The global rise of energy consumption combined with severe environmental issues and climate change has promoted the search for **alternative energy sources** which use green and sustainable technologies. Therefore, in recent decades, a lot of investigations have focused on the development of **H_2-based technologies** such as proton exchange membrane fuel cells (PEMFCs), which are one of the most promising solutions for energy conversion in portable and stationary small devices, as well as automotive applications. The joint of high efficiency with low emitted pollution level gives them a great advantage over conventional power sources. However, the widespread commercialization of this type of technology has been greatly hindered due to serious issues in performance, cost, and durability of important fuel cell components, especially the used Pt-based electrocatalysts. Despite these limitations, for practical use, theirs regarded as the most effective catalysts, particularly for cathode oxygen reduction reaction (ORR). Therefore, **the optimization of ORR active centers and their more efficient utilization, with simultaneous minimizing the Pt content** without loss of performance and durability are essential to ensure wider use of hydrogen fuel cells.

The proposed research project is devoted to the design and investigation of **multi-functional hybrid electrocatalysts** consisting of carbon-supported Pt active centers combined with selected sub-stoichiometric metal oxides of the MO_x type (M = Ce, Pr, Ti) in respect to their **durability and selectivity** in the ORR in acid media. Obtaining the stable oxides phases with **tailored redox properties and the presence of oxygen vacancies** will be controlled by the optimization synthesis conditions and the inclusion of selected dopants (D = Zr, Nb, Cu, W, Ta). The **main scientific objective** of the project is to reveal the role of the **sub-stoichiometric metal oxides** incorporated into the carbon-supported **low-Pt content ORR electrocatalysts**. **The secondary goal** is devoted to an investigation into the effect of redox properties and the presence of oxygen vacancies of the metal oxides, controlled by composition and structure, in the respect to Pt/C electrocatalysts' long-term durability. As a **research hypothesis**, we assume that the nature of the nonstoichiometric metal oxides, controlled by the degree of defects in the structure, determines the dispersion and the electronic structure of Pt nanoparticles, as well as the amount of undesirable hydrogen peroxide intermediate, consequently leads to improving stability and selectivity of low-Pt content ORR electrocatalysts. Furthermore, due to the strong **chemical interactions** between sub-stoichiometric oxides, carbon supports, including products of carbon corrosion, the degradation of support and formation of the poisoning CO adsorbates can be diminished. Additionally, we made an assumption that the **enhanced long-term durability** of the proposed electrocatalysts is the result of **synergistic interactions** between the unique properties of individual components. To achieve the project objectives systematic examination of the composition, morphology, and structure of the metal oxides with the respect to their properties important for the oxygen reduction will be accomplished.

The planned studies will focus on explaining the **role of sub-stoichiometric metal oxides** incorporated into **low-Pt content oxygen reduction electrocatalysts** in the context of their **selectivity and long-term stability in acidic media**. The project consists of three interconnected parts – synthesis, physicochemical characterization, and catalytic activity tests. Particular attention will be devoted to obtaining the carbon-supported sub-stoichiometric metal oxides nanoparticles, with tailored redox properties under optimized conditions. The detailed physicochemical investigations of the proposed materials by the modern spectroscopic, microscopic, and diffraction methods will be performed. The performance of the **Pt/MO_x/C hybrid electrocatalysts** for the oxygen reduction reaction in an acidic environment will be evaluated by advanced electrochemical measurements, using the rotating ring disk electrode and the gas diffusion electrode. The best promising electrocatalysts will be tested in the model fuel cell system.

The clarification of the role of the applied sub-stoichiometric metal oxides will be significant from a scientific and practical point of view. It is reasonable to expect that careful description and a better understanding of the mutual interactions between all catalysts' components will contribute to the development of affordable, effective, and stable **multi-functional hybrid catalytic systems with low-Pt content for the ORR**, which is critical for the widespread commercialization of the low-temperature PEMFCs. Due to this fact, the obtained results will be interesting to a broad circle of scientists involved in energy-related subjects, catalysts, and fuel cells.