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Syngas production for Fischer-Tropsch process *via* co-electrolytic processes of CO_2 reduction and NH_3 oxidation

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ABSTRACT

As a solution for simultaneously reducing harmful air pollutants containing ammonia and CO_2, with respect to ameliorating the effects of global warming, we report a co-electrolytic process involving ammonia oxidation reaction (AOR) and an electrochemical CO_2 reduction reaction (ECR) for syngas production that uses less energy compared to the conventional process. The conventional process is based on ECR and an oxygen evolution reaction (OER), and it requires a high amount of energy because of its higher thermodynamic and practical operation voltage. By contrast, the new co-electrolytic process employs an AOR instead of an OER, and a decreased energy consumption (maximum 34.04%) is observed with the addition of ammonia. The new process provides advantages with respect to its lower energy consumption and controllable hydrogen and carbon monoxide ratio. We also found that this syngas production method, in which the NH_3 concentration and applied current can be controlled, produces syngas with different H_2 and CO ratios, it is comparable to that used in the conventional Fischer-Tropsch process.

1. Introduction

Developing sustainable technologies is necessary to reduce environmental pollutants and mitigate climate change caused by high carbon dioxide (CO_2) concentrations owing to industrialization [1]. Of the various methods used, the electrolytic process provides several advantages that complement the conventional technique. For example, it employs mild operating conditions and atom-efficient strategies for selective conversion using electrons as reactants, which are known as oxidation and reduction steps [2]. Further, as no harmful or toxic chemical agents are used, it efficiently minimizes social and environmental damage [3–5].

Electrochemical CO_2 reduction (ECR) employs a mild operating temperature and pressure and is thus is a promising electrolytic process for producing value-added chemicals from waste CO_2 [6–8]. Energy-dense molecules are converted by the ECR process, and these can be selectively controlled by controlling the electrochemical conditions and developing the electrocatalyst materials. In addition, the ECR process can be easily scaled up [9]. It has thus become an important technology for reducing the accumulation of CO_2. It has no carbon footprint, and it can be used in combination with renewable energy, such as that obtained by solar, wind, and hydroelectric power systems [6,9,10].

The development of electrocatalysts has been the primary focus of many ECR process studies [11–13] because the final product can be controlled depending on the type of electrocatalyst applied. For example, Au-and Ag-based materials are the most well-known electrocatalysts for producing carbon monoxide (CO) from CO_2 [14,15], and Cu-based electrocatalysts produce multiple carbons such as ethylene,

Abbreviations: AOR, Ammonia oxidation reaction; FE, Faradaic efficiency; GC, Gas chromatography; GDE, Gas diffusion electrode; GIST, Gwangju Institute of Science and Technology; HER, Hydrogen evolution reaction; LSV, Linear sweep voltammetry; OER, Oxygen evolution reaction; TCD, Thermal conductivity detector; UV, UV-Vis; BK, blank anolyte; ECR, electrochemical CO_2 reduction reaction.

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