

Effect of Preoxidation on the Effectiveness of Gd₂O₃ Nanoparticles Applied as a Source of Active Element in the Crofer 22 APU Coated with a Protective-conducting Spinel Layer

Authors : Łukasz Mazur, Kamil Domaradzki, Maciej Bik, Tomasz Brylewski, Aleksander Gil

Abstract : Interconnects used in solid oxide fuel and electrolyzer cells (SOFCs/SOECs) serve several important functions, and therefore interconnect materials must exhibit certain properties. Their thermal expansion coefficient needs to match that of the ceramic components of these devices - the electrolyte, anode and cathode. Interconnects also provide structural rigidity to the entire device, which is why interconnect materials must exhibit sufficient mechanical strength at high temperatures. Gas-tightness is also a prerequisite since they separate gas reagents, and they also must provide very good electrical contact between neighboring cells over the entire operating time. High-chromium ferritic steels meet these requirements to a high degree but are affected by the formation of a Cr₂O₃ scale, which leads to increased electrical resistance. The final criterion for interconnect materials is chemical inertness in relation to the remaining cell components. In the case of ferritic steels, this has proved difficult due to the formation of volatile and reactive oxyhydroxides observed when Cr₂O₃ is exposed to oxygen and water vapor. This process is particularly harmful on the cathode side in SOFCs and the anode side in SOECs. To mitigate this, protective-conducting ceramic coatings can be deposited on an interconnect's surface. The area-specific resistance (ASR) of a single interconnect cannot exceed 0.1 Ωm² at any point of the device's operation. The rate at which the CrO₃ scale grows on ferritic steels can be reduced significantly via the so-called reactive element effect (REE). Research has shown that the deposition of Gd₂O₃ nanoparticles on the surface of the Crofer 22 APU, already modified using a protective-conducting spinel layer, further improves the oxidation resistance of this steel. However, the deposition of the manganese-cobalt spinel layer is a rather complex process and is performed at high temperatures in reducing and oxidizing atmospheres. There was thus reason to believe that this process may reduce the effectiveness of Gd₂O₃ nanoparticles added as an active element source. The objective of the present study was, therefore, to determine any potential impact by introducing a preoxidation stage after the nanoparticle deposition and before the steel is coated with the spinel. This should have allowed the nanoparticles to incorporate into the interior of the scale formed on the steel. Different samples were oxidized for 7000 h in air at 1073 K under quasi-isothermal conditions. The phase composition, chemical composition, and microstructure of the oxidation products formed on the samples were determined using X-ray diffraction, Raman spectroscopy, and scanning electron microscopy combined with energy-dispersive X-ray spectroscopy. A four-point, two-probe DC method was applied to measure ASR. It was found that coating deposition does indeed reduce the beneficial effect of Gd₂O₃ addition, since the smallest mass gain and the lowest ASR value were determined for the sample for which the additional preoxidation stage had been performed. It can be assumed that during this stage, gadolinium incorporates into and segregates at grain boundaries in the thin Cr₂O₃ that is forming. This allows the Gd₂O₃ nanoparticles to be a more effective source of the active element.

Keywords : interconnects, oxide nanoparticles, reactive element effect, SOEC, SOFC

Conference Title : ICNNTFEA 2024 : International Conference on Nanotechnology, Nanomaterials and Thin Films for Energy Applications

Conference Location : Rio de Janeiro, Brazil

Conference Dates : February 01-02, 2024