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Editorial

Special Issue on "Hydrogen Production Technologies"

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According to energy crisis and environmental concerns, hydrogen has been driven to become one of the most promising alternative energy carriers for power generation and high valued chemical products. To meet the requirements of global energy demand, which continuously increase each year, efficient technologies to produce hydrogen are therefore necessary. This Special Issue on "Hydrogen Production Technologies" covers outstanding researches and technologies to produce hydrogen of which their objectives are to improve process performances. Both theoretical and experimental investigations were conducted for the investigation of parametric effects in terms of technical and/or economical aspects for different routes of hydrogen production technologies, including thermochemical, electrochemical, and biological. In addition, techniques used to storage and utilize hydrogen were also demonstrated.

Steam electrolysis reaction is a technique used to produce hydrogen through solid oxide electrolysis cells (SOECs). Visvanichkul et al. [1] studied the effect of CuO addition into $Sc_{0.1}Ce_{0.05}Gd_{0.05}Zr_{0.89}O_2$ (SCGZ) electrolyte as a sintering additive on phase formation, cell densification, and electrical performance at elevated temperature. The results showed significant effect on the sinter ability of SCGZ. With the addition of 0.5 wt% CuO phase transformation and impurity were not observed. However, the sintering ability of the electrolyte achieved 95% relative density with a large grain size at 1573 K. Electrochemical performance evaluated at the operating temperature ranging from 873 K to 1173 K under steam to hydrogen ratio at 70:30 showed activation energy of conduction (E_a) of the SCGZ with CuO of 74.93 kJ mol^{-1} compared to that without Cu of 72.34 kJ mol^{-1}. Another work presented by Gannon et al. [2] was conducted in improving performance of electrode for water splitting under room temperature. Titanium nitride coating 316 grade stainless-steel electrode was found to be able to extend the electrode lifetime to over 2000 cycles lasting 5.5 days and was observed to outperform the uncoated material by 250 mV.

An alternative route for hydrogen production is from the conversion of solar energy. Tapia et al. [3] investigated the use of multi-tubular solar reactors for hydrogen production through thermochemical cycle using CFD modelling and simulations to design the reactor for a pilot plant in the Plataforma Solar de Almería (PSA). The developed CFD model showed its validated results with the experimental data having a temperature error ranging from 1% to around 10%, depending upon the location inside the reactor. The thermal balance solved by the CFD model revealed a 7.9% thermal efficiency of the reactor, and ca. 90% of the ferrite domain could achieve the required process temperature of

900 °C. Treatment of reactants before producing hydrogen is another technique that helps to enhance process efficiency. Zaidi et al. [4] studied the effect of using microwave (MW) and Fe_3O_4 nanoparticles (NPs) to improve biodegradability of green algae, yielded biogas—a source of hydrogen production. Their results showed both yields of biogas and hydrogen could be improved when compared to the individual ones. The biogas amount of 328 mL and 51.5% v/v hydrogen were produced by MW pretreatment + Fe_3O_4 NPs.

Integrated techniques to improve hydrogen production performances have also been investigated. Ngoenthong et al. [5] developed a catalyst for hydrogen production from a two-step thermochemical cycle of water-splitting, applied with two different reactor types, packed-bed and micro-channel reactors. Ceria-zirconia ($Ce_{0.75}Zr_{0.25}O_2$) was found to offer better catalytic activity than fluorite-structure ceria (CeO_2), which was suggested to be due to higher oxygen storage capacity. The micro-channel reactor showed 16 times higher H_2 productivity than the packed-bed reactor at the same operating temperature of 700 °C. The better performance of the micro-channel reactor was considered as a result of high surface-to-volume ratio of the reactor, facilitating accessibility of the reactant molecules to react on the catalyst surface. Chimpae et al. [6] evaluated performance of a combined gasification and a sorption-enhanced water–gas shift reaction (SEWGS) for synthesis gas production using mangrove-derived biochar as a feedstock. Multifunctional material was applied in this integrated process and the effects of biochar gasification temperature, pattern of combined gasification and SEWGS, amount of co-fed steam and CO_2 as gasifying agent, and SEWGS temperature were studied. The studies revealed that the hybrid process could produce greater amount of H_2 with a lower amount of CO_2 emissions when compared with separated sorbent/catalyst material. Syngas production was found to depend upon the composition of gasifying agent and SEWGS temperature. An integrated steam methane reforming-hydrotreating (SMR-HT) pyrolytic oil upgrading process enhanced by membrane gas separation system was proposed by Chen et al. [7]. Process design and process optimization were developed through simulation framework of commercial software Aspen HYSIS along with the developed self-defined extensions for Aspen HYSYS. The results revealed that the proposed process could provide 63.7% conversion with 2.0 wt% hydrogen consumption and 70% higher net profit could be obtained when compared with the conventional process. Khaodee et al. [8] proposed systems of compact heat integrated reactor system (CHIRS) of a steam reformer, a water gas shift reactor, and a combustor for stationary hydrogen production from ethanol. Their performances were simulated using COMSOL Multiphysics software.

As there are a number of different techniques that could be used to produce hydrogen, we therefore need to consider a selection of technologies for its production. One tool that could be used to assist decision making is data analysis. Xu et al. [9] developed a framework includes slack-based data envelopment analysis (DEA), with fuzzy analytical hierarchy process (FAHP), and fuzzy technique for order of preference by similarity to ideal solution (FTOPSIS), to prioritize hydrogen production in Pakistan. Five criteria, including capital cost, feedstock cost, O&M cost, hydrogen production, and CO_2 emission were taken into consideration. The results showed that wind electrolysis, PV electrolysis, and biomass gasification offered fully efficient and were recommended as sustainable selections for production of hydrogen in Pakistan.

High production of hydrogen demand leads also to high demand of efficient hydrogen storage system. Kapoor et al. [10] developed electrochemical hydrogen storage by integrating a solid multi-walled carbon nanotube (MWCNT) electrode in a modified unitized regenerative fuel cell (URFC). A method to fabricate solid electrode from MWCNT powder and egg white as an organic binder was investigated. The results showed that the developed porous MWCNT electrode had electrochemical hydrogen storage capacity of 2.47wt%, comparable with commercially available AB_5-based hydrogen storage canisters.

All the above papers show high-quality research articles on various innovative hydrogen production related technologies. The works and topics address current status and future challenges in unit scale and overall process performances. Under the high demand of renewable and sustainable energy at present, we believe that these articles would find beneficial to a wide interest of readers.

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