COMPARING PYROLYSIS BEHAVIOR OF VIRGIN AND WASTE PLASTICS

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1. Introduction

Pyrolysis of polymers is often regarded as the most promising technology for resource recovery from waste polymer materials[1].Quite a lot of research work on the pyrolysis of individual and mixed plastics into liquid products has been reported[2]. However, in case of waste plastics, additives as well as “weak bonds” caused by aging might change the pyrolysis behavior when compared to virgin plastics. Moreover, many new catalysts have been developed for the pyrolysis of plastics [3]. Although most of them showed quite high catalytic cracking abilities for virgin plastics, the feasibility to be used for waste plastics should be proved. In this paper, preliminary work has been done in order to compare the pyrolysis behavior of virgin and waste plastics.

2. Experimental

The pyrolysis of polymers was carried out in a glass reactor (20 ml volume) by batch operation. In a typical pyrolysis run, about 1.3 g of materials and 0.065 g catalysts (for catalytic pyrolysis reaction) were added to the reactor and reacted at 430 °C until no liquid was produced. The pyrolysis oils were obtained using a Shimadzu GC 17A gas chromatography equipped with a Shimadzu GCMS-QP5000 mass selective detector (GC/MS) and a 25 m × 0.25 mm × 0.4 µm Chrompack capillary column.

3. Results and discussion

As for pyrolysis behaviors of HDPE, HDPE waste produces higher liquid yield and lower residue yield compared with that of virgin HDPE (Tab.1). Moreover, the liquid distribution is similar to the virgin one with a wide and evenly distributed carbon number distribution (C_5-C_{34}) (Fig.1). HDPE waste are composed of granules with different colors. After pyrolysis, clear yellowish liquid product has been obtained that owns similar appearance with that of liquid from virgin HDPE. Moreover, it can be observed that the blue dyes were left in residue. The HDPE waste probably owns higher amounts of “weak bonds” such as carboxyl and hydoxyl groups due to the aging process under natural environment or these groups may be formed during processing of polymer, which is beneficial to the thermal degradation of HDPE.

In addition, SiO_2-Al_2O_3 showed similar catalytic cracking ability for both virgin HDPE and HDPE waste, i.e., increased liquid yield and decreased residue yield; narrower and lighter liquid carbon number distribution (C_5-C_{16}), indicating the additives in HDPE waste such as dyes would not affect the catalytic cracking activities of SiO_2-Al_2O_3.

PP waste showed much higher liquid yield and lower residue yield than those of HDPE waste due to the methyl group in PP molecular chain. Compared with virgin PP, PP waste owns a slightly lower liquid yield and higher residue yield (Tab.1). However it has to be considered that inorganic filling materials may also be the cause of increase in residue amounts. The additives such as antioxidants in PP waste maybe responsible for the inhibited thermal degradation behavior of PP. Moreover, SiO_2-Al_2O_3 showed similar catalytic cracking ability for virgin PP and PP waste, suggesting only minor influence of the additives in PP for the catalytic cracking abilitiy of the SiO_2-Al_2O_3.

For pyrolysis behaviors of polystyrene (PS), waste PS produced higher liquid yield (89.23 wt%) and lower gas yield (1.54 wt%) than those of PS. Moreover, waste PS had much higher heavier liquid components (trimer). In addition, similar with virgin HIPS, SiO_2-Al_2O_3 showed few catalytic cracking effects for PS waste.

Tab. 1 Product Yields from thermal and catalytic pyrolysis of virgin and waste HDPE, PP and PS

Materials	Product yield (wt. %)		
	Liquid	Gas	Residue
HDPE	34.85	10.61	54.55
HDPE waste	46.92	10.77	42.31
PP	80.77	12.31	6.92
PP Waste	72.31	13.08	14.62
HIPS	79.39	7.63	12.98
Waste PS	89.23	1.54	9.23
HDPE- SiO_2-Al_2O_3	73.85	21.15	5.00
HDPE waste- SiO_2-Al_2O_3	73.08	21.15	5.77
PP- SiO_2-Al_2O_3	73.85	10.77	10.38
PP waste- SiO_2-Al_2O_3	70.77	17.31	11.92
PS	79.39	7.63	12.98
PS-SiO_2-Al_2O_3	83.21	1.53	15.27
PS Waste	89.23	1.54	9.23
PS Waste /SiO_2-Al_2O_3	86.92	5.77	7.31

