Response characteristics of fuel cell type alcohol sensor using Nafion membrane

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1. Introduction

Recently, growing attention has been paid on the accidents made by car drivers and people who operate complex equipment with their judgments impaired by alcohol. The number of arrests drunk driving have been about 40,000 over the years in Japan.

Some sensors used in the alcohol breath check of gas are semiconductor-based sensors. But accuracy of semiconductor type sensor is poor because there is a problem with the gas selectivity. While fuel cells type alcohol sensor is a sort of devices generating direct current by directly converting chemical energy of fuel to electrical energy. Gas selectivity of fuel cell type is good. Additionally, the reproducibility of output is good when fuel is fixed number of moles.

The membranes of commercial alcohol sensors are soaked with sulfuric acid. However, the durability of the sensor is short due to the leakage of sulfuric acid. In this study, we used a polymer electrolyte membrane, Nafion membrane, instead of the liquid electrolyte for fabricating fuel cell sensors for ethanol. The purpose of this study is to evaluate the performance of Nafion-type sensor. The transient responses of the cell using various amounts of catalyst and different membranes were measured at room temperature. The relationships between amounts of anode catalyst and peak current density, amount coulomb were evaluated.

2. Experimental

2.1. Preparation of catalyst ink and electrode

The anode catalyst ink was prepared as follows : 0.3 g of Pt black (TKK, 98.0 wt% Pt) was mixed with 10 wt% triton (0.28 g), 1.5 wt% CMC (2.52 g) and distilled water by ultrasonic dispersion for 10 min. Then PTFE (MKBF0591, 60 wt % solution supplied by SIGMA-ALDRICH), diluted to 6 %, was added to the ink and mixed by little and little by magnetic stirrer[1]. The ratio of Pt to PTFE in the catalyst ink was controlled at 95:5, respectively. This ink was spread on the carbon cloth (Ballard Power Systems, 107HCB) with 2, 4, 10, 20, 25 mg cm^{-2} Pt loading and sintered at 305 ^{o}C for 2 h. Prior to fabrication of the MEA, the electrode were coated with 1 mg cm^{-2} of 5 wt% Nafion® solution[2] and dried for 20 min at 60 ^{o}C.

A commercially available catalyst of Pt/C (TKK, 45.8 wt% Pt) was used as cathode catalyst. A 0.369 g of Pt/C catalyst was mixed with 8 mg of 5 wt% Nafion® solution and 4 g of Butyl acetate by sonication for 40 min. This ink was spread on the carbon cloth with 1.0 mg cm^{-2} Pt loading and dried at 60 ^{o}C for 40 minutes.

2.2. Preparation of MEA

In this study, Nafion 211® membrane (25.4 μm thick), Nafion 212® membrane (50.8 μm thick), Nafion 117® membrane (178.8 μm thick) were used as a polymer electrolyte membrane. The electrodes and membrane were subject to hot pressing at 3 MPa for 2 min at a temperature of 125^{o}C.

2.3. Measurements of sensor response

The measuring method was amperometric (short circuit current). The measurement of the current was carried out upon instantaneous injection of ethanol gas and a fixed volume, using the fuel cell assembly.

Using a syringe, 2 mL of the ethanol gas (0 ~ 300 ppm : Air, H_2O, ethanol gas) was introduced into the anode side of the fuel cell 20 seconds after the start of the measurement at 25 ^{o}C.

3. Results and discussion

Fig. 1 shows the results of the transient response using various quantities Pt as anode catalyst. The same cathodes (Pt/C, 1.0 mg cm^{-2}Pt) were used in all cases. As shown in Fig. 1, the current densities sharply increased as soon as ethanol fuel was injected and then started to decrease due to the disappearance of the fuel.

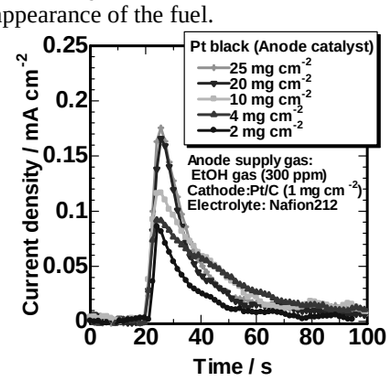

Fig. 1 Response transients to ethanol gas (300 ppm) using Pt black (2, 4, 10, 20, 25 mg cm^{-2}Pt) as anode catalyst.

Fig. 2 shows dependence of peak current density and coulomb to various Pt loading on anode. From Figs. 1 and 2, the peak current density grows and response to return to the background was faster with increasing anode catalyst quantities. This indicates that ethanol oxidation reaction enhances because of increasing catalytic activities and reactant was constant. But response performance using 20 and 25 mg cm^{-2}Pt was similar. Catalytic amount was excessive when using 25 mg cm^{-2}Pt. However, the amount of the charge was constant from 4 mg cm^{-2} to 25 mg cm^{-2}Pt. The number of electron during ethanol electro-oxidation reaction was 4.5.

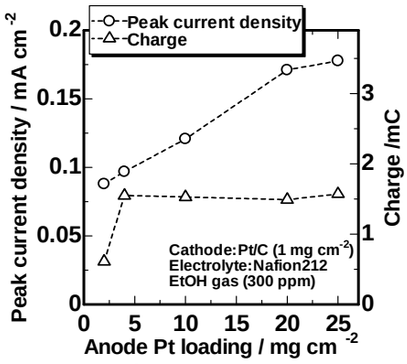

Fig. 2 Dependence of peak current density and coulomb to various Pt loading on anode.

Reference

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2) L. Krishnan, S. Morris, and A. Eisman; “Platinum Black Polymer Electrolyte Membrane Based Electrodes Revisited,” *J. Electrochem. Soc.*, **155**, B869-B876 (2008)