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Synthesis, characterization, and catalytic performance of Ni supported on sustainable POFA-derived SBA-15 for hydrogen-rich syngas from CO_2 reforming of methane

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ABSTRACT

Palm Oil Fuel Ash (POFA) is massively produced by numerous palm oil mills worldwide, creating an environmental waste disposal problem. Notably, POFA serves as a cost-effective alternative silica source instead of the expensive tetraethyl orthosilicate (TEOS). This research focused on synthesizing SBA-15 from POFA waste and examining the effect of promoters on POFA-derived SBA-15-supported Ni-based catalysts. The 10 wt% Ni/SBA-15-POFA catalyst was sequentially impregnated with promoters having 1 wt% loading of Zr, Ce, La, and Cr. The catalysts were tested for CO_2 methane reforming (CMR) at 800 °C for 8 hours while maintaining a stoichiometric feed ratio. Various characterization techniques, including XRD, FESEM, XPS, H_2-TPR, CO_2-TPD, and BET analysis were employed to assess the catalyst physicochemical properties. The addition of promoter changed the properties of catalyst. Except for Cr-promoted catalyst, the addition of promoters positively impacted catalytic performance, activity, and stability. XRD analysis showed that Cr addition had detrimental effects on the crystallite structure of the Ni/SBA-15-POFA catalyst. In contrast, Zr, Ce, and La additions significantly reduced the crystallite size and improved active metal dispersion. Overall, the Zr-promoted catalyst exhibited the best performance in terms of activity and stability, with a CH_4 conversion of 90 % and CO_2 conversion of 94.4 %. The spent catalyst characterization, including XRD, FESEM, O_2-TPO, and RAMAN, showed that promoter addition significantly reduced carbon deposition. The stable and superior perfromance of Zr-promoted catalyst was attributed to the production of MWCNTs. Conversely, the rapid deactivation of the unpromoted catalyst may be due to the formation of amorphous carbon, which tends to quickly block active sites and reduce the catalytic activity.

Introduction

Palm oil fuel ash (POFA) is a byproduct of the palm oil industry resulting from the incineration of palm oil plant residues in palm oil mill boilers for energy production. Global palm oil production in 2020 reached 72.27 million metric tons, with Indonesia, Malaysia, Thailand, and Colombia being the top palm oil exporters [1]. After palm fruit oil extraction, the remaining husks and shells are burned as boiler fuel, generating ash known as POFA. Each combustion cycle in steam boilers yields approximately 5 % of solid waste as POFA [2]. The substantial production of POFA by palm oil mills poses environmental waste disposal challenges and odor concerns. Improper disposal can contaminate soil and water due to its alkaline nature and high levels of heavy metals and trace elements, jeopardizing ecosystem health and fertility. Furthermore, inadequate disposal methods like open dumping or landfilling can release harmful particulate matter and gases, contributing to air pollution [3]. Moreover, the widespread production and disposal of POFA may exacerbate land use issues and deforestation, intensifying

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