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High performance carbon-supported IrRu alloy catalyst for the in an alkaline anion-exchange membrane fuel cell[☆]

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ABSTRACT

The alkaline anion-exchange membrane fuel cell (AAEMFC) is characterized by an excellent efficiency due to the low reaction activation energy of its cathode. However, the slow hydrogen oxidation reaction (HOR) at the anode degrades its performance. Herein, to improve the HOR kinetics, carbon-supported IrRu of varying compositions are prepared using the polyol process. According to spectroscopic analyses, the IrRu catalysts exhibit strong electronic interactions between Ir and Ru. In particular, before and after the accelerated stress stability cycles, the HOR activities of IrRu₂/C are 2.4 and 3.8 times higher than that of the commercial Pt/C catalyst, respectively. Therefore, these results demonstrate the excellent HOR activity and catalytic stability of IrRu₂/C. The membrane electrode assembly tests conducted to validate the catalytic effect reveal that the performance (800 mA cm⁻²) of IrRu₂/C as an anode catalyst is 4.1 times higher than that of Pt/C (195 mA cm⁻²) at 0.6 V. The IrRu₂/C catalyst proposed in this study is a suitable replacement for the Pt/C catalyst and an excellent HOR catalyst for cost-effective AAEMFC applications.

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1. Introduction

The alkaline anion-exchange membrane fuel cell (AAEMFC) exhibits a high energy conversion efficiency because of its low oxygen reduction reaction (ORR) activation energy under the alkaline condition. In addition, because non-Pt catalysts can be employed as active cathode materials, the AAEMFC is recognized as a cost-effective fuel cell [1–4].

However, in alkaline media, the hydrogen oxidation reaction (HOR) involving Pt is slower by over two orders of magnitude as compared to the reaction in acidic media [4–6]. The main factors that determine the HOR kinetics are the (1) size effect of nanoparticles, (2) hydrogen binding energy (HBE), and (3) reactive OH_{ads} species accompanied by metal oxophilic properties [1,6]. Moreover, it is well-known that both the strength of the HBE and the oxophilic properties were mainly derived from the electronic effect [7].

Recently, precious group metal (PGM)-(e.g., IrRu and PtRu) [8–10] and PGM-free (e.g., NiMo and Ni/N-CNT)-based [11,12] alkaline HOR catalysts have been developed. For PGM-free-based HOR catalysts, the challenge is to maintain a partially oxide-free metal surface up to an anode potential of 0.1 V. Therefore, PGM-based HOR catalysts such as IrRu were proposed to alleviate this challenge. The area of the H-underpotential desorption (H_{UPD}) for the Ir/C is larger than that for the Ru/C, indicating that the Ir/C has higher H adsorption capacities [13,14]. It could also be observed that the H_{UPD} peak of the Ru/C is located in the cathodic position compared to that of the Ir/C. This means that the desorption kinetics of H_{ads} for the Ru/C is more favorable than that for the Ir/C. Consequently, it can be inferred that the HOR activity could be enhanced via the alloying of the Ir and Ru. Actually, Ohyama, et al. demonstrated that the weakening of the metal-H_{ads} interaction via Ir–Ru alloying leads to improved HOR activity based on the DFT calculation [8].

Recently, improved HOR activity was reported for an Ir–Ru nanowire (NW) [9] prepared from NaBH₄ and surfactants using a microemulsion process. The HOR activity of the Ir₁Ru₁ NW catalyst was comparable to that of Pt/C because of the following reasons: (1) the low HBE caused by the Ir and Ru electronic interactions and (2) the enhanced oxophilic property of the IrRu alloy because Ru is more oxophilic than Ir.

[☆] HBE, hydrogen binding energy; AST, accelerated stability test; MEA, membrane electrode assembly; HOR, hydrogen oxidation reaction; CCMS, catalyst-coated membranes; ECSA, electrochemical surface area; EIS, electrochemical impedance spectroscopy

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