OBTAINING AND CHARACTERISTICS OF RADIATION-MODIFIED PROTON-EXCHANGE POLYPROPYLENE MEMBRANES

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Currently, fuel cells (FCs) are attracting more and more attention, as they are an alternative to reducing the use of fuel with high efficiency and low/zero emissions. A fuel cell is an electric generating device in which chemical energy is converted into electrical energy. Proton-exchange membrane fuel cells (MEA) usually use hydrogen as a fuel. Transportation and storage of hydrogen, as well as the purity of hydrogen, significantly complicate the use of hydrogen-air FCs. Therefore, applications of FCs with direct methanol conversion (DMFC) are widely considered, since the liquid nature of methanol, as well as its simple refueling, makes it attractive for use as a fuel instead of hydrogen.

Patent research conducted by the authors between 1960 and 2020 showed that there was a significant increase in interest in direct methanol fuel cells (DMFCs) because they do not store any electricity directly generated by them. They have advantages over conventional batteries such as longer battery life, reduced weight and easy charging. A wide range of fuel cell applications can also provide an alternative for stationary and transport power sources. The main component of FC is a polymeric proton-exchange membrane. The current use of a commercial perfluorinated proton-exchange membrane of the “Nafion” type for a fuel cell with direct methanol conversion has a number of limitations. This is due to the high methanol permeability through the membrane, low proton conductivity and high cost.

In this work, the possibility (in order to reduce the methanol crossover) of changing the properties of polymer membranes made of non-fluorinated polymers – polypropylene (PP) and high-pressure polyethylene (LDPE) – was investigated using the method of radiation-chemical modification [1]. When polymeric materials are modified by radiation grafting of functional polar groups, their chemical structure and, accordingly, their physical properties change.

The object of research were PP and LDPE films, the nominal thickness of the sample was 20-50 μm. As a monomer for radiation modification, 10 % of acrylic acid (high purity grade) was used in a solution of a polarized dielectric. For the modification process of polymeric materials, the direct grafting method and the “Post-effect” grafting method were used. Samples of polymeric materials were placed in specially designed containers, which were filled with a grafting solution. Oxygen was removed from the container by bubbling the solution with an inert gas (helium, argon). To create centers for initiation of grafting polymerization, irradiation was performed on a 28 MeV helium ion beam extracted into the air. For uniform irradiation, the sample container was rotated at a speed of 30 rpm.

Irradiation was performed on a Cyclotron R7M TPU accelerator at room temperature and a dose rate of 700-1000 kGy. The grafting degree was determined by gravimetric method [2]. The grafted samples were analyzed using UV and IR spectroscopy. The surface morphology of grafted membranes was studied using a “Hitachi” scanning electron microscope. The methanol permeability was measured using a gas-liquid diffusion cell. Conductivity measurements were performed by impedance spectroscopy in a specially designed cell.

As a result of the research, the following results were obtained: the PP (radiation-modified) membrane with a thickness of 50 μm had a methanol permeability of $1.45 \cdot 10^{-8}$ cm^2/s, and a proton conductivity of 94 mS/cm. For comparison, a sample of the “Nafion-117” membrane with a permeability of $2.5 \cdot 10^{-6}$ cm^2/s and a proton conductivity of 60 mS/cm was studied.

In conclusion, it should be noted that radiation modification of commercially available non-fluorinated polymers can be considered as a good alternative to replacing the expensive polymer “Nafion” in fuel cells with direct conversion of methanol.

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