Solid oxide cells (SOCs) offer great prospects for the efficient and reversible conversion of chemical to electrical energy. Therefore, they are expected to play a key role in the renewable energy landscape. However, their limited lifetime under operating conditions hinders their widespread usage. The degradation processes are mainly attributed to morphological changes occurring within the electrodes microstructure. Therefore, precise tracking of 3D microstructural evolution during operation is considered crucial to understanding the complex relationship between microstructure and performance.

In this work, X-ray ptychographic tomography is applied to SOC materials, demonstrating unprecedented spatial resolution and data quality. The effect of a complete redox cycle on the same Ni-YSZ microstructure is visualized ex-situ in 3D, showing major rearrangement of the nickel network after reduction, the formation of cracks in the YSZ, and void formation in nickel oxide after oxidation.

Capitalizing on the high resolution of ptychography, the effect of nickel coarsening on the Ni-YSZ microstructure evolution is studied ex-situ in three dimensions, while the sample is repeatedly scanned and treated at high temperature in dry hydrogen. The analyses show the substantial evolution of the nickel and pore networks during the first 3 hours of treatment. The nickel coarsening leads to loss of nickel connectivity, a decrease in specific interface area and a decrease in total triple phase boundary density.

The ex-situ experiment on a redox cycle provides new insights on the nature of the redox processes occurring within a SOC fuel electrode. However, only the initial and final steps of the reactions can be analyzed. To gain information about the intermediate steps of the reduction and oxidation, in-situ holographic tomography is applied. Preliminary results show rapid kinetics for the two reactions. During oxidation, void formation in metallic particles is observed. During reduction, the nickel oxide particles first evolve to a nano-porous system of nickel crystallites and then coarsen towards dense nickel particles.