Production of hydrogen from biomass: Integrated biological and thermo-chemical approach

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Introduction

Research on hydrogen is given much attention nowadays due to its importance as a future alternate energy source. It reduces the dependence on fossil fuel and carbon-based emissions. Currently, about 90% of the hydrogen is produced by the reactions of natural gas and steam reforming of light oil fractions [1]. These methods mainly consume fossil fuel as energy source, which is not only fraught with emission problems, but also fossil fuels are depleting at alarming rate. Therefore, there is need to find alternative ways of hydrogen production based on renewable energy sources such as biomass. The most common techniques for biomass conversion are gasification and pyrolysis [2]. However, the major disadvantage of these processes is the decomposition of the biomass feed stock leading to char and tar formation [3,4].Overcoming this difficulty, Aqueous Phase Reforming (APR) has been demonstrated as an alternative technique for hydrogen production from sugars [5].

Because of the limitations found in the reforming of solid biomass feedstock, we envision an integrated scheme in which conventional conversion processes based on fermentation and catalytic reforming are combined to convert waste biomass into hydrogen. In this way, biomass in food processing and agricultural waste can be converted, nearly eliminating the cost of raw materials (or even possibly generating revenue by reducing waste disposal related costs) and improving the overall economics of the process.

Materials and Methods

Glucose was used as the surrogate for the biomass feedstock. Glucose was first converted to ethanol in fermentation process using *Saccharomyces cerevisiae.* The resultant fermentation broth was then used for subsequent aqueous phase reforming reactions. The APR reactions were carried out in a flow reactor at 250 °C and 600 psi. The results obtained during APR of fermentation broth were compared with the results obtained from a simulated sample containing 5 % (by wt) pure ethanol. The gas products of the APR were analyzed using mass spectrometer (Pfeiffer-vacuum). The liquid products were analyzed using high pressure liquid chromatography (Shimadzu). Catalysts used in APR were prepared by wet impregnation technique. X-ray diffraction technique was used for the phase change analysis of the catalysts. BET surface area analysis, pulse chemisorption experiments were carried out in micromeritics instrument.

Results and Discussion

APR of simulated sample containing 5 % pure ethanol at 250 °C and 600 psi gave around 20 % H_2 yield. The H_2 yields obtained during simulated sample were found to be steady for 100 h of run time. However, when fermentation broth containing approximately same amount of ethanol was used in APR process, the H_2 yields started decreasing. There was severe catalyst deactivation observed in case of fermentation sample. However, the pre-treatment of the fermentation sample helped in extending the deactivation time, indicating that the fermentation impurities were the cause of the catalyst deactivation. XRD studies on the fresh and used catalyst sample showed that the Al_2O_3 support undergone phase change with Al_2O_3 being transformed to boehmite phase. Figure 1 shows the XRD pattern for fresh, used catalyst, and support. However, the phenomenon of support phase change was observed for both simulated sample and fermentation sample. Therefore, catalyst deactivation in case of fermentation broth could not be attributed to the phase change of the alumina support.

In order to develop stable catalyst for APR of fermentation broth, alternative support materials have been prepared and evaluated. The preliminary results, shown in Figure 2, demonstrate that these alternative supports can provide enhanced stability for hydrogen production from fermentation broth. Further support development and analysis is ongoing.

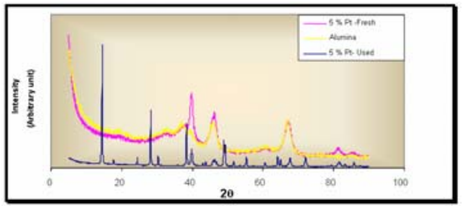

Figure 1. XRD pattern for 5 % pt on Al_2O_3 catalyst used for APR [fresh, used and support]

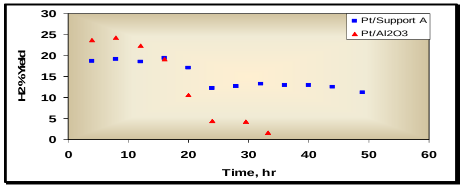

Figure 2 comparison of Pt catalyst performance for two different supports

Significance

Aqueous phase reforming is conceived as an alternative to steam or autothermal reforming of biomass-derived compounds. APR is a low temperature process (~ 250 °C) compared to high temperature steam reforming (~800 °C). Dilute aqueous organic streams obtained from biomass fermentation can be reformed to hydrogen using APR, without char formation. Because the APR process is carried out at lower temperature at which water gas shift (WGS) reaction is thermodynamically favorable [6], CO concentrations are extremely low. Thus, a high pressure hydrogen product with ppm level CO is obtained that potentially can be used as feed for a PEM fuel cell.

References

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