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Oxidation Behavior of Ferritic Stainless Steel Interconnects Modified Using Nanoparticles of Rare-Earth Elements under Operating Conditions Specific to Solid Oxide Electrolyzer Cells

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Abstract : The rising global power consumption necessitates the development of new energy storage solutions. Prospective technologies include solid oxide electrolyzer cells (SOECs), which convert surplus electrical energy into hydrogen. An electrolyzer cell consists of a porous anode, and cathode, and a dense electrolyte. Power output is increased by connecting cells into stacks using interconnects. Interconnects are currently made from high-chromium ferritic steels – for example, Crofer 22 APU – which exhibit high oxidation resistance and a thermal expansion coefficient that is similar to that of electrode materials. These materials have one disadvantage – their area-specific resistance (ASR) gradually increases due to the formation of a Cr_2O_3 scale on their surface as a result of oxidation. The chromia in the scale also reacts with the water vapor present in the reaction media, forming volatile chromium oxyhydroxides, which in turn react with electrode materials and cause their deterioration. The electrochemical efficiency of SOECs thus decreases. To mitigate this, the interconnect surface can be modified with protective-conducting coatings of spinel or other materials. The high prices of SOEC components - especially the Crofer 22 APU- have prevented their widespread adoption. More inexpensive counterparts, therefore, need to be found, and their properties need to be enhanced to make them viable. Candidates include the Nirosta 4016/1,4016 low-chromium ferritic steel with a chromium content of just 16.3 wt%. This steel's resistance to high-temperature oxidation was improved by depositing Gd_2O_3 nanoparticles on its surface via either dip coating or electrolysis. Modification with CeO_2 or $Ce_{0.9}Y_{0.1}O_2$ nanoparticles deposited by means of spray pyrolysis was also tested. These methods were selected because of their low cost and simplicity of application. The aim of this study was to investigate the oxidation kinetics of Nirosta 4016/1,4016 modified using the afore-mentioned methods and to subsequently measure the obtained samples' ASR. The samples were oxidized for 100 h in the air as well as air/H_2O and Ar/H_2/H_2O mixtures at 1073 K. Such conditions reflect those found in the anode and cathode operating space during real-life use of SOECs. Phase and chemical composition and the microstructure of oxidation products were determined using XRD and SEM-EDS. ASR was measured over the range of 623-1073 K using a four-point, two-probe DC technique. The results indicate that the applied nanoparticles improve the oxidation resistance and electrical properties of the studied layered systems. The properties of individual systems varied significantly depending on the applied reaction medium. Gd_2O_3 nanoparticles improved oxidation resistance to a greater degree than either CeO_2 or $Ce_{0.9}Y_{0.1}O_2$ nanoparticles. On the other hand, the cerium-containing nanoparticles improved electrical properties regardless of the reaction medium. The ASR values of all surface-modified steel samples were below the 0.1 $\Omega.cm^2$ threshold set for interconnect materials, which was exceeded in the case of the unmodified reference sample. It can be concluded that the applied modifications increased the oxidation resistance of Nirosta 4016/1.4016 to a level that allows its use as SOEC interconnect material. Acknowledgments: Funding of Research project supported by program "Excellence initiative – research university" for the AGH University of Krakow" is gratefully acknowledged (TB).

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