An Analytical Study of Treated Nafion® Membrane Ssurfaces and its Cell Performances

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To increase the MEA performance, the interfacial resistance between electrode and membrane should be minimized. The interfacial resistance and electrochemical reaction area can be controlled by various ways. This can be done by optimizing hot-pressing condition for assembling electrodes and membrane, applying the catalytic layer directly on the membrane surface, and using the various techniques such as spray coating, decal process, sputtering, and so on. In this work, we applied ion beam bombardment technique to enlarge surface area and vary surface contact angle.

The roughening treatment of the membrane can be achieved by the various methods. In this work, the ion beam bombardment technique was used for the modification of the surface of the Nafion®115 membrane, and the performance of the cell equipped with the modified membrane was examined as a function of the ion irradiation strength and ion dose intensity. It can also modify the chemical properties of the membrane surface by ion-assisted reactions.

Ion beam treatment

Fig. 1 shows the SEM images of the untreated and ion beam-treated Nafion®115 membrane surfaces. Ion beam irradiation was performed at the acceleration energy of 1.0 keV and at the pressure of 1.0 x 10^{-5} torr. The ion beam intensity is (a) untreated (b) 1 x 10^{15} ions/cm^2 (c) 1 x 10^{16} ions/cm^2 (d) 1 x 10^{17} ions/cm^2. As shown in Fig. 1, roughness of the membrane surface increased with increasing ion beam intensity. The surface area and roughness factor was obtained from AFM (Atomic Force Microscopy). The surface area of the treated membranes of (b), (c), and (d) increased 1.0, 1.7 and 3.7 times compared to that of the untreated membrane, respectively. Also, RMS (root mean square) and average roughness of the treated membranes increased 1.5, 4.1, and 9.7 times, respectively, where RMS and average roughness were defined as in the case of the membrane (d), a lot of mounts and valleys were developed on the membrane surface and the mean height of the mounts was measured about 1.13μm. Considering that the thickness of the untreated Nafion®115 membrane was 120μm, we can see that ion beam treatment can give rise to only minor modification on the membrane surface. From these results, it was concluded that the ion bombardment on the Nafion®115 membrane modifies the membrane surface, resulting in the increment of surface area and roughness of the membrane without any damages to the bulk properties of the membrane. The ionic conductivity of treated membrane was also measured using Pt plated platinum cell. As the ion beam intensity increased, the conductivity was increased to 1 x 10^{16} ions/cm^2, and then at the 1 x 10^{17} ions/cm^2, the conductivity was decreased slightly. But the order of conductivity of all the samples was the same.

Cell performance and electrochemical characteristics of the ion beam-treated membrane.

Fig. 2 shows the effect of ion beam treatment of membrane on the single cell performance. Both of the cells tested have Pt loading amount of 0.05 mg-Pt/cm^2 at the both sides of the membrane. It shows the effect of the ion beam intensity irradiated at the membrane surface on the single cell performance. Single cell performance of the ion beam-treated membrane increased with increasing the ion beam intensity, but shows a maximum performance at an ion beam intensity of 1 x 10^{16} ions/cm^2. Ion beam treatment of Nafion®115 membrane was performed at the energy of 1.0 keV and ion beam intensity of 1 x 10^{16} ions/cm^2. The cell performance of the ion beam-treated membrane increased dramatically compared to that of untreated membrane, and this trend was more remarkable at high current density range.

Fig. 3 shows the cyclic voltammogram of the cells equipped with untreated and ion beam treated membrane, respectively. It was shown from this figure that the height of oxygen reduction peak that appeared at the potential of around 750 mV vs. NHE increased for the treated membrane. Along the anodic section of the curve, the hydrogen covering the surface is oxidized. As a result, enlarged surface area caused reduction of hydrogen diffusion limiting current. It means that the electrochemical activity of the catalyst layer at the cell increased because of the rapid mass transfer rate of the species, which took part in the electrochemical reaction at the interface.

From these results, it is concluded that the cell performance can be improved by modification of membrane surface using ion bombardment technique. By optimizing the treated conditions, the best cell performance can be achieved at the same Pt loadings.

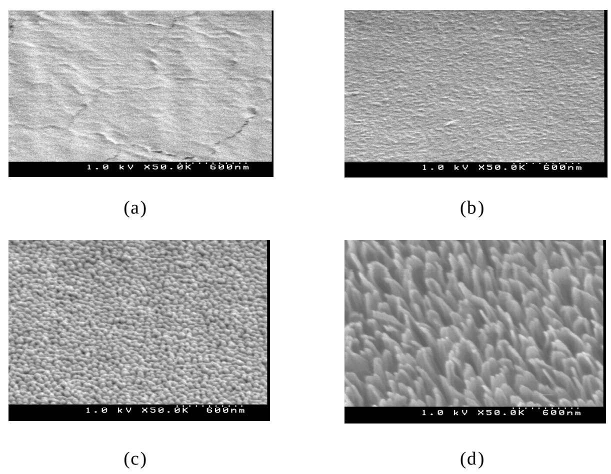

Fig. 1 SEM images of treated membrane surface
(a) untreated membrane (b) 1 keV, 1×10^{15} ions/cm^2
(c) 1 keV, 1×10^{16} ions/cm^2 (d) 1 keV, 1×10^{17} ions/cm^2

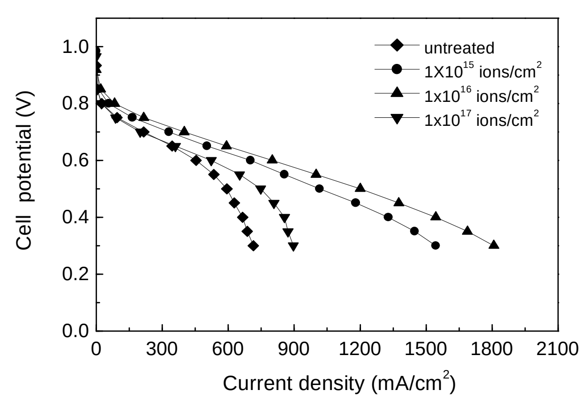

Fig. 2 Effect of the ion beam intensity on the cell performance, when anode = cathode = 0.05mgPt/cm^2, P_{H2}=P_{O2}=1atm, and T=80°C.

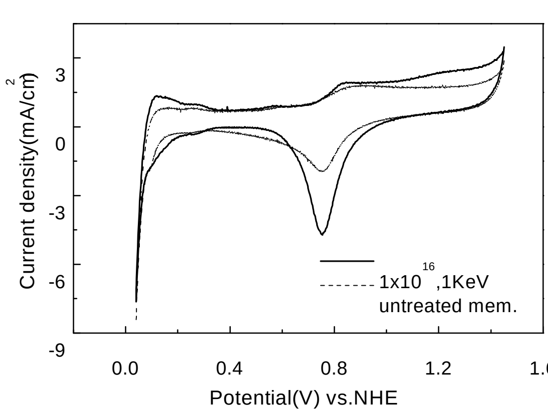

Fig. 3 Comparison of the cyclic voltammogram between ion beam-treated membrane and untreated membrane.