EFFECT OF COEXISTING MATERIALS ON STEAM GASIFICATION OF E-WASTE

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Abstract

Steam gasification of tantalum electronic capacitors or phenolic boards in the presence of LNK ternary eutectic carbonates (Li_2CO_3, Na_2CO_3, and K_2CO_3) was carried out at 550-675ºC under atmospheric pressure to produce clean hydrogen. Rates of hydrogen formation were accelerated in the presence of the metal contained in tantalum (Ta) capacitors as well as nickel metal powder (-50+100 mesh). The results showed that nonsupported nickel metal or the metal contained in the connecting terminals of electronic devices is effective to increase the rate of hydrogen production by steam gasification.

Keywords: *tantalum capacitor; steam gasification; ternary eutectic carbonates, WEEE*

1. Introduction

Recovery of valuable metals from waste electrical and electronic equipment (WEEE) is important to reduce landfill. Also, conversion of plastics contained in the electronic devices to clean hydrogen by steam gasification has been demonstrated to be feasible [1].
Phenolic resin/polymer is a widely used material for the manufacture of printed circuit boards. A tantalum (Ta) capacitor is a component on the PCBs of electronic devices and it is composed mainly of tantalum, which is an essential material for manufacturing electronic devices. Three different parts compose the capacitor: terminal, sintered electrode and fireproof epoxy resin. The terminal is made of iron, nickel, or copper. The inner part of the capacitor is the sintered electrode and it is mostly composed by compacted Ta fine powder (90 wt. %). It is covered by a fireproof epoxy resin with SiO_2 powder to enhance its thermal durability [2].
In this work, steam gasification experiments of phenolic boards or Ta capacitors were carried out in the presence of eutectic carbonates mixture (Li_2CO_3, Na_2CO_3, and K_2CO_3) to produce clean hydrogen fuel. The presence of nickel, inherent in WEEE, is studied in order to determine its catalytic effect in steam gasification.

2. Materials and Methods

2.1 Samples

Ta capacitors and phenolic boards (PL-1102, Sumitomo Bakelite Co., Ltd.) are grinded (0.15 mm of particle size) and used as samples for the thermogravimetric studies or steam gasification experiments. The eutectic LNK carbonate was prepared by mixing equal weights of three carbonates (Lithium carbonate, sodium carbonate, and potassium carbonate, supplied by Wako Pure Chemical Industries, Ltd.). Nickel powder (-50+100 mesh), with 99.7 % purity, was provided by ALFA AESAR.

2.2 Experimental procedure

2.2.1 Thermogravimetric studies

Thermogravimetric studies for phenolic boards were performed in a Rigaku Thermoplus TG8120 thermobalance, in nitrogen and steam atmosphere. Experiments for Ni (-50+100 mesh) and phenolic boards plus 75% wt. Ni (-50+100 mesh) samples were also carried out in order to study the behavior of the nickel metal and its effect in the decomposition of phenolic boards under steam conditions. The heating ramp was 10ºC/min to reach 900ºC and a 50 ml/min of nitrogen flow was used for inert atmosphere. To obtain steam conditions, the nitrogen flow is bubbled in water at 75ºC.

2.2.2 Steam gasification

A diagram of the process is presented in Fig. 1 and it shows that the equipment was composed of the sample feeder, the reactor (ID: 32 mm, L: 125 mm), the heater, the steam generator and a cooling system. Composition of the gas products was analyzed every 5 min by gas chromatography (Varian CP-4900) and the gas flow rate was measured by an integrating flow meter. LNK carbonates (30 g) and nickel (1.5 g) were preloaded in

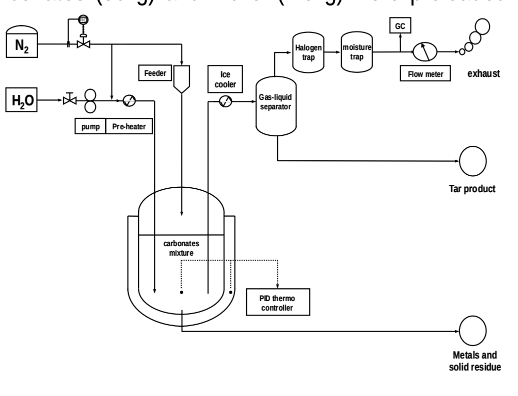

Fig. 1. Experimental diagram

the reactor vessel at the start of an experiment. N_2 gas (40 cm^3/min) and ultra pure water (0.26 ml/min) were introduced into the reactor after a preheating treatment at 500ºC. Phenolic boards or Ta capacitors (0.5 g) were fed to the reactor after the reactor temperature reached the set value (550, 600 and 675ºC). The mixture of N_2 gas and steam was injected into LNK molten carbonates to improve the efficiency of physical contact between the solid sample and the LNK molten carbonates.