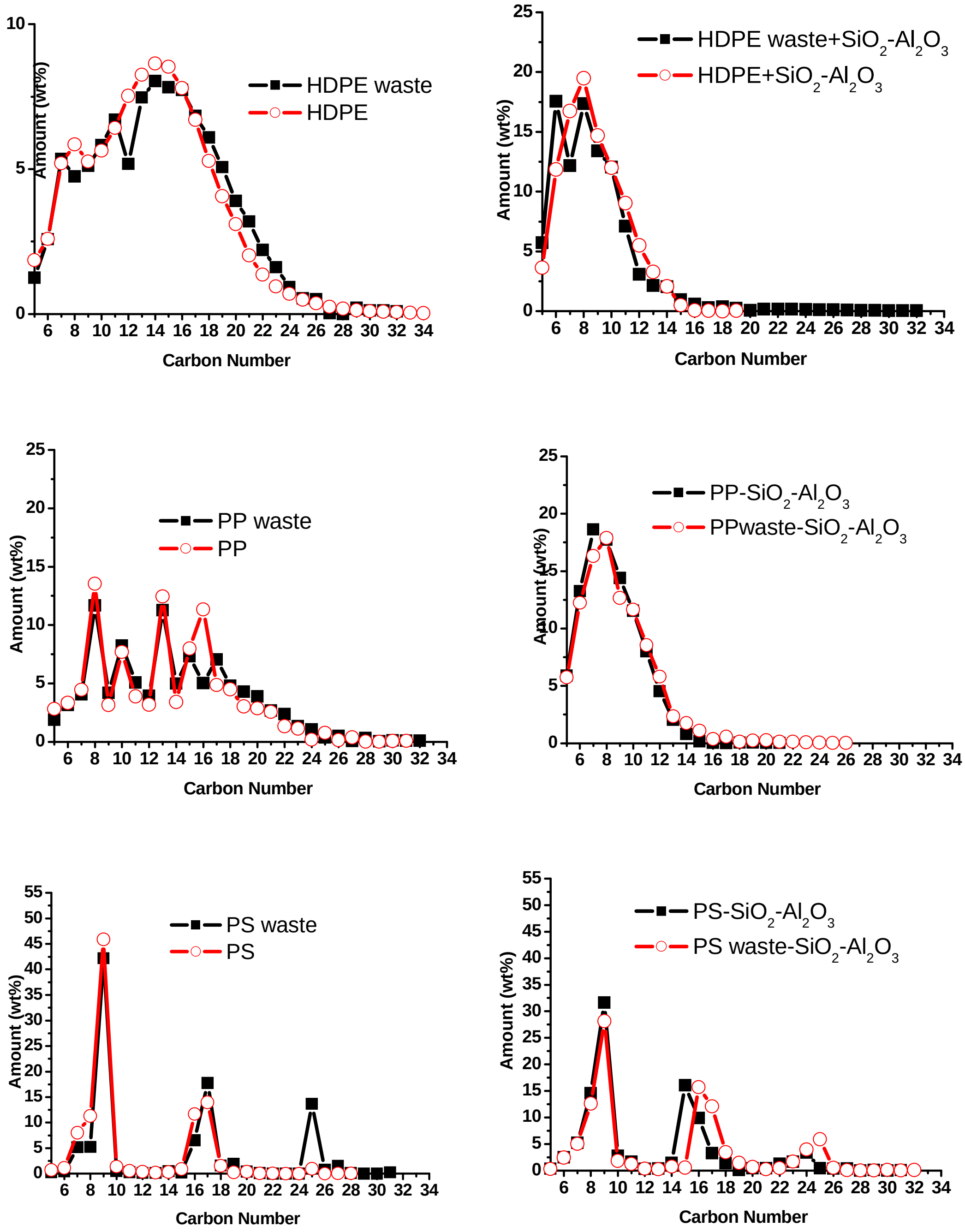

Fig.1 Liquid product distribution from thermal and catalytic pyrolysis of virgin and waste HDPE, PP and PS

4. Conclusions

(1) HDPE waste owns a higher pyrolysis activities than those of virgin HDPE. The liquid product distribution is similar with that of virgin HDPE. SiO_2-Al_2O_3 showed similar catalytic cracking ability for both virgin HDPE and HDPE waste.

(2) PP waste owns a slightly lower pyrolysis activities than those of virgin PP. Moreover, SiO_2-Al_2O_3 showed similar catalytic cracking ability for both virgin PP and PP waste, suggesting the additives in PP didn't affect the catalytic cracking abilitiy of the SiO_2-Al_2O_3.

(3) Waste PS produced higher liquid yield and lower gas yield than those of virgin HIPS. Moreover, waste PS had much higher heavier liquid components. Similar with virgin HIPS, SiO_2-Al_2O_3 showed few catalytic cracking effects for PS waste.

References

[1] W. Kaminsky, F. Hartmann, Angew. *Chem. Int. Edit.* **2000**, *39*, 331.

[2] P. T. Williams, E. A. Williams, J. Anal. *Appl. Pyrolysis*. **1999**, *51*, 107.

[3] Q. Zhou, Y. Z. Wang, C. Tang, Y. H. Zhang, *Polym. Degrad. Stab*, **2003**, *80(1)*, 23.