of a sealing material can potentially induce detrimental reactions, limiting the stability of the interface with the interconnect. Within this context, developments in coating technology to limit degradation phenomena related to the use of stainless-steel ICs are crucial in improving the durability of SOC stacks and their rollout as commercial industrial systems.

This PhD thesis investigates and validates the electrophoretic deposition (EPD) as an adaptable and scalable technique, to produce effective protective coatings for SOC interconnects, while potentially reducing processing time and cost.

The application of a protective coating on the IC is considered a viable solution to limit oxidation and chromium evaporation. In this work, an innovative approach for the electrophoretic co-deposition of three spinel precursors was conceived and optimised to obtain protective manganese cobaltite spinel coatings modified *in-situ* by the simultaneous addition of iron and copper. The synergic effect of different levels of Cu and Fe co-doping was observed on the densification of the coatings, the stability of the spinel phase, the coefficient of thermal expansion, the corrosion resistance up to 1000 h at 750 °C, the area specific resistance. The findings here reported provide the first comprehensive assessment of Fe-Cu co-doping in the Mn–Co spinel and lay the groundwork for future research into use of EPD as a valuable method to design and produce in-situ modified spinel coatings.

The complex geometry of the interconnects requires a proper selection of the coating deposition technique. To investigate the suitability of the EPD process to coat real size interconnects, two cases of apparatus upscaling of the technique were pursued. First, EPD-coated Crofer22APU interconnects, subjected to stack test at 850 °C were deeply characterised, including transmission electron microscopy analyses. Then, SUS 445 stainless-steel interconnects produced through powder metallurgy were coated by EPD with $MnCo_2O_4$ spinel coating. The optimisation of the sintering allowed to reach a low area specific resistance of 12.7 mΩ cm^2 after 1500 h at 800 °C, with a degradation rate below 1.2 mΩ cm^2/kh for the best coating system. Overall, the studies here reported provided proof of the suitability and maturity of EPD as an effective deposition technique for the processing of ceramic coatings on SOC interconnects at an industrial scale.

The definition of specific routes to enhance the mechanical resistance and stability of the interconnect-sealant interfaces plays a key role for the future development of SOC technologies. In this works, two designs were proposed and validated. First, the optimisation of the EPD procedure allowed achieving an innovative interconnect aluminization process, by depositing a homogeneous layer of aluminium precursor on Crofer22APU. The deposited layer was subsequently converted by a thermal consolidation treatment in an alumina coating with enhanced surface roughness. Furthermore, a laser machining of the steel to induce tuned surface roughness and a tailored mechanical interlocking at the sealant interface was validated. Both surface modification solutions were tested at relevant SOC conditions and compared. The evaluation of the shear strength was conducted by torsion test on joined systems, finding out that both steel modification routes ensured cohesive fracture propagation. EPD-alumina-coated samples demonstrated comparable shear strengths both in the as-prepared (31.2±2.0 MPa) and after 1000 hour-aging at 850 °C (33.0±1.0 MPa) cases. The laser-machined Crofer22APU samples demonstrated around 30% increase in torsional shear strength compared to unmodified steel samples. Both alumina-coated and laser-machined Crofer22APU joined with glass-ceramic sealant were tested in dual atmosphere simulating SOEC conditions at 850 °C up to 1000 h. The study revealed interesting insights into the possibility of modifying the surface properties of the interconnect at the interface with the sealing material.