Hydrogen and hydrocarbons belong to the group of fuels that can generate electricity using electrochemical processes in high-temperature fuel cells (MCFC and SOFC types). Each fuel cell consists of a cathode, an electrolyte, and an anode. At the cathode, oxygen is reduced forming oxygen ions and electrons, which are transported by an external electrical circuit. Oxygen ions move through the electrolyte towards the anode. At the negative electrode, hydrogen is oxidized and combined with the supplied ions and electrons, leading to water formation. Fuel cells are characterized by several advantages that distinguish them from conventional solutions. First of all, they do not emit greenhouse gases and, therefore, help fight against climate change. They don't contain moving parts, which allows for quiet operation. They are characterized by very high efficiency and can be used in a cogeneration system. The rapid growth of the number of publication in this subject, as well as the increasing number of commercial installations, shows the great potential of fuel cells, both for academia and industry.

The proposed carbonate-oxygen fuel cell is a system that combines the best solutions used in high-temperature fuel cell technologies, such as a molten carbonate electrolyte (MCFC) and a solid oxide electrolyte (SOFC). Thanks to the simultaneous use of a liquid electrolyte, conducting carbonate ions, and a solid electrolyte, conducting oxygen ions, the efficiency of the cell is increased at lower operating temperatures, which has been experimentally proven in several research studies. One of the critical parameters affecting the conductivity of a solid electrolyte is its thickness. The resistance of the electrolyte layer increases proportionally to the distance over which the oxygen ions have to move. In a standard MCFC, the electrolyte layer is 0.8-1 mm thick, which is too much for a system combining two types of electrolytes. A technological problem blocking further thickness reduction is the high brittleness of thin, low-sintered ceramic tapes. Within this project, three methods of producing electrolyte layers directly on the cathode will be tested: tape casting, spray coating, and electrophoretic deposition. Thanks to this, it will be possible to create a gradient structure with increased mechanical strength and continuous ion conductivity paths between all cell elements. This will significantly reduce overall cell resistance, due to low contact resistance, high electronic and ionic conductivity. The proposed methods allow for the scale up of the fuel cell fabrication process, which is important for commercial applications in the future.

The project aims to fabricate the elements of a carbonate-oxygen fuel cell, their precise characterization and testing in a fuel cell assembly. The research will include an in-depth analysis of materials and single cells, including their performance and degradation over time. Within the project the numerical modelling (both at the atomic and microstructural level) will be performed in order to explain the superior conductivity of the system, which combines two types of electrolytes. The results of computer modelling will also facilitate the optimization of the novel fuel cell materials.

The results of this project will be published in scientific journals with a high Impact Factor, such as the Journal of Power Sources, Materials & Design, International Journal of Hydrogen Energy, and similar.