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ABSTRACT OF THE DISSERTATION
„Forming spinel layer on steel components for use in stacks of Solid Oxide Fuel Cells (SOFC)"

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The energy transition is contributing to the development of low-carbon ways of generating energy and storing it. In this context, hydrogen technologies, including electrochemical cells, are increasingly receiving attention. This doctoral dissertation discusses solid oxide electrochemical cells (SOC, Solid Oxide Cell), which, depending on the need, can either produce electricity through the electro-oxidation reaction of hydrogen with oxygen from the air or store electricity by converting it into a stable carrier, such as hydrogen, hydrocarbons or ammonia. Technologies of this type can contribute to the development of RES (Renewable Energy Sources) on a massive scale by enabling the storage of very large amounts of energy in the above-mentioned chemical compounds.

A single SOC cell, operating in fuel cell mode, when powered by hydrogen has an open circuit voltage (OCV) of about 1.15-1.30 V, while under current load it can operate between OCV and 0.7 V. A single cell is capable of operating under a load of less than about 0.5 A/cm^2. Thas, in order to obtain a higher power device, cells are assembled into electrochemical cell stacks. Stacks are devices that consist of stacked fuel cells electrically connected in series. They are constructed using seals and structural steel components that separate the air and fuel zones. In the next step, electrochemical cell stacks can be used to build MW-class systems, operating at fuel cell mode (SOFC, Solid Oxide Fuel Cell), electrolyzer (SOE, Solid Oxide Electrolyser) or alternately in both modes (rSOC, reversible Solid Oxide Cell).

For proper and reliable operation of stacks at 700-800 °C, adequate protection of steel elements - protective layers - is required. The aim of the dissertation was to increase the reliability of the operation of a stack of solid oxide electrochemical cells by introducing modifications in the area of materials and the method of manufacturing ceramic protective coatings that guarantee long-term, failure-free operation of the cells without a decrease in their performance. To this end, modified protective coatings were developed on interconnectors, i.e. steel elements in the stack in direct contact with SOC cells.

The research included a scientific part and a typical implementation part. The scientific part of the work involved the selection of suitable materials, the study of slurries used for the formation of protective coatings by electrophoretic deposition (EPD), the design of multimodal powder systems, electrophysical, microstructural studies, and a series of material analyses to optimally obtain and characterize a high-quality protective coating, and, most importantly, to understand the processes occurring during the formation of protective layers and their operation in long-term studies lasting minimum 1000 h. The implementation part involved designing and building a station for coverage of full-size steel elements used in the stack using the EPD method, then covering interconnectors and testing them in a prototype electrochemical cell stack being developed at the Institute of Power Engineering - National Research Institute. The EPD method is a well-known and scalable technique used to coat large area and complex shaped components, but in the literature it is not a commonly used method in fabrication protective coatings to full-sized SOC cell stack components.

This doctoral dissertation presents the effect of the grinding process and the formation of multimodal mixtures of $Mn_{1.5}Co_{1.5}O_4$ (MC11) powder on the quality of the formed layers. Protective coatings obtained from unmodified ceramic powder had higher porosity and lower electrical conductivity compared to grinded powders and powder mixtures. In addition, a lower degradation rate was demonstrated for protective coatings obtained from modified powders in 1000 h tests than for unmodified materials, which is an important factor for the reliable and trouble-free operation of SOC cell stacks during their operation.

Protective coatings were also obtained on full-size SOC stack elements using the EPD method and tested in a stack developed at the Institute of Power Engineering - National Research Institute.

Keywords: protective coating, manganese-cobalt spinel, electrophoretic deposition, solid oxide fuel cell – SOFC, solid oxide electrolyzer cell (SOEC), SOC stack, ASR

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