STEAM GASIFICATION OF EPOXY BOARD WITH TERNARY EUTECTIC CARBONATES

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Abstract

Recovery of useful metals from end-of-life electric devices is important not only to lessen environmental burden, but also to secure strategic materials essential to the electronic industry. Epoxy resins are common plastics applied on the metal parts, which are hard to separate from metals cleanly. In this study, steam gasification of epoxy board with ternary eutectic carbonates (Li_2CO_3, Na_2CO_3 and K_2CO_3) was carried out at 600-700 °C under the atmospheric pressure. Effects of the eutectic carbonates on epoxy board steam gasification were investigated. The experimental result indicated that the epoxy board could be gasified rapidly with the main gas product of hydrogen, and the yield of tar as byproducts was much lower than that in conventional gasification. It can be concluded that steam gasification at the presence of carbonate is an effective method to recover useful metals from the end-of-life electric devices, and to convert plastics to hydrogen.

Keywords: *epoxy board; steam gasification; ternary eutectic carbonates, end-of-life electric devices*

1. Introduction

Recovery of useful metals from end-of-life electric devices is important not only to lessen environmental burden, but also to secure strategic materials essential to the electronic industry. End-of-life electric devices (E-wastes) contain not only valuable metals, but also toxic substances which will cause environment issues if treated improperly [1], [2]. Technologies for recovering those useful metals economically with minimum environmental impact have been expected eagerly for effective recycling of E-wastes. Epoxy resins are a kind of common plastics contained in E-wastes. In our study, steam gasification of epoxy board was carried out under the presence of eutectic carbonates composed of Li_2CO_3, Na_2CO_3 and K_2CO_3 (LNK carbonate). Effects of the LNK carbonate on epoxy board steam gasification were investigated to convert plastics into hydrogen effectively for recovering of useful metals.

2. Materials and Methods

2.1 Samples

Glass fiber reinforced epoxy board (EL-3762, Hitachi Chemical Company) was used as a model material of epoxy resins, which widely used in electrical industry. The low melting point eutectic LNK carbonate was prepared by equal weight mixing of three carbonates (Lithium carbonate, sodium carbonate, and potassium carbonate, obtained from Wako Pure Chemical Industries, Ltd.).

2.2 Experimental procedure

Schematic outline of the experimental apparatus is shown in Fig.1. The equipment was composed of the sample feeder, the reactor (ID: 32 mm, L: 125 mm), the heater, the steam generator, the gaseous products cooling system, and the gas analyzing system. The carbonates were preloaded in the reactor vessel at the start of the experiment. Nitrogen gas (40~100 cm^3/min) and ultra pure water (0.2~1.3 g/min) were introduced into the reactor after preheated. An epoxy sample (0.5 g) was fed into the reactor through a tube after the temperature of the reactor reached to the designated value (600-700°C). Mixture of nitrogen gas and steam was injected into molten carbonate to improve the efficiency of physical contact between the solid sample and the molten carbonate. Composition of the gaseous products was analyzed by the rapid gas chromatography (Varian CP-4900) and the flow rate of the gas was measured by an integrating flow meter.

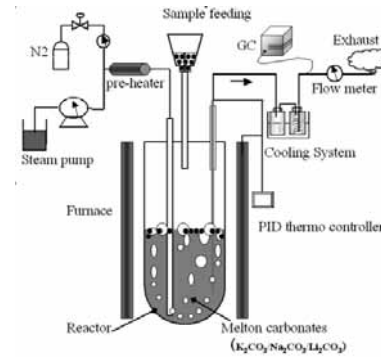

Fig.1. Experimental apparatus

3. Results and Discussion

Main gas products detected every five minutes by the rapid GC were shown in Fig.2. Remarkable production of carbon dioxide that was formed from hydrolysis of carbonate was observed after beginning of steam blowing into the molten carbonate. The main product, hydrogen, was detected when the epoxy sample was introduced after the carbon dioxide produced by hydrolysis of the carbonate had decreased small enough to ignore. In addition, the trace amount of carbon monoxide and methane were detected also.

$$C+2H_20 \longrightarrow CO_2+2H_2 \quad (1)$$

In the steam gasification, hydrogen and carbon dioxide are produced as shown in the equation (1). However, production of carbon dioxide whose amount should be half of hydrogen was not observed in our experiment. We estimated that carbon dioxide derived from the steam gasification reacted with hydroxide compounds in the molten carbonate. And then carbon dioxide was produced gradually from hydrolysis of the carbonate again.

