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Operational durability of three-dimensional Ni-Fe layered double hydroxide electrocatalyst for water oxidation

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ABSTRACT

Water electrolysis for hydrogen and oxygen production is a key technology in next-generation energy carrier and conversion. In particular, renewable energy sources integrated water electrolysis system has emerged due to its eco-friendly and highly energy efficient process. However, inherent limitations of renewable energy sources including intermittent and unpredictable energy production restrict stable water electrolysis cell operating. Therefore, investigation on cell performance depending on various operation conditions is absolutely required. Here, we synthesized Ni-Fe layered double hydroxide (Ni-Fe LDH) electrodes and studied their oxygen evolution reaction (OER) activities under various operational conditions matching actual environmental conditions when utilizing renewable energy sources. Changes in morphology and electrocatalytic performance were systematically studied by using XRD, FE-SEM, and EIS measurement. Our results showed that operation of water electrolysis cell in an accelerated stress condition could result in changes in morphology of crystal structure of LDH, thus restricting ions to be fully utilized at active site for OER.

1. Introduction

Water splitting system for the production of molecular hydrogen and oxygen has been regarded as one of important technologies in next generation energy conversion and storage sources [1–4]. Generation of H_2 and O_2 in a stable and efficient way holds a key to various energy related fields including rechargeable metal-air batteries, fuel cell, and energy storage systems. Among various water electrolysis technologies, alkaline electrolysis is the oldest and mature one that has been installed for practical use due to its high energy conversion efficiency and reliable performance. Water electrolysis utilizing renewable energy sources including solar cell and wind power system is another emerging technology due to increasing interest in eco-friendly and highly efficient energy sources. With such renewable energy system as a power source for water electrolysis, net energy consumption would be greatly reduced to realize a genuinely green chemistry. However, such integrated system has an inherent disadvantage from the view point of stable power supply. For example, for solar cell system, light source is often intermittent and unpredictable in nature as it produces energy only when the sun shines. Power generation of most renewable energy resources strongly depends on environmental conditions including the amount of solar radiation, humidity, temperature, the strength of wind, and so on. Such power fluctuation potentially leads to changes in negative limit potential that can result in gradual degradation of electrode structure. Therefore, additional energy storage system such as a rechargeable battery is required to accommodate such uncertainty and variability. However, it will increase both cost and system volume.

In the present study, we investigated that the effect of fluctuation of power source on oxygen evolution reaction (OER) behavior. As an electrode material, three-dimensional Ni-Fe layered double hydroxide (LDH) was utilized in this study. Recently, Fe incorporated Ni oxide/hydroxide catalysts have received much attention owing to their outstanding OER activity [5–14]. Furthermore, due to their abundancy and cost-effectiveness as well as long-term stability of such non-noble transition metal components, they have been regarded as promising candidates for replacing precious metal-based catalysts including platinum (Pt), iridium (Ir), and

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