Novel DMFC Cathode Catalysts Derived from TiO_2 powder

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Abstract

Titanate nano fibers (TNFs) were prepared from anatase type of TiO_2 powders by a hydrothermal method. Nanosized titanates containing various amounts of nitrogen (N-TNs) were obtained from TNFs by heating between 800°C and 950°C under NH_3 atmosphere. All N-TNs have ORR activity and therefore N-TNs are promising as novel DMFC cathode catalysts. Nanosized titanates containing niobium (Nb-TNs) were also prepared and their ORR activities were investigated.

Introduction

Direct methanol fuel cell (DMFC), which is operated by methanol as fuel, is expected as power sources for portable devices such as mobile phones, notebook computers, FCHV (fuel cell hybrid vehicles), and so-on. The power density of DMFC depends on methanol concentration. Unfortunately, when methanol concentration increases, unreacted methanol diffuses from the anode to the cathode through the electrolyte and is oxidized on Pt of the cathode catalysts resulting in decrease in the power density. In order to solve this problem, the electrode catalyst having high activity for oxygen reduction reaction (ORR) in the presence of methanol is required. According to the reference report [1], nanosized titanates containing nitrogen or niobium were prepared and their activities for ORR were investigated in the presence of methanol.

Experimental

Spherical TiO_2 powder (P25, AEROSIL, Japan) was dispersed in 8.0 mol dm^{-3} (mol dm^{-3} = M) KOH aqueous solution. Here, the molar ratio of Ti and K was fixed at 1:6. The dispersion liquid was transferred into a heating chamber and was heated at 150°C for 20 hours. The product was washed with 0.1 M HCl aqueous solution and purified water following drying at 110°C for 24 hours. Nb-TNs were also prepared by the same

procedure as denoted above using the mixture of P25 and niobium oxide (Nb_2O_5, aldrich) at various molar ratios of Ti:Nb = 1:99, 5:95, and 10:90. Nanosized nitrogen doping titanates (N-TNs) were prepared by heat treatment at 800 – 950^{o}C under NH_3 gas. These materials were characterized by XRD, XPS, SEM equipped with EDS, and their ORR activities were investigated in 0.1 M sulfuric acid aqueous solution containing 0.1 M methanol under oxygen atmosphere at room temperature.

Results and Discussions

Figure 1 shows SEM image of the product by hydrothermal reaction from the mixture at molar ratio of Ti:Nb = 1:99. TNFs and Nb-TNs of ca. 20 nm in diameter each were observed to be aggregated, showing that the mixture material of TNFs and Nb-TNs were prepared.

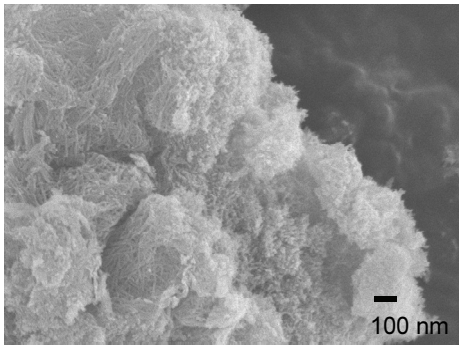

Fig. 1. A typical SEM image of the product by hydrothermal reaction from the mixture at molar ratios of Ti:Nb = 1:99.

All N-TNs show ORR activity in the presence of methanol and the onset-potential is summarized in Table 1. Here, the onset-potential was estimated at the reduction current of -5×10^{-5} A m^{-2}. The onset potential for ORR of N-TNs was positive when heat-treatment temperature increased and as a result, increase of nitrogen content occurred. This result suggests that ORR activity is related to nitrogen content in N-TNs. The ORR activity of Nb-TNs will also be mentioned in the presentation.

Table 1. Onset potential for ORR of the samples.

Heat treatment Temp. /℃	TNF	N-TNF				
	300	800	850	900	950	950 (2h)
ORR potential / V	0.22	0.41	0.39	0.66	0.65	0.55

Conclusions

Titanates containing various amounts of nitrogen (N-TNs) and niobium (Nb-TNs) were obtained from anatase type of TiO_2 powder as titanium material. All N-TNs show ORR activity and therefore N-TNs are considered to be promising material as novel DMFC cathode catalysts.

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Reference

[1] S. Mitsushima, *et. al*., *J. Electrochem. Soc.*, 154 (7) B664-B669 (2007).