3. Results and Discussion

The thermogravimetric profiles of phenol boards are shown in Fig. 2, where a one-step degradation can be seen to take place around 200ºC for phenolic boards in inert or steam conditions, and char corresponding to 30% of initial phenol board remained above 600ºC. However, in the presence of nickel metal, phenolic board reacted completely by steam gasification. Nickel metal (-50+100 mesh) and terminal metal samples had no significant weight loss in the same conditions. Thus, these results suggest that the presence of nickel metal particles can improve steam gasification of phenolic boards above 600 ºC.

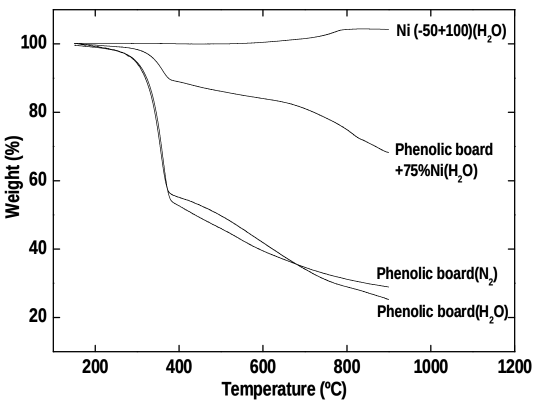

Fig. 2. TG profiles of the samples

Steam gasification of Ta capacitors and phenolic boards is described by: $C + 2H_2O \rightarrow CO_2 + 2H_2$ (1)
H_2 and CO_2 were the main products, but traces of CH_4 and CO were also detected. The results obtained in previous studies showed that steam gasification of phenolic board in the presence of LNK carbonates mixtures was complete. In this work, the results for steam gasification of phenolic boards and Ta capacitors at 550, 600 and 675ºC are presented in Fig. 3 and Fig. 4, respectively. Hydrogen production by steam gasification of phenolic boards and Ta capacitors increased with temperature. In the presence of 1.5 g of nickel in LNK carbonates mixture, higher rate of hydrogen production was observed. The experimental results indicate that nickel powder accelerated hydrogen production in the steam gasification of phenolic boards.
The activation energy for steam gasification of phenolic boards in the presence of LNK carbonates was calculated as 146 kJ/mol. However, when steam gasification of the same sample took place in the presence of both LNK carbonates and nickel metal, the activation energy decreased to 131 kJ/mol. The values obtained for steam gasification of phenolic boards are similar than those obtained in previous studies [1]. Regarding steam gasification of Ta capacitors, the activation energy in the presence of LNK carbonates was 88.5 kJ/mol. These experimental results indicate that metals contained in WEEE have a catalytic role for steam gasification of plastic components and can improve the yield of hydrogen production on steam gasification of WEEE.

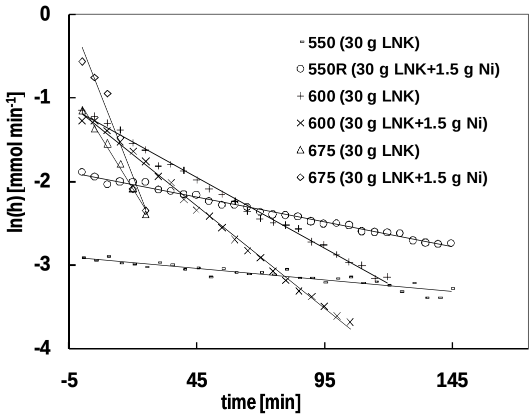

Fig 3. Hydrogen production from steam gasification of phenolic board

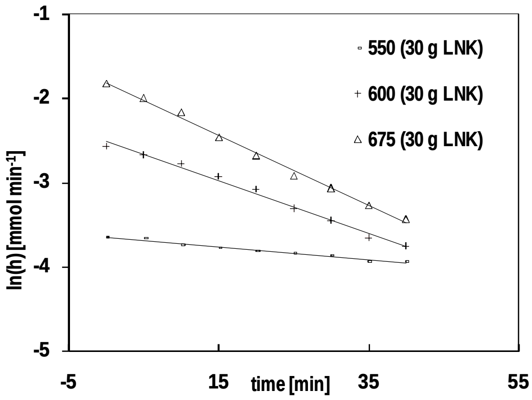

Fig 4. Hydrogen production from steam gasification of Ta capacitor

4. Conclusions

The results showed that nickel metal particles improve hydrogen production rate for steam gasification of WEEE in the presence of LNK carbonates mixture. It can be concluded that metal scrap can act as a cheap and valuable catalyst for WEEE degradation which can be easily recovered after the process.

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References

[1] S. Zhang, K. Yoshikawa, H. Nakagome and T. Kamo. *Applied Energy* 101 (2013) 815-821.

[2] K. Mineta & T. H. Okabe. *Journal of Physics and Chemistry of Solids* 66 (2005) 318-321.