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Cathode durability enhancement under start-up/shut-down process using $IrRuO_x/C$ catalyst in polymer electrolyte membrane fuel cell

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HIGHLIGHTS

- Carbon-supported 80 wt% $IrRuO_x/C$ catalysts is prepared by a sub-substrate method.
- $Ir_1Ru_1O_x/C$ is observed to be the best catalyst in terms of activity and stability.
- The application of a 2.5 wt% catalyst in cathode improves SU/SD MEA durability.
- The AST resulted in the 15% reduction of ECSA of the Pt in the OER-added cathode.

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ABSTRACT

The disruptive degradation of the electrode in the membrane electrode assembly (MEA) under the transient situation during the fuel cell electric vehicle operations such as fuel starvation, start-up and shut-down (SU/SD), etc. is to be addressed. To mitigate the carbon corrosion in the electrode, the catalyst for oxygen evolution reaction (OER) has been investigated recently. It evolves oxygen from water, thereby mitigating carbon corrosion at voltages over 1.5 V, which is typically induced during SU/SD cycles. In this study, carbon-supported IrRuOx catalysts towards OER are synthesized using a sub-substrate method, and their electrochemical and physicochemical properties are analyzed using several methods. $Ir_1Ru_1O_x$ (Ir:Ru = 1:1 at. ratio in the oxide form) is observed to be the best catalyst in terms of activity and durability. The application of a 2.5 wt% OER catalyst to the cathode improves the carbon corrosion durability of the MEA by approximately 88 %. After 4000 SU/SD cycles, the electrochemical surface areas of the Pt in the OER-added MEA and reference MEA are reduced by 15 % and 57 %, respectively. When the OER catalyst is applied to the reference cathode electrode, it enhances the durability of the MEA without compromising the performance significantly.

1. Introduction

The polymer electrolyte membrane fuel cell (PEMFC) is a viable alternative powertrain for next-generation vehicles because of its higher energy density, higher conversion efficiency, and lower emissions of environmental pollutants compared with conventional energy sources [1,2]. After the commercialization of the fuel cell electric vehicle (FCEV) by the Hyundai Motor Company in 2013, Toyota, Honda, and Mercedes Benz have sequentially launched the Mirai in 2014, Clarity FCEV in 2016, and GLC F-Cell in 2018, respectively [3,4]. Despite the continuous developments of PEMFC systems, several challenges still persist for expanding the FCEV market including cost, performance, and durability [3,5]. The ultimate durability target set by the United States Department of Energy (DOE), which has been updated recently, is more than 8000 operation hours [6]. Although it is difficult to clearly define the lifetime of a PEMFC, it is generally accepted that existing technologies cannot achieve the target lifespan. Particularly, repeated start-up/shut-down (SU/SD) conditions induce a carbon oxidation reaction (COR) and lead to overall performance degradation. The mechanism of COR is shown in Eq. (1)

$$C + 2H_2O \rightarrow CO_2 + 4H^+ + 4e^- \quad E^o = 0.207 \text{ V vs. RHE (reversible hydrogen electrode)} \tag{1}$$

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