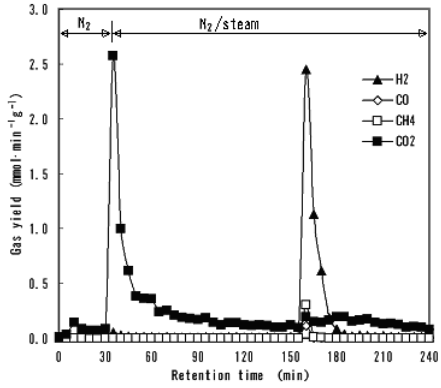

Fig.2. Main products detected by GC

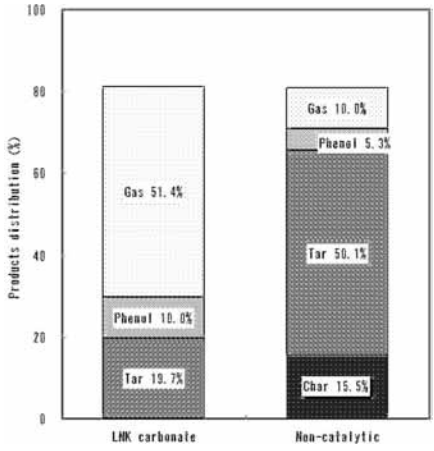

Fig.3. Product distribution in steam gasification with/without carbonate mixture

Fig.3 shows the distribution of products in the steam gasification of epoxy board with/without the ternary eutectic carbonate. The percentages shown in this graph indicate the weight ratios of carbon contained in each product to the carbon in the epoxy board. The amount of produced carbon dioxide was calculated from that of hydrogen by using the equation (1). Gaseous products were observed mainly in the presence of the LNK carbonate. These high yields of gaseous products indicate that the carbonates promoted conversion of tar into gas.

Fig.4 shows the Arrhenius plot of the rate of hydrogen formation in the steam gasification of epoxy board with/without the ternary eutectic carbonate assuming the pseudo-first-order reaction. The reaction rate increased with temperature. The activation energy of the reaction with/without carbonate was 118.4kJ/mol or 159.6kJ/mol respectively. The ternary eutectic carbonate is estimated to have catalytic effect on this steam gasification, because the activation energy with the carbonate was slightly lower than that without carbonate.

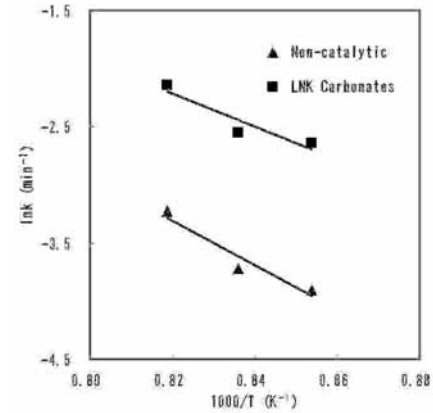

Fig.4. Arrhenius plots for steam gasification with/without carbonate mixture

4. Conclusions

The ternary eutectic carbonates (Li_2CO_3, Na_2CO_3 and K_2CO_3) accelerated steam gasification of the epoxy board at 600-700°C under the atmospheric pressure. Hydrogen was produced mainly and the yield of tar as byproducts was much lower than that in conventional gasification. We can conclude that steam gasification in the presence of carbonates is an effective method to recover useful metals from the E-wastes, and to convert plastics into hydrogen.

References

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