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Investigation on thermal decomposition and kinetics study of recovered oil from electronic waste by thermogravimetric analysis

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Abstract

This paper investigated thermal decomposition during pyrolysis of a recovered oil from electronic waste (e-waste). The sample used in this study was High-Impact Polystyrene (HIPS). The pyrolysis target temperature was 400–550 °C. It was found that the maximum oil yield (32.5 wt.%) was obtained at the pyrolysis temperature of 450 °C. After the pyrolysis test, thermogravimetric analysis (TGA) was performed on the HIPS-derived oil to study on decomposition and kinetics. The produced pyrolysis oil that contained highest Styrene component (19.52%) was processed at 450 °C. From GC-MS and TGA, the first range (40-120 °C) could be devoted to moisture and other low volatility compounds such as Stylene, Benzene and 2-Hydroxymethyl. Then, the 1,2-Diphenylcyclopropane and α-Methylstyrene might be extensively decomposed at the second range (120-340 °C). The final peak (450-560 °C) could be the decomposition of Tetraphenylhexane. Activation energy of the pyrolysis oil was around 40-43 kJ/mol and 10-18 kJ/mol for the first and the second decomposition range, respectively, and the pyrolysis temperature did not significantly affect the activation energy of the produced oil.

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Keywords: Pyrolysis; Electronic waste; Kinetic study; Thermogravimetric analysis.

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1. Introduction

Nowadays, the amount of electronic waste is increasing and common disposal of electronic waste are inappropriate, such as open burning circuit boards, electronic parts, cable TV, for precious metals recycling. This caused an impact on environment severely due to heavy metals or hazardous substances spreading into the soil, water and air. Moreover, the disassembly of the phone may cause the spread of drifting dust lead harmful to the

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screening and environment. Recycle of electronic waste can be done by several ways, such as mechanical recycling, chemical recycling and thermal recycling [1]. Thermal recycling was utilized because it is a simple process and low cost. The thermochemical conversion process, i.e. pyrolysis, was applied for oil and char recovery. Pyrolysis has been widely tested on plastic materials, including electronic waste [2] and municipal plastic waste [3]. Generally, thermogravimetric analysis (TGA) is a well-known tool for decomposition and kinetic study. It has been used to characterize raw material prior to the pyrolysis process such as printed circuit board (PCB) [4]. However, the utilization of TGA to study thermal decomposition behavior of the pyrolysis oil was rarely performed. In this paper, the representative plastic material from electronic waste was processed by pyrolysis process with variation of the reaction temperature. Produced oil was characterized by GC-MS. To understand the characteristics of thermal decomposition of oil product, it was analyzed by TGA and kinetics study.

2. Material and Experimental

2.1 Raw Material

Raw material used in pyrolysis experiment was raw High Impact Polystyrene (HIPS). It was obtained from a plastic recycling plant. Raw material was in form of square rectangle with the size of 2 x 3 mm (width x length).

2.2 Pyrolysis experiment

The pyrolysis reactor was made from Stainless Steel (SUS316) with cylindrical shape. The heater was an 8-kW electric coil, which was controlled by a PID controller. The target temperature was 400, 450, 500, and 550 °C heated at the rate of 25 °C /min under nitrogen flow of 50 ml/min. The pyrolysis furnace was held at target temperature for 1 h. During the pyrolysis, gaseous product was condensed at oil recovery unit (set of impingers), where it was cooled down at 10 °C in water. Schematic diagram and the reactor of the pyrolysis process are shown in [3].

2.3 Analysis method

The proximate analysis of raw HIPS (ASTM D7582) was conducted by Simultaneous Thermal Analyzer model (449 F3) and the ultimate analysis of raw HIPS (ASTM D5373) was conducted by Micro Corder JM 10 Elemental Analyzer. Results are shown in Table 1.

Table 1 Proximate analysis and ultimate analysis of HIPS sample.

Proximate analysis	wt.%	Ultimate analysis	wt.%
Moisture	0.33	C	89.77
Volatile	97.59	H	7.54
Fixed carbon	2.05	O*	2.2
Ash	0.69	N	0.27

* Oxygen was calculated by difference.

The yield of oil and solid product were measured by an electronic balancer. The yield of gas product was calculated by subtracting the weight of solid product and oil product from the total weight of sample. The oil composition was analyzed by gas chromatography with a mass spectrometry (GC-MS). The column was HP-5MP and size 0.25 mm, 30 mm, 0.25 μm the injection temperature was 300 °C. The temperature program used initial temperature of 40 °C for 10 minutes followed by heating 5 °C/min to 300 °C held at 300 for 10 minutes. The ion source were 230 °C.

2.4 Thermogravimetric analysis and kinetics study

Thermogravimetric analysis (TGA) of oil was performed by 209 F3 Tarsus thermogravimetric analyzer, which measured the change in the weight of a product when it was heated. During the TGA test, the sample was heated from the room temperature to 700 °C with heating rate 5 °C/min .The flow rate of carrier gas (Air) was 150 mL/min.