Electrochemical Impedance Study for Enzymatic Biosensor and Biofuel Cell

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We have been investigated enzyme-functional electrodes utilized for biosensors and biofuel cells by electrochemical impedance spectroscopy. In the present paper, we discuss three topics as follows.
(1) Faradaic impedance for analysis of a mediator-type enzyme immobilized electrode.
(2) Branch structure transmission line model for analysis of an enzyme immobilized porous carbon electrode
(3) Instantaneous impedance analysis for biofuel cell anode and cathode.

(1) Faradaic impedance for analysis of a mediator-type enzyme immobilized electrode.

We proposed a theoretical equation of Faradaic impedance (Z_F) for amperometric biosensor analysis by introducing a new theoretical model in which the diffusion of mediator and substrate, enzymatic reaction and electrode reaction are considered [1,2]. Figure 1 shows the typical Faradaic impedance spectrum. The Faradaic impedance spectrum describes the locus of the semicircle on the Nyquist plane, due to the electric double layer capacitance and charge transfer resistance of the mediator on the electrode surface. The finite diffusion impedance is also observed whose locus shows straight line of 45 degrees to real axis in and converges on real axis in the low frequency limit. In the present paper, we discuss the behaviors of the impedance spectra of a mediator-type amperometric biosensor using the Faradaic impedance simulation by changing in the simulation parameters.

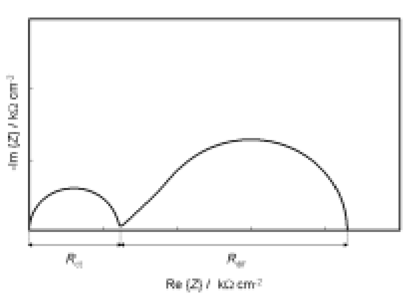

Fig. 1 Typical impedance spectra of a mediator-type enzyme-functional electrode .

(2) Branch Structure transmission line model for analysis of an enzyme immobilized porous carbon electrode

A carbon cryogel (CCG) has many pores with fractal structure. In addition, the pore size is easy to control by changing the ratio of precursors. Recently, we applied the CCG to a mediator-type enzyme electrode for high power biofuel cell [2,3]. It can be expected that increase of current depended on enzyme reaction by high electrode surface area and high efficiency electron transfer between the enzyme and the electrode. In the present paper, we discuss impedance spectra for a direct electron transfer type enzyme modified CCG electrode. We simulated the impedance spectra of the enzyme modified CCG electrode with a brunch structure transmission line model (Fig. 2) [4].

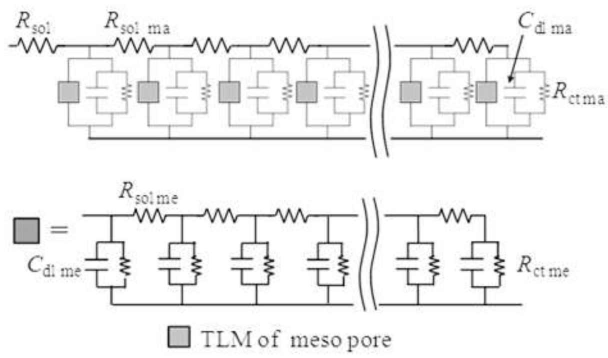

Fig. 2 Transmission line model using the impedance simulation (ma and me show macropore and mesopore, respectively).

(3) Instantaneous impedance analysis for biofuel cell anode and cathode.

We also reported the method to measure instantaneous impedance which is very useful for determination of an impedance of enzyme-functional electrodes[5,6]. The Nyquist plot of the impedance of enzyme functional electrodes sometimes shows the deviation from the semicircle in the low frequency range. 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 paper, we discuss about the instantaneous impedance spectra of biofuel cells using porous carbon materials such as carbon cryogel and carbon fiber sheet.

References

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