Simultaneous catalytic abatement of plastic waste and CO_2 over MFI and Ni-MFI coated open-cell ceramic foams

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Highlights

- Simultaneous catalytic abatement of plastic waste and CO_2 was carried out successfully.
- BTEX rich pyrolysis oil and light HCs containing pyrolysis gas was produced over MFI catalyst.
- Ni-MFI coated foam catalysts showed appreciable catalytic activity in CO_2 reforming of light HCs.
- The study may provide new insights towards the development of processes for the chemical recycling of waste plastics and CO_2.

1. Introduction

The exponential growth in plastic waste and ever-increasing rates of CO_2 emissions represent serious threats to both terrestrial and marine ecosystems. A promising solution for the reduction of both plastic waste and CO_2 is to use them as feedstocks for the production of valuable chemicals which can be employed as secondary feedstocks in chemical and petrochemical industries [1–3]. Here, chemical recycling of plastics via thermo-catalytic pyrolysis and catalytic CO_2 reforming of hydrocarbons are considered as important processes for the transformation of waste plastics and CO_2, respectively. Furthermore, a combination of these processes offers the possibility of simultaneous reduction of both hazardous substances. In this context, zeolites and zeolite-based composite materials are among the interesting and versatile catalytic materials for the thermo-catalytic treatment of plastics as well as catalytic CO_2 reforming of hydrocarbons (HCs) [1, 4]. In continuation of our recent work on chemical recycling of plastics [1, 5], the present work deals with the simultaneous abatement of plastic wastes and CO_2. The aim was to transform plastic waste into BTEX (benzene, toluene, ethyl benzene, xylenes) rich pyrolysis oil and light HCs containing pyrolysis gas. A further aim was to perform catalytic CO_2 reforming of pyrolysis gas over Ni containing structured zeolite composites for syngas production.

2. Methods

For this study, a three-stage experimental setup was employed. In the first stage, pyrolysis vapors were produced by thermal (non-catalytic) treatment of waste polyolefins. In the second stage, thermo-catalytic conversion of the pyrolysis vapors over commercial powdered MFI type (HZSM-5) zeolite catalyst (with feed to catalyst ratio of 10) was carried out to obtain BTEX rich pyrolysis oil and pyrolysis gas containing light HCs. After the second stage, the pyrolysis oil produced was separated from the pyrolysis gas. The pyrolysis gas was then mixed with CO_2 and Ar and fed to the third stage reactor for the catalytic dry reforming over Ni-MFI (Ni-silicalite-1) coated open-call ceramic foam using a gas hourly space velocity (GHSV) of 48 $L.h^{-1}.g_{Ni}^{-1}$ for syngas production. All catalysts were characterized by XRD, NH_3-TPD, H_2-TPR, SEM, and N_2 physisorption. The influence of catalyst properties, reactor configuration (packed bed and structured foam catalyst) as well as the operating conditions on the product distribution was investigated.

3. Results and discussion

Thermo-catalytic pyrolysis of waste polypropylene over HZSM-5 catalyst produced ca. 55 wt. % BTEX rich pyrolysis oil and over 40 wt.% pyrolysis gas containing C_1-C_4 alkanes and C_2-C_4 olefins mainly with traces of C_5 species. This can be attributed to the cracking and dehydroaromatization of pyrolysis

vapors over acidic HZSM-5 catalyst. Furthermore, in the third stage, Ni-silicalite-1 coated foam composites showed appreciable conversions of pyrolysis gas and CO_2 into syngas (Figure 1). A detailed and systematic study on the influence of catalyst properties, reactor configuration and reactor temperature on the product distribution is underway and the results will be presented.

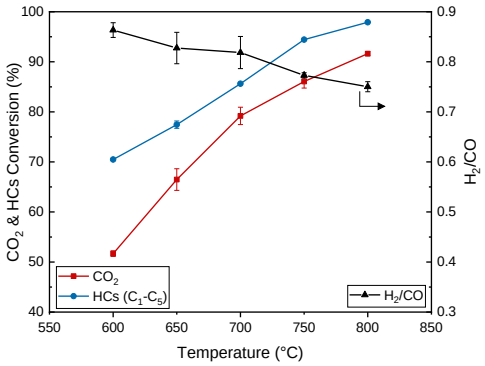

Figure 1. Conversion of CO_2 and HCs (from pyrolysis gas) over Ni-Silicalite-1/foam composite with H_2 to CO ratio in the produced syngas.

4. Conclusions

Thermo-catalytic pyrolysis of plastics and catalytic CO_2 reforming of hydrocarbons are promising processes for the simultaneous abatement of plastic wastes and carbon dioxide. It was demonstrated that depending upon the process parameters, catalyst types and reactor configurations, plastic wastes and CO_2 can be converted into a diverse array of valuable chemicals that can be used as secondary feedstocks in chemical and petrochemical industry. This study may provide new insights towards the development of processes for the chemical recycling of waste plastics and CO_2.

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Keywords

Chemical recycling, thermo-catalytic pyrolysis, dry reforming, zeolite catalysts.

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