Solid-State Proton-Conducting Cells: Development and Evaluation for Green Hydrogen Production

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Solid-state proton conducting cells (PCCs) provide a pathway to hydrogen production and electricity generation at intermediate temperatures (400–600°C), lower than those required for conventional solid oxide cells, which typically operate between 600–800°C. Operation at reduced temperature can extend system lifetime, an essential requirement for industrial deployment (>80,000 h), but simultaneously decreases electrochemical reaction kinetics [Blum, L. et al., 2020. International Journal of Hydrogen Energy, 45(15), 8955–8964]. Consequently, electrode design becomes critical, and significant resources are directed towards developing highly active electrodes with controlled microstructures that support activity, gas transport, and long-term stability.

In PCCs, the fuel electrode(FE) microstructure is governed by several fabrication parameters, including powder characteristics, processing route, sintering temperature, and reduction protocol [Nasani, N. et al., 2014. International Journal of Hydrogen Energy, 39, 21231–21241]. A detailed understanding of how fabrication parameters influence electrode microstructure is therefore essential for the rational design of high-performing PCCs. Figure 1a-b illustrates the development of the Gen2 fuel electrode after sintering and after reduction (Figure 1c).

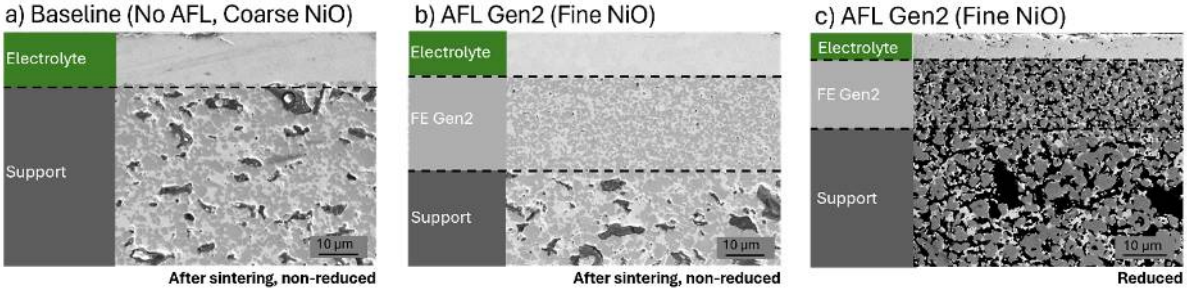

Figure 1) SEM-images of a) sintered half-cell without a fuel electrode(FE), b) sintered half-cell with FE Gen2, and c) sintered half-cell with FE Gen2 after reduction .

This study investigates the effect of the initial NiO particle size on the microstructure of the FE. Composite 60:40wt.% NiO-$BaCe_{0.7}Zr_{0.1}Y_{0.1}Yb_{0.1}O_{3-\delta}$ (BCZYYb7111) electrodes were fabricated by tape casting using NiO–BCZYYb7111 powders with an initial d_{50} of 0.5µm. The green tape was co-sintered between the support and the electrolyte in air for 5-7h at 1300-1400°C. After sintering, particle coarsening was observed, resulting in a Feret's Diameter of 2.1µm. Following reduction at 700°C in 5%H_2/N_2, the Ni phase underwent volumetric shrinkage and reorganised into a percolating Ni network. This microstructural rearrangement resulted in a slight further increase in Feret's Diameter to 2.5µm. Full cells incorporating the Gen2 fuel electrode were cut into 14mm-diameter button cells and evaluated electrochemically.