DEGRADATION OF POLYSTYRENE USING MONTMORILLONITE CLAY CATALYSTS

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Abstract

The performance of acid-treated montmorillonite catalysts in the degradation of polystyrene (PS) was investigated in this study. The degradation was carried out in a semi-batch reactor with a mixture of PS and catalyst at 400-450°C. The commercial Süd Chemie acid-treated montmorillonite clays (K-series) showed good catalytic activity for the degradation of PS. The styrene monomer and ethylbenzene were major liquid products. The increase of surface acidity enhanced further cracking of styrene dimer and trimer to produce styrene monomer. Higher production of ethylbenzene for K30 may be related to its bigger pore volume and surface area compared to those of K5. High degradation temperature favored styrene monomer production.

Keywords: Polystyrene, catalytic degradation, montmorillonite clay, aromatics

INTRODUCTION

Waste plastics can be converted into fuel oils by thermal or catalytic process. The oils produced by catalytic degradation are known to contain a relatively narrow distribution of hydrocarbons, lower amount of olefins and higher amount of aromatics compared to the oils from the thermal degradation. An excellent summary of the catalytic recycling of polymers was reported by Uemichi [1]. In contrast to polyethylene (PE) and polypropylene (PP), polystyrene (PS) can be thermally depolymerized to obtain the styrene monomer.

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with a high selectivity [2,3]. Natural untreated clays possess a very low ability to catalyze reactions in either polar or non-polar media. However, the structural properties of these materials can be modified by various activation methods in order to produce catalysts with high acidity, surface area, porosity and thermal stability. Acid activation of clay minerals is one of the most effective methods that has been used to produce active materials for adsorption and catalysis proposes [4,5]. Montmorillonite is a good example of natural clays. Different grades of acid-activated montmorillonites are tailored to different applications. Acid-treated montmorillonites can be purchased from a variety of commercial sources.

In the present work, we investigated the performance of the K-series montmorillonite clays (K5, K10, K20, K30), purchased from Fluka AG, in the degradation of PS to fuel oils.

EXPERIMENTAL

K-montmorillonites are produced by Süd-Chemie AG from raw clays of Bavaria, Germany, and laboratory quantities are commercially available from Fluka. Polystyrene (PS), in powder form, was supplied by LG Chemical Co. (Grade 50IS, Mn=98000-99000, melt index=7.5 g/10 min, density=1.03 g/cm³). PS samples of 60-150 mesh size were used for this study. A mixture of 3.0 g of PS and 0.3 g of the catalyst was loaded inside a Pyrex vessel of 30 mL and heated at a rate of 30ºC/min up to a desired temperature. The distillate from the reactor was collected in a cold trap (-5ºC) over a pre-determined time.

The composition of the K-montmorillonite was determined by X-ray fluorescence analysis (Philips PW2400). The acidic properties of the catalysts were determined by conventional temperature-programmed desorption (TPD) of ammonia in the temperature range of 373-973 K at a constant heating rate of 5 K/min. The specific surface area and pore size of the catalysts were measured by a BET apparatus (Micromeritics ASAP 2010). The amount of coke deposit on the catalyst was calculated by measuring the desorbed amount of carbon dioxide during temperature-programmed oxidation of used catalysts. The gases were analyzed by an on-line GC (HP 5890) with a Porapak Q column. The condensed liquid samples were analyzed by a GC-MS (Micromass Co., Auto spec.) with a capillary column (HP-5MS).

RESULTS AND DISCUSSION

Table 1 shows chemical compositions of K-series catalysts measured by X-ray fluorescence (XRF). Si/Al ratio increases from K5 to K30 due to the increase of dealumination. The distribution of acid sites for the K-catalysts was studied by