

Degradation of Gaskets for PEMFCs

At KIST, a counter-flow type 40-cell proton exchange membrane fuel cell (PEMFC) tack with an effective electrode area of 200 cm² has been assembled and its performance was investigated. Under the condition of atmospheric pressure and 75 °C, the maximum power of the stack was 2.89 kW (0.36 W/cm² per cell) and 2.3 kW (0.29 W/cm² per cell) for H₂/O₂ and H₂/Air, respectively [1].

After continuous operation of 1800 h, the components of the MEA have been analyzed to investigate the reason for the rapid decay in performance of the stack. When the stack was disassembled, it was observed that the silicon gasket was attached firmly to the Nafion electrolyte membrane. Fig. 1 shows the SEM images of the pure Nafion and the one after the disassembly. As can be seen in the SEM images, the silicon gasket was buried beneath the Nafion membrane surface. It is believed that some of the silicon gasket dissolved and then penetrated the Nafion membrane due to the acidity of the moisturized Nafion which corresponds to 1 M sulfuric acid solution.

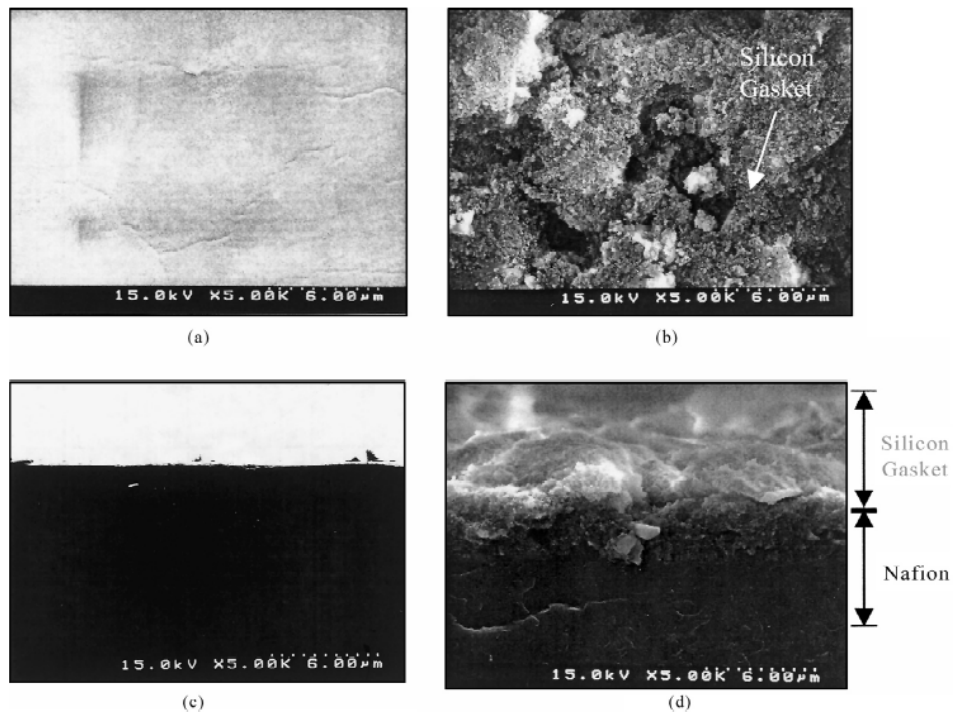


Fig. 1 SEM images of the Nafion 115 before and after 1800 h operation. (a) Surface, before; (b) surface, after; (c) cross-section, before; (d) cross-section, after.

Gulzow et al. [2] have reported that during operation, dispersion of the platinum catalyst of both electrodes was changed due to the electrochemical stress during the stack operation. Namely, on the anode side, platinum–hydrogen complexes were formed and then migrated from the anode to the interface between anode and the Nafion membrane, and on the cathode side, platinum oxides were formed and then migrated from the cathode to the backing of the cathode. If silicon is dissolved in the membranes, then it will also migrate from the anode to the cathode side due to the electrochemical stress. The silicon gasket originally contacts only the Nafion membrane without the direct contact with the electrode in the MEA and, thus, there should not be any Si in the membrane, nor in the electrode. Therefore, the edge of the MEA near the silicon gasket was analyzed by the EPMA line profile technique to check the contamination and degradation of the MEA. The physical characterization of new and electrochemically stressed MEA is a suitable tool to investigate the contamination and degradation of the MEA components. Fig. 2 shows results of the EPMA analysis for the dispersion of Pt, Si, and O in the MEA. As can be seen in the EPMA images, Pt peaks existed in the catalytic layers of anode and cathode in all cases. In case of Si, however, Si peaks did not appear in the pure MEA before operation; whereas they existed in the electrochemically stressed MEA after operation. Particularly, Si was detected in the catalytic layers of the anode and the cathode and also at the surface of the Nafion membrane near the catalytic layer. In the case of oxygen, O peaks also appeared after the operation and they existed at the catalytic layer of the electrochemically stressed cathode as a form of platinum oxide. However, we could not confirm the existence of the platinum–hydrogen complexes because no Pt peaks of the electrochemically stressed anode appeared between the catalytic layer and the Nafion membrane.

