Molecular Catalysis 547 (2023) 113311

Contents lists available at ScienceDirect

Molecular Catalysis

journal homepage: www.journals.elsevier.com/molecular-catalysis

Ultra-high surface area fibrous silica-zirconia support for renewable energy production by CO_2 methanation

A.H. Hatta [b], A.A. Jalil [a,b,*], N.S. Hassan [a], M.Y.S. Hamid [a,b], M.N. Haron [c], W. Nabgan [d], M.B. Bahari [e], M. Asmadi [b], H.D. Setiabudi [f]

[a] Centre of Hydrogen Energy, Institute of Future Energy, UTM Johor Bahru, Johor 81310, Malaysia
[b] Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia, UTM Johor Bahru, Johor 81310, Malaysia
[c] Faculty of Chemistry and Biology, Grenoble Alpes University, 470 Rue de la Chimie, Saint-Martin-d'Hères 38400, France
[d] Departament d'Enginyeria Química, Universitat Rovira I Virgili, Av Països Catalans 26, Tarragona 43007, Spain
[e] Faculty of Science, Universiti Teknologi Malaysia, UTM Johor Bahru, Johor 81310, Malaysia
[f] Faculty of Chemical and Process Engineering Technology, College of Engineering Technology, Universiti Malaysia Pahang, Lebuhraya Tun Razak, Gambang, Kuantan, Pahang 26300, Malaysia

ARTICLE INFO

Keywords:
CO_2 methanation
Zirconia
Fibrous morphology
Nickel
Methane

ABSTRACT

The spherical mesoporous nickel−loaded fibrous silica zirconia (Ni/FSZr) were successfully synthesized utilizing hydrothermal system followed by impregnation technique and catalytically assessed in CO_2 hydrogenation for methane production, a valuable alternative renewable fuel. The Ni/FSZr catalyst, including Ni/SiO_2-ZrO_2 and Ni/ZrO_2, were tested in a fixed-bed reactor at 150 to 500 °C while sustaining atmospheric pressure. Results showed that Ni/FSZr outperformed the other catalysts, with 91.32% CO_2 conversion and 91.31% CH_4 yield achieved at 500 °C. The catalyst's surface area was found to significantly impact their performance, with Ni/FSZr exhibiting a surface area 28 times higher than the other catalysts. The Ni/FSZr also have moderate basicity and greater amounts of reduced Ni^0 which can enhance CO_2 methanation activity. Importantly, all catalysts exhibited exceptional stability with no deactivation observed, but the thermal stability of Ni/FSZr was superior, indicating that the fibrous morphology may possibly withstand the formation of coke and resist deactivation. These findings suggest that Ni/FSZr is an effective catalyst for efficient CO_2 methanation, which can be beneficial in reducing greenhouse gas emissions and providing a sustainable alternative to traditional fossil fuels.

Introduction

Since Sabatier and Senderens discovered methane creation by the process between carbon oxide and hydrogen, the methanation reaction has been well investigated. It plays a vital role in chemical production, including removing CO_x residue from the rich hydrogen feed gas, reformate gas refinement for fuel cells, and generation of alternative energy resources, substitute natural gas (SNG) [1,2]. In terms of cost-effectiveness, SNG can be distributed utilizing the existing pipeline infrastructure. Furthermore, several national and worldwide strategies to minimize CO_2 emissions have been implemented by international governments [3]. Consequently, the exigency for natural gas has increased, which is regarded as a more environmentally friendly fuel than other fossil fuels since it offers more substantial environmental advantages than those provided by other fossil fuels. The increased affordability of natural gas in recent years has made it more accessible to consumers and a more attractive and sustainable alternative to other forms of energy, with positive impacts on the environment [4]. The mineral-free nature of natural gas makes it a more environmentally conscious fuel choice than coal, since it burns cleaner and leaves behind no ash residue, which helps reduce pollution and greenhouse gas emissions [5]. Hence, due to its lower concentration of carbon, natural gas has the potential to outperform coal and other liquid fuels, making it a more viable and sustainable energy source with promising environmental benefits [5].

CO_2 methanation is an efficient means of producing methane, which is the primary component of natural gas, and typically necessitates the use of a catalyst to lower the activation energy and enhance the conversion of CO_2 to methane, as the process is highly exothermic. Many investigations have been conducted to determine the specific reaction

* Corresponding author at: Centre of Hydrogen Energy, Institute of Future Energy, UTM Johor Bahru, Johor 81310, Malaysia.
E-mail address: aishahaj@utm.my (A.A. Jalil).

https://doi.org/10.1016/j.mcat.2023.113311
Received 7 May 2023; Received in revised form 27 May 2023; Accepted 10 June 2023
Available online 13 June 2023