

One of the main challenges facing our society is the way to respond to the growing demand for energy. The most promising and forward-looking strategy involves the use of solar and wind energy, and then its conversion to electricity. The generated electricity can be sent directly to consumers or stored in the form of chemical bonds, and then converted into electricity as required. Energy conversion processes require appropriate electrochemical devices and catalysts. In the initial stages of the active development of new materials for fuel cells, the accent was put on the synthesis of catalysts with the highest activity. It is now becoming more obvious that the durability of catalysts is equally or even more important.

In fuel cells (in particular in fuel cells with a polymer membrane) noble metal nanoparticles dispersed on porous carbon materials are mainly used. The most commonly used catalysts are Pt or Pt-alloy nanoparticles deposited on porous carbon black. These systems operate in harsh conditions, especially during start-up and shutdown, leading to catalyst degradation. Therefore, the aim of the proposed project is to define new relationships between the structure and activity of catalytic systems, which should then contribute to the construction of more durable and efficient fuel cells.

The project focuses on explaining changes in the structure of the catalytic system (platinum nanoparticles and carbon-based support) during use, by creating conditions similar to the working conditions of the fuel cell. These observations should explain why the catalyst activity is decreasing and what can be proposed to limit this effect. Therefore, during the implementation of the proposed project, special attention will be devoted to the analysis of the structure, including characterization at the atomic level. Transmission electron microscopy TEM is one of the most powerful techniques (in some cases the only one) that allows achieving this goal with the expected spatial resolution. Modern electron microscopes can be treated as laboratories in which a complete set of information is obtained simultaneously and in the same place of the sample. TEM application allows to determine the relationship between the synthesis conditions, structure and application properties of the tested material. To assess durability and explain why the catalyst activity is decreasing, the catalysts will be analyzed using advanced electron microscopy techniques under conditions as close as possible to the fuel cell operating conditions. This possibility is provided by holders with a liquid cell for in-situ TEM in a liquid environment and with the possibility of electrochemical tests. The second method developed and applied in recent years consists in monitoring changes in catalyst structure (IL-TEM method). The idea of this method is to observe exactly the same sample fragments (for example, selected carbon black aggregates).

The importance of the proposed project is particularly important for the development of new materials used for energy conversion. The knowledge acquired during the implementation of the planned project may help to design more durable fuel cells. Despite the fact that the results will be obtained for a (simple) catalytic model, in the future such an approach can be extended to more advanced systems, including other catalysts (for example consisting of two or three element elements, other metals, nanocatalysts with a dedicated shape), supports and systems dedicated to other applications (for example, lithium batteries).