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Microstructure characterization of Nafion HP JP as a proton exchange membrane for fuel cell: positron annihilation study

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Proton exchange membrane fuel cell (PEMFC) achieves a potential success as an alternative energy source due to its direct electricity conversion, being environmentally friendly and high efficiency. The improvement of an efficient PEMFC strongly depends on the development of a polymer electrolyte membrane (PEM) with high proton conductivity, low fuel cross-over and low cost. Positron annihilation lifetime spectroscopy (PALS) can describe the internal microstructure of the material. In PEM, free volume strongly affects membrane characteristics such as proton conductivity and fuel crossover. In this work, the variation of the free volume of Nafion HP JP membrane was investigated at a wide range of temperature and relative humidity. The influence of temperature and relative humidity on the microstructure of the membrane under study was detected by studying the variation of the o-Ps lifetime τ_3 and its intensity I_3. It was found that increasing temperature of the sample increases the value of τ_3 as a result of thermal expansion. Phase transition occurred from the glassy state to the rubbery state at glass transition temperature. The crystal structure and thermal stability were compared before and after heat treatment by wide angle x-ray diffraction and thermo gravimetric analysis, respectively. On the other hand, the effect of relative humidity up to 80% on the free volume has been also studied by PALS technique using a specially designed chamber and accurately controlled humidity system. A correlation between data obtained from PALS and proton conductivity measurement was successfully achieved. All the previous measurements were carried out under the same conditions to the standard Nafion NRE212 for comparison.