Instantaneous Impedance Study for Biofuel Cell based on Screen-Printed Porous Carbon Electrodes

Yukihiro YOSHIHATA[a], Yoshinao HOSHI[a],
Isao SHITANDA[a], Masayuki ITAGAKI[a],
Seiya TSUJIMURA[b]

[a] *Department of Pure and Applied Chemistry, Faculty of Science and Technology,*
Tokyo University of Science
2641, Yamazaki, Noda, Chiba 278-8510, Japan

[b] *Division of Materials Sciences,*
Faculty of Pure and Applied Sciences,
University of Tsukuba,
1-1-1 Tennodai, Tsukuba, Ibaraki, 305-8573, Japan

E-mail address: *shitanda@rs.noda.tus.ac.jp (I. Shitanda)*

Screen-printing has been used to prepare enzymatic electrodes because it is possible to use variety inks and control the film thickness with good reproducibility. [1]

The electrochemical impedance spectroscopy (EIS) is useful tool for analysis of reaction process and electrode structure. We reported the method to measure instantaneous impedance which is very useful for determination of a impedance for an biofuel cell. The Nyquist plot of the impedance of an enzymatic functional electrode used for the biofuel cell sometimes shows the deviation from the semicircle in the low frequency range.[2] In the instantaneous impedance measurement, the impedance is measured with recording times successively. The measured impedance spectra are plotted on 3-D Nyquist plane, whose axes were real and imaginary components and time. The data is joined by a smooth curve at the same frequency using spline function. The instantaneous impedance can be determined by the cross section of 3-D Nyquist plot. In the present study, we fabricated screen-printed open-air type biofuel cell using porous carbon inks and investigated by the instantaneous impedance measurement.

Figure 1 shows the Nyquist plots of the instantaneous impedance at 0.4 V (cell voltage) at 500 sec. We obtain the part of the semicircle due to the double layer capacitance and charge transfer resistance in both the anode and cathode.

Figure 2 shows the equivalent circuit for the curve fitting. Constant phase element (CPE) is used when the capacitive semicircle strain in the direction of the real axis. Impedance of the CPE is represented as following equation.

$$Z_{\mathrm{CPE}} = \frac{1}{(j\omega)^p T_{\mathrm{CPE}}} \qquad (1)$$

R_{ct} and T_{CPE} were estimated by the curve fitting. The relation of an electric double layer capacitance C and T_{CPE} are represented as following equation.

$$C = T_{\mathrm{CPE}}{}^{1/p} R^{(1-p)/p} \qquad (2)$$

The electric doublelayer capacitance of the cathode and anotde were calculated about 30.5 mF and 25.3 mF, respectively. The effective surface areas of the anode and cathode were estimated by using electric double layer capacitance of the activated carbon (25 μF cm^{-2}).[3] The effective surface areas of cathode and anode were calculated 1220 cm^2 and 1012 $cm^{2,}$ respectively. It is found that specific surface area increased about 1000 times by using porous carbon. R_{ct} of the cathode was 406 Ω, and was greater than that of the anode. In the present study, we fabricated several different screen-printed porous carbon electrodes and investigated the impedance spectra in detail.

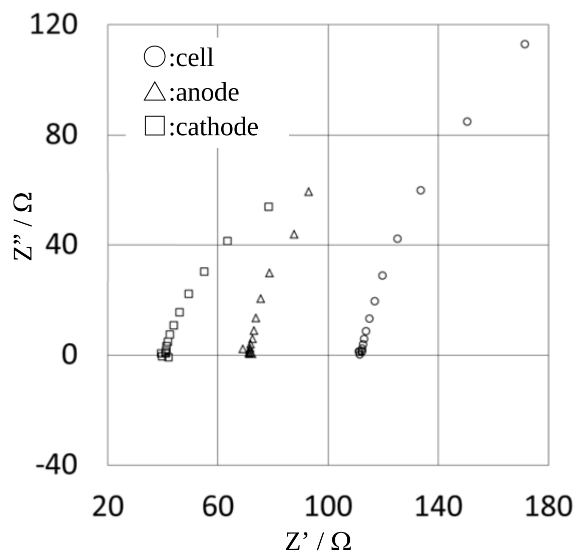
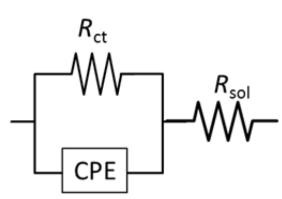


Figure 1 Nyquist plots of the impedance at 0.4 V (cell voltage) at 500 sec(100 Hz- 100 mHz)



R_{ct}: charge transfer resistance
R_{sol}: solution resistance
CPE: constant phase element

Figure 2 Equivalent circuit used for the fitting

References

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