Since the **Industrial Revolution**, energy production around the world has been based on burning fossil fuels, which is responsible for three-quarters of global greenhouse gas emissions, as well as air pollution leading to many health problems. Global energy consumption is projected to increase by 50% by 2050, and alternative energy sources will play a key role in decarbonizing the world's industry thanks to their low or zero environmental impact. Fuel cells (**FC**s) and ion exchange membrane electrolyzers have become one of the fastest-growing technologies in recent years. **Fuel cells with polymer membranes** are widely recognized as the most promising future energy source, mainly due to their environmentally friendly nature. The high efficiency of the system and the elimination or significant reduction of toxic emissions account for their attractiveness as clean sources of electricity. Key materials for these technologies are ion-conducting membrane electrolytes, which enable selective conduction of protons or hydroxide ions in acidic or basic environments, respectively. The FCs play an important role in the transition to a future low-carbon economy. Proton (H^+) exchange polymer membrane fuel cells, (**PEM FC**) have already demonstrated technological maturity. Anion exchange membrane fuel cells (**AEM FC**), on the other hand, have the potential to become more cost-effective hydrogen fuel cells, because at the high pH at which AEM FCs operate, platinum group metal-free catalysts and cheaper hydrocarbon membranes can be used. However, a significant challenge with AEM FCs is the durability of the cells due to the limited long-term stability of hydroxide ion (OH^-) conducting ionomers.

Therefore, the proposed research project aims to investigate the degradation of Membrane Electrode Assemblies (**MEA**s) for alkaline FCs, induced mainly by radicals generated in FCs, and to reduce such degradation. This is to be achieved through a comprehensive approach dedicated to clarifying the role of radicals, both from a mechanistic-fundamental and practical-applicational point of view, determining the synergistic effect of degradation-accelerating factors (such as OH^- anions and temperature), and evaluating the role of each MEA component, as well as MEA as a whole, in degradation processes. Finally, the potential for extending the life of FCs by preventing radical-induced degradation will be assessed. The mechanism and kinetics of the interaction between radicals and the membrane, ionomer, and carbon carrier in an alkaline environment have not yet been thoroughly investigated, and current understanding of the process is limited. Being an important degradation pathway, radical degradation of MEA is well studied for proton exchange membranes (acidic environments), but not in alkaline environments. Therefore, the **main scientific goal** of the project is to elucidate the role of radicals ($^{\bullet}H$, $^{\bullet}OH$, $^{\bullet}OOH$) in the degradation of MEA-based hydroxide ionomers. **Additional objectives** are to characterize the interactions between the considered radicals and ionomers by means of theoretical studies (DFT), to determine the probable mechanisms and products of radical-induced degradation of ionomers, and to develop methods to inhibit such processes. The novelty of this project lies in the comprehensive study of radical-induced MEA degradation in alkaline media, by combining experimental and theoretical (DFT) studies of the degradation processes of anion-exchange membranes and individual MEA components (ionomer, carbon carrier), which have been neglected so far. As a **research hypothesis**, we made an assumption that radicals play an important role in MEA degradation not only in acidic but also in alkaline environments, regardless of the fact that at high pH the oxygen radicals are deprotonated and that the use of free radical scavengers can significantly prolong the lifetime of AEM FCs.

This research will be carried out in cooperation with **Prof. Dario R. Dekel** (Technion – Israel Institute of Technology), a world-renowned expert on AEMFCs.

The project is in line with the **Polish Hydrogen Strategy** (PHS) until 2030 with an outlook until 2040, developed by the Ministry of Climate and Environment. The PHS is consistent with national strategic documents on energy and climate: Strategy for Responsible Development, Poland's Energy Policy until 2040, and the National Energy and Climate Plan. The Strategy aims to establish the Polish hydrogen industry and its development towards achieving climate neutrality through, among other things, the use of hydrogen fuel cells as an alternative power source for urban transport, road transport, light fleet vehicles, and electrochemical energy storage. The results will interest a wide range of researchers working on topics related to energy, polymer chemistry, fuel cells, and batteries. Obtaining affordable and stable AEMs will significantly contribute to the spread of fuel cells. The development of green energy sources will have a positive impact on the sustainable development of civilization and society.