Description for the general public

Ceramic ionic conductors are applied in innovative systems for highly efficient and clean power generation. The oxygen separation membranes and solid oxide fuel cells (SOFC) can be the examples.

Fuel cells with solid oxide electrolyte are a complex electrochemical devices made of three basic functional layers – two electrodes separated by an electrolyte. Generally, electrochemical cell which can be operated in a fuel cell mode, generates electricity while fuel and oxidant are consumed. It is known that systems with electrochemical cells which can be reversed or operated in regenerative mode or operated in electrolysis mode exist. Such cells are commonly called SOEC – solid oxide electrolysis cells. In such cells, hydrogen and oxygen are generated from water vapour using electricity.

During over the last decades it was proven that an electrochemical cell can be reversed during operation. It means that the SOFC can be converted into SOEC or backwards. It is done by the change of the cell's polarization. The recent works indicate that the microstructural properties, including the porosity are the key factors influencing electrolysis reaction done with ceramic ionic conductors. Additionally it was found that the optimal values of the parameters for SOFC mode lay elsewhere than for SOEC mode.

Influence of various structural properties of ceramic ionic conductors which are used for solid oxide fuel cells was well-defined and described using several mathematical models. Such parameters as ionic and electronic conductivity, porosity, tortuosity, shape and distribution of pores were included. In case of solid oxide electrolysis cells, effects of these parameters on the electrolysis reaction remain unclear and obscure. There is no clearly defined correlation, neither there is an optimization tool for modification of the parameters to maximize the performance of solid oxide cell operating in regenerative mode.

For that reason it is necessary to perform a complete comprehensive analysis combining both the experimental and numerical techniques to identify the key microstructural parameters and their correlation with the performance of electrochemical reaction.

Knowledge resulting from the proposed project as well as the generalized mathematical description can aid in future in defining optimal microstructural parameters of ceramic ionic conductors for operation in high temperature electrolysis mode (SOEC). Additionally, it will make it possible to define strategies for minimization of degradation, which will lead to increase of the durability and lifetime of reversible solid oxide cells made of ceramic ionic conductors.

In broad global aspect, results of the project can accelerate the development of reversible SOFC/SOEC cells. Such systems can be applied in power sector, which will comprise intermitted energy sources (renewables such as wind, PVs, etc.) which require storage capabilities. Use of reversible cells allows to store the excess electricity in a form of hydrogen generated via the electrolysis. During peak demands for power, this hydrogen can be recombined with oxygen in an electrochemical reaction taking place in SOFC.

Research tasks planned in the project include experimental characterization of a large population of samples of cells made of ceramic ionic conductors, including cells with modified electrodes and electrolyte. During the project, the initial correlation of parameters with the performance will be identified. On that basis, the required modification of samples will be defined, afterwards they will be fabricated and tested during long-term experiments. The *post mortem* microstructural studies and mathematical modelling using advanced simulation methods during stationary and dynamic operation are a complementary activities.