This proposal concerns elucidation of the fundamental chemical and electrochemical processes occurring in the operating air electrode of reversible Solid Oxide Cells (rSOC) constructed using novel, Cu-containing complex oxides with $RE_{1-x}A_xM_{1-x}Cu_xO_{3-\delta}$ (RE: selected rare-earth elements, A: selected alkaline-earth metals, M: selected 3*d* metals) chemical formula. Focus of the studies will concern identification and understanding of the principles governing the electrocatalytic activity toward the oxygen reduction and oxygen evolution reactions. Based on the research it will be possible to propose the optimized, chemically and thermomechanically stable Cu-based compounds, ensuring efficient operation of the air electrode in the fuel cell and electrolyzer modes at reduced temperatures, below 800 °C (with the aim of effective operation in the vicinity of 600 °C). At the same time, through chemical and materials engineering approach, air electrodes with spatially-oriented morphologies will be designed, manufactured and tested, in order to understand role of the surface properties in the operation of rSOC-type cells. While most of the so far developed air electrode materials rSOC are Co-based, there are strong reasons to mitigate the dependence on cobalt: deposits of Co ore are limited, and known commercial-level sources are localized in regions with volatile economic and unstable political situation, also, cobalt is classified as carcinogenic. On the other hand, there are large resources of cheap and environmentally-benign Cu, particularly in Poland.

The research tasks proposed in the project are based on carefully planned activities performed using advanced experimental techniques, as well as on quantum mechanical calculations that allow to predict and model structural and transport properties of the analyzed materials. The presented research methodology includes the synthesis of materials by high temperature method and/or sol-gel method, structural analysis at room temperature and at high temperatures, spectroscopic and microstructural studies, chemical and thermal stability tests, as well as extensive analysis of ionic and electronic conductivity. Thermogravimetric measurements will be carried out (measurement of the mass of the sample relative to temperature changes), allowing to determine the oxygen content and its temperature dependence, measurements of transport properties (including determination of ionic and electronic transference numbers) as a function of temperature, determination of diffusion coefficient D and surface exchange coefficient k from relaxation measurements. In addition, the designed modifications of the microstructure of electrode materials are the key part of the project, i.e. planned micro- or nanofiber morphology for the air electrode material, with increased specific surface area and optimal porosity. At the same time, studies of chemical and thermomechanical compatibility of La-doped ceria as the candidate buffer layer and possible solid electrolyte in the anode-supported planar cells will be done. It is expected that novel, high current-density electrochemical devices will be developed in this project.

The main reasons for undertaking the proposed research topic include the desirability of development of the new, clean, effective and cheap energy technologies, while from the scientific side, the necessity to expand knowledge in the field of chemistry and solid state physics, electrochemistry and catalysis. Considering the first aspect, it should be noted that the constantly decreasing fossil fuel resources create the need to develop modern technologies for obtaining electricity, without which it is difficult to imagine not only everyday life of the average person, but actually, operation of the industry areas. Among those alternative technologies, we may distinguish photovoltaic cells, wind turbines and the most promising, fuel cells that are the subject of the project. Solid Oxide Fuel Cells (SOFC) are devices converting chemical energy stored in fuel (e.g. hydrogen, carbon monoxide or hydrocarbons) and oxidant directly to electricity. Typically, they operate at temperatures of 800-1000 °C, which entails a number of difficulties in their construction, reduces lifetime and increases costs of production. In recent years, a lot of research has been focused on development of SOFC technology working at a reduced temperature range, i.e. 600-800 °C. Also, reversed operation as the high-temperature electrolyzer is of a special interest, as this enables to produce hydrogen with the surplus electrical energy. It seems that new possibilities will be opened for the practical use of generators based on reversible Solid Oxide Cells. Unfortunately, there are also fundamental obstacles in creation and implementation of the effectively working designs. First of all, the lowering of the working temperature of the cell causes an exponential increase in electrode's polarization losses and resistance of the ceramic electrolyte (and as a result, a significant decrease of the generated power density). This requires the development of modern electrode and electrolyte materials that can effectively operate in such conditions.

From the scientific point of view, the implementation of research tasks will have a significant impact on the development of science in the aspect of understanding of ionic-electronic transport mechanism in electrode materials and processes occurring at the electrode/electrolyte interface of oxides with perovskite structure and composite materials. In addition, a model of electrode reactions, including the determination of the impact of the modifications applied on the catalytic activity of electrodes will be proposed within the project.