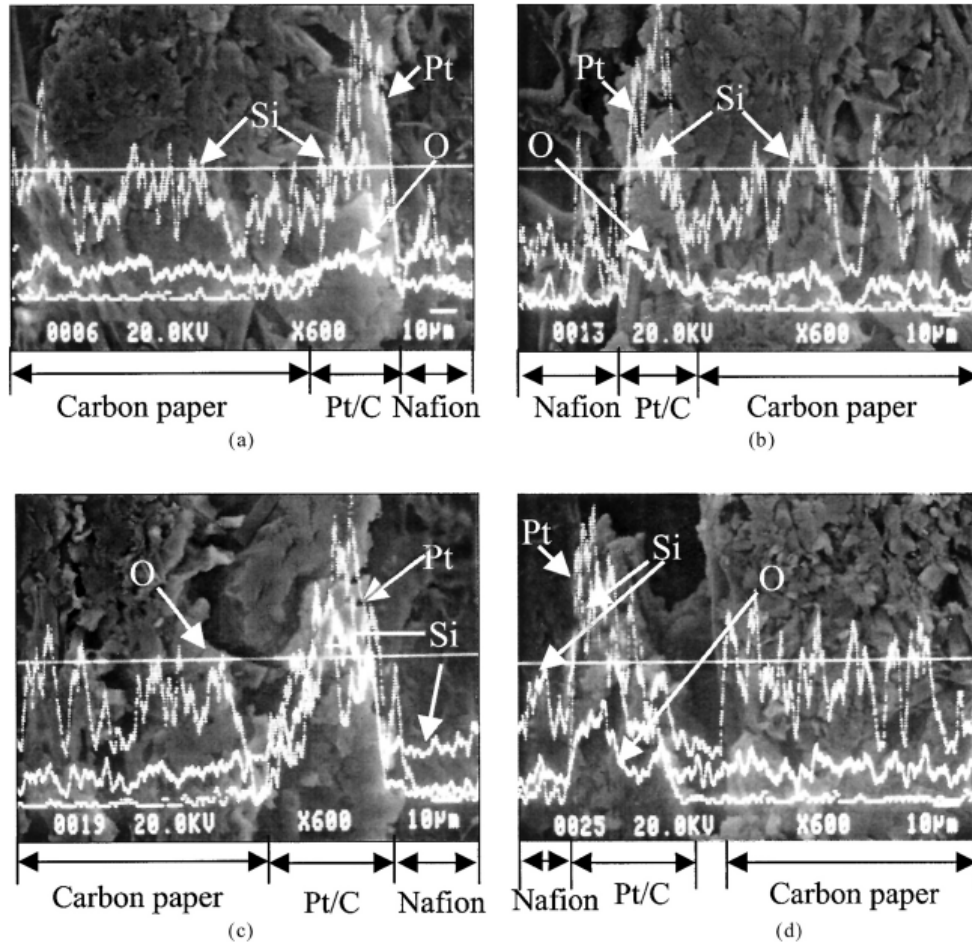


Fig. 2 EPMA images of the MEA before and after 1800 h operation. (a) Anode, before; (b) cathode, before; (c) anode, after; (d) cathode, after.

It is seen from the Pt and O peak distribution that platinum oxide was formed at the catalytic layer of the electrochemically stressed cathode, although it did not migrate to the backside of the cathode as indicated by Gulzow et al. [2]. The existence of platinum oxide in the catalytic layer of the cathode strongly suggests that the catalysts in the cathode were degraded. The Si peak distribution implies that Si was dissolved into the Nafion membrane first and then migrated through the membrane, followed by penetration into the catalytic layer of the electrochemically stressed MEA. It may be concluded from these analyses that the catalysts in the cathode were degraded by the formation of platinum oxide and the catalysts and Nafion membrane were contaminated by silicon which was dissolved from the gasket. The possibility that the Nafion membrane and the

MEA exposed to the coolant was contaminated by impurities in the coolant was examined by the XRF technique. The amounts of impurities in the coolant are shown in Table 1, and those in the MEA along a section are summarized in Table 2. It is seen from the table that Si, Al, S, K, Fe and Cu existed in the coolant and they were also detected at most regions of the MEA. It is confirmed from the analyses that contaminants from the coolant contaminated the MEA through the Nafion membrane and the existence of such impurities might inhibit the proton conduction.

Table 1. The results of XRF analysis for impurities in the coolant after continuous operation

Elements	Amounts (wt.%)
Al	10^0
Si	$10^{0\sim 1}$
S	10^{-1}
K	10^{-2}
Fe	10^{-2}
Cu	10^{-2}
Cl	10^{-2}
V	10^{-3}
Cr	10^{-3}

Table 3. The results of XRF analysis for the impurities in the MEA along the position after continuous operation (unit: wt.%)

Distance from edge of the MEA	Elements									
	Al	Si	S	K	Fe	Cu	Ni	Zn	Pb	Pt
0	10^{-2}	10^0	10^0	10^{-2}	10^{-2}	10^0	10^{-2}	10^0	10^{-2}	$10^{0\sim 1}$
1/3	10^{-2}	$10^{-1\sim 0}$	10^0	10^{-2}	10^{-2}	10^0	10^{-2}	10^0	10^{-2}	$10^{0\sim 1}$
2/3	-	$10^{-1\sim 0}$	10^0	10^{-2}	10^{-2}	10^0	10^{-2}	$10^{-1\sim 0}$	10^{-3}	$10^{0\sim 1}$
3/3 (center of the MEA)	10^{-2}	$10^{-1\sim 0}$	10^0	10^{-2}	10^{-2}	$10^{-1\sim 0}$	10^{-2}	$10^{-1\sim 0}$	10^{-3}	$10^{0\sim 1}$

References

1. S. -Y. Ahn, S. -J. Shin, H. Y. Ha, S. -A. Hong, Y. -C. Lee, T. W. Lim and I. -H. Oh, *Journal of Power Sources, Volume 106, Issues 1-2, 1 April 2002, Pages 295-303*
2. E. Gulzow, H. Sander, N. Wagner, M. Lorenz, A. Schneider, M. Schulze, Fuel Cell Seminar Abstracts, Portland, 2000, p. 156.