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An efficient process for sustainable and scalable hydrogen production from green ammonia

Junyoung Cha [a,b,1], Yongha Park [a,1], Boris Brigljević [c,1], Boreum Lee [c], Dongjun Lim [c], Taeho Lee [a], Hyangsoo Jeong [a], Yongmin Kim [a], Hyuntae Sohn [a], Hrvoje Mikulčić [d,e], Kyung Moon Lee [f], Dong Hoon Nam [f], Ki Bong Lee [b], Hankwon Lim [c,***], Chang Won Yoon [a,g,**], Young Suk Jo [a,*]

[a] Center for Hydrogen and Fuel Cell Research, Korea Institute of Science and Technology (KIST), 5 Hwarang-ro 14-gil, Seongbuk-gu, Seoul, 02792, Republic of Korea
[b] Department of Chemical and Biological Engineering, Korea University, 145, Anam-ro, Seongbuk-gu, Seoul, 02841, Republic of Korea
[c] School of Energy and Chemical Engineering, Ulsan National Institute of Science and Technology, 50 UNIST-gil, Eonyang-eup, Ulju-gun, Ulsan, 44919, Republic of Korea
[d] Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Zagreb, Croatia
[e] MOE Key Laboratory of Thermo-Fluid Science and Engineering, Xi'an Jiaotong University, Xi'an, China
[f] Hydrogen Energy Business Development Team, Hyundai Motor Company, 37, Cheoldobangmulgwan-ro, Uiwang-si, Gyeonggi-do, 16082, Republic of Korea
[g] Department of Chemical Engineering, Pohang University of Science and Technology (POSTECH), 77 Cheongam-ro, Nam-gu, Pohang, 37673, Republic of Korea

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ABSTRACT

This study comprehensively investigates hydrogen production from green ammonia reforming, including synthesis of catalysts, reactor development, process integration, and techno-economic analysis. In-house developed $Ru/La–Al_2O_3$ pellet catalyst having perovskite structure showed high catalytic activity of 2827 h^{-1} at 450 °C and stability over 6700 h at 550 °C, exceeding the performance of the majority of powder catalysts reported in the literature. A scalable 12-faceted reactor adopting the as-produced catalyst was designed to enhance heat transfer, producing over 66 L min^{-1} of hydrogen with state-of-the-art ammonia reforming efficiency of 83.6 %. Near-zero CO_2 emission of hydrogen extraction from green ammonia was demonstrated by-product gas recirculation as a combustion heat source. A techno-economic assessment was conducted for system scales from 10 kW to 10 MW, demonstrating the effect of reduced minimum hydrogen selling prices from 7.03 USD kg^{-1} at small modular scales to 3.98 USD kg^{-1} at larger industrial scales. Sensitivity analyses indicate that hydrogen selling prices may reduce even further (up to 50 %). The suggested hydrogen production route from green NH_3 demonstrates superior CO_2 reduction ranging from 78 % to 95 % in kg CO_2 (kg H_2)$^{-1}$ compared to biomass gasification and steam methane reforming. These findings can be used as a basis for following economic and policy studies to further validate the effectiveness of the suggested system and process for H_2 production from NH_3.

Abbreviations: Abs, Adsorber; CAPEX, Capital expense; CE, Costing exponent; CNT, Carbon nanotube; FFR, Fuel flow rate; GHSV, Gas hourly space velocity; HX, Heat exchanger; LHV, Lower heating value; MHSP, Minimum hydrogen selling price; NCF, Non-discounted cash flow; NPV, Net present value; OPEX, Operating expenses; PEMFC, Polymer electrolyte membrane fuel cell; PFD, Process flow diagram; PSA, Pressure swing adsorption; REF, Reformer; SC, Storage cost; SMR, Steam methane reforming; STP, Standard temperature and pressure; TCI, Total capital investment; TEA, Techno-economic assessment; TEM, Transmission electron microscopy; TIC, Total installation cost; TOF, Turnover frequency.

* Corresponding author. Center for Hydrogen and Fuel Cell Research, Korea Institute of Science and Technology (KIST), 5 Hwarang-ro 14-gil, Seongbuk-gu, Seoul, 02792, Republic of Korea.
** Corresponding author. Center for Hydrogen and Fuel Cell Research, Korea Institute of Science and Technology (KIST), 5 Hwarang-ro 14-gil, Seongbuk-gu, Seoul, 02792, Republic of Korea.
*** Corresponding author. School of Energy and Chemical Engineering, Ulsan National Institute of Science and Technology, 50 UNIST-gil, Eonyang-eup, Ulju-gun, Ulsan, 44919, Republic of Korea.
E-mail addresses: hklim@unist.ac.kr (H. Lim), cwyoon@postech.ac.kr (C.W. Yoon), yjo@kist.re.kr (Y.S. Jo).
[1] These authors contributed equally.

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