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Anhydrous proton exchange membranes based on poly(vinyl alcohol) modified with reactive ionic liquids as separators in high temperature PEMFC

The aim of this basic research project is to prepare the membrane materials containing reactive ionic liquids permanently bonded to the polymer matrix as an electrolyte for high temperature proton exchange membrane fuel cell (HT-PEMFC) application operating under anhydrous conditions.

A fuel cell is a fascinating device, which converts the energy of a chemical reaction into the electrical energy. The hydrogen that fuels the fuel cell is oxidized at the anode to a hydrogen ion (proton) and an electron. The obtained particles are subsequently transported to the cathode: protons through the electrolyte, electrons through the external circulation producing the electric current. Simultaneously, the oxygen, which is supplied to cathode, is reduced to an oxygen atom. When the proton, electron and oxygen atom meet, water molecule is formed. According to NASA, the obtained water is characterized with high purity, and hence it would be possible to drink. Therefore, the electricity production using fuel cell is considered as the environmental friendly method in contrast to fossil fuels, which exploitation results in the harmful gases emission. As a result, fuel cells are the attractive source of renewable energy.

The membrane is a key component of PEMFC that allows the selective protons (hydrogen cations) transport from the anode to the cathode being non-permeable to generated electrons. Despite of the numerous advantages of the currently used Nafion® membrane, this membrane do not meet all the requirements of good separator because of its high price as well as the sensitivity to moisture and drying. It should be noted that the Nafion® humidity level is essential for the effective protons transport. As a result, the operation temperature range of PEMFC (up to 80°C) is limited which is attributed to the anode sensitivity towards carbon monoxide (CO) impurities present in hydrogen. In order to eliminate these restrictions of fuel cell, researchers are investigating the new membrane materials by modifying the existing ones or creating the novel ones by using the ionic liquids.

Ionic liquids are a type of salts, which can be in the liquid state at the room temperature. In order to understand the ionic liquids phenomenon, it should considered what the salt is, by using the sodium chloride (NaCl known as a table salt) as an example. Due to its crystalline structure that is associated with short distances between the relatively small sodium and chloride ions, NaCl requires the very high energy supply to melt the salt. In the case of ionic liquid, cation and/or anion is much bigger, therefore the interactions between them are much weaker. This explains the liquid form of ionic liquids as well as their name. Thanks to the unlimited possibilities of cations and anions combinations the ionic liquids possess the various attractive properties (e.g. high ionic conductivity or good thermal stability). As a consequence, ionic liquids gained the researchers attention and are extensively used to modify the properties of membranes applied in PEMFC allowing fuel cell to work efficiently without membrane humidification. Moreover, such membrane materials can maintain the desired ionic conductivity during operation of the cell PEMFC above 100°C.

Ionic liquids, however, possess a major drawback – it was noted that the ionic liquid gradually leaches out from the membrane structure during operation of the cell decreasing its efficiency. It became obvious to undertake the study on the chemical polymer modification with the ionic liquid. So far, the membranes doped with ionic liquids possess the physical intermolecular interactions between the components which explains the difficulty to entrap the ionic liquid in the membrane structure resulting in its elution during cell operation.

In this project, the RIL-PVA membrane prepared from the chemically modified polymer solution will be analyzed in terms of their mechanical, physicochemical, and electrochemical properties using spectroscopic, microscopy, and thermogravimetric analysis. The membranes effectiveness will be tested in HT-PEMFC. Evaluation of the fuel cell performance will be carried out based on the current-voltage characteristics.