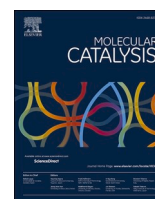




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Ultra-high surface area fibrous silica-zirconia support for renewable energy production by CO₂ methanation

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'Heres 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

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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 CO₂ hydrogenation for methane production, a valuable alternative renewable fuel. The Ni/FSZr catalyst, including Ni/SiO₂-ZrO₂ and Ni/ZrO₂, 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% CO₂ conversion and 91.31% CH₄ 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 Ni⁰ which can enhance CO₂ 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 CO₂ 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, reformat 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 CO₂ 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].

CO₂ 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 CO₂ 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).

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