Description for the general public

The goal of the proposed project is to perform experimental and numerical work, dedicated to studies of the mechanism of mass transport in porous materials. A series of experiments aim at gaining new knowledge in specific operating conditions: at high temperature and in the regime of significant concentration gradients of gas components. Analysis of multi-faced nature of mass transfer mechanism required support from numerical analysis in order to understand and classify each single phenomena occurring during the test, according to their significance and impact on the overall process.

Solid Oxide Fuel Cell (SOFC) will be used for the purpose of testing campaign. Fuel cell is an electrochemical cell which converts chemical energy from the fuel into electricity through an electrochemical reaction. SOFC fuel cells are dedicated to work in temperatures above 650°C, and can be fuelled by a number of different fuels. In addition to high electrical efficiency, fuel flexibility is one of the key advantages of high-temperature SOFC fuel cells. The fuel may be hydrogen, CO or short-chain hydrocarbons (methane, ethane, propane). Moreover, SOFC technology is environmental friendly due to marginal emission of detrimental gaseous and highly effective fuel conversion. Potential application of SOFC is cogeneration unit, which work as a primary or backup power generator with power up to sever hundred kilowatts.

SOFC fuel cell consists of three main components: two electrodes (cathode, anode) and the electrolyte. The electrodes are porous, gas-permeable materials. The electrolyte is a thin, gas-tight ceramic made of zirconium oxide, cerium or perovskites materials which has oxygen ion conductivity. The high ionic conductivity of the membrane is the results of the small thickness of the electrolyte layer (single microns for anode supported solid oxide fuel cells) and the high operating temperature (> 650°C). When oxygen ions reach the surface of the anode, they react with gaseous fuel. The products of this reaction are depleted fuel (water, H_2, N_2) and electrons which return to cathode through the external circuit, generates a useful work.

Under optimal conditions the cell is supplied with sufficient fuel and an oxidant. The concentration of the reactants it is crucial for the velocity of electrochemical reaction and thereby affects the power of a single cell. The planned series of tests and numerical calculations will help to explain mass transfer processes in specified operating conditions: significant concentration gradients of gas components and high operating temperature. Usually it is not recommended to operate SOFC in the above mentioned conditions due to high risk of significant degradation of cells. In present work investigations will be focused on boundary of the safe operation conditions, namely on domain, where diffusion supply of the fuel is not high enough to keep electrochemical oxidation in linear mode. This regime is of particular interest, because it can be reached in case when SOFC is overloaded or if fuel supply is in off-design regime. Whilst this topic is of substantial importance, it is studied fragmentary.

Within the project a general mathematical model and thermodynamic analysis of mass transport in porous media will be created in order to describe the process control variables. Project is focused on extending the range of optimal operating conditions for following devices: fuel cells, high temperature membranes, separators, selective sieves or porous filters.