

Degradation Analysis of Long-term Solid Oxide Fuel Cell Stacks with Respect to Chromium Poisoning in $\text{La}_{0.58}\text{Sr}_{0.4}\text{Co}_{0.2}\text{Fe}_{0.8}\text{O}_{3-\delta}$ and $\text{La}_{0.6}\text{Sr}_{0.4}\text{CoO}_{3-\delta}$ Cathodes

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Abstract

Chromia-forming steels or chromium containing alloys are widely used in solid oxide fuel cell (SOFC) stacks and systems. Chromium poisoning as a result of Cr evaporation from the metallic components and thereafter the deposition at cathode side (i.e. air side) is one of the most critical degradation mechanisms in SOFCs. Although the chromium poisoning mechanisms have been studied intensively in the last decades worldwide, there are still debates and contradictory results on different aspects of the mechanism. Despite of these debates, degradation due to chromium poisoning has been reduced largely through optimized protective coatings on the interconnector and improvement of cathode materials. Previous long-term stack tests at the Forschungszentrum Jülich have shown that a reproducible low degradation rate of less than $0.3 \text{ \%kh}^{-1}$ can be obtained with the state-of-the-art plasma-sprayed MCF coating (i.e., $\text{MnCo}_{1.9}\text{Fe}_{0.1}\text{O}_{3-\delta}$) and LSCF cathode (i.e., $\text{La}_{0.58}\text{Sr}_{0.4}\text{Co}_{0.2}\text{Fe}_{0.8}\text{O}_{3-\delta}$) when operating at $700 \text{ }^{\circ}\text{C} \sim 750 \text{ }^{\circ}\text{C}$ with hydrogen and compressed air under a current density of $0.5 \text{ A}\cdot\text{cm}^{-2}$ and fuel utilization of 40%. Recently, the LSC cathode (i.e., $\text{La}_{0.6}\text{Sr}_{0.4}\text{CoO}_{3-\delta}$) has shown more promising results in both fuel cell and electrolysis modes than LSCF due to its higher ionic conductivity, despite of a relatively larger thermal expansion coefficient (TEC). Furthermore, it has been reported by other research groups that the oxygen surface exchange kinetics and Sr stability/activity of LSC may suggest a higher resistance against Cr poisoning, compared to LSCF. For these reasons, long-term stack operation with both LSCF and LSC cathodes were performed in two different stack designs (i.e., robust F-design and lightweight cassette design). The degradation behaviour of the stacks with respect to Cr poisoning was analysed with the support of electrochemical impedance spectroscopy and post-mortem analysis (e.g., microanalysis using scanning electron microscopy and chemical analysis using inductively coupled plasma – optical emission spectroscopy). In this work, the results of more than four stacks with an operating time between 5,000 h and 10,000 h will be presented.