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Metal extraction from the discarded printed circuit board by leaching

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Abstract
In the last years, there is an increasing acknowledgment of our impact on the environment due to our lifestyle, while the need to adopt a more sustainable approach as to our consumption habits emerges as of particular significance. This trend regards industrial sectors affecting the consumption habits and, especially, electronic industry where the short life cycles and the rapidly developing technology have led to increased e-waste volumes, such as discarded electronic equipment. The majority of such elements result in landfills. However, their partial recyclability, due to their material composition (combination of different metals, such as copper, aluminium and steel, attached to, covered with or mixed with several types of plastics and ceramics) along with the unavoidable restrictions in landfills, has led to the development of retrieval techniques for their recycling and re-use, highlighting the significance of e-waste recycling, not only from a waste management aspect but also from a valuable materials' retrieval aspect. In this paper the method of hydrometallurgy is adopted to recycle metals from waste printed circuit board (PCB). An experimental leaching test was built up to recover precious and hazardous metals from the PCB. Experimental results showed that it can be used as metals-formation material to separate metal from PCB during the leaching process. Those results helped to find a way to recover metals and precious metals from PCB. It was revealed that the metal elements in e-waste can be dissolved using this method and further investigation to increase the dissolution rate is required to ensure that the method proposed is applicable in industry. However, dissolved concentration of PCB must be controlled to ensure that it follows the permissible amount set under environmental standard.

Keywords: PCB waste, e-waste, dissolution, recycling, hydrometallurgical, leaching

1. Introduction

Our world is undergoing a rapid growth in the production of electrical and electronic equipment's (EEE). It is undeniable that without the EEE, there is no high technology can be created or designed. However, along with the fast growth of EEE production, tremendous amount of E-waste has also been produced every year. It is estimated that by 2020, the cumulative total of E-waste from seven categories of E-waste (television sets, personal computers, mobile phones, refrigerators, air conditioners, washing machines and rechargeable batteries) that will be discarded in Malaysia is about 1,165 billion units (21.379 million metric tons) (DOE Malaysia, 2006). In Malaysia, E-waste is generally defined as 'used' electrical and electronic assemblies categorized as scheduled wastes in the First Schedule of the Environmental Quality (Scheduled Wastes) Regulations 2005, administered by the Department of Environment (DOE) (Chong T.L., 2008) [2]. E-waste management is taken seriously nowadays not only because of the tremendous amount of production volume but also because it has grown in increasing complexity. It is chemically and physically distinct from other forms of municipal or industrial waste; it contains both valuable and hazardous materials that require special handling and recycling methods to avoid environmental contamination and detrimental effects on human health (Terazono A. *et al.* 2006) [11]. There are many health and environmental problems occurred from e-waste such as the toxic pollution from materials such as cadmium, chromium, lead, mercury, beryllium and many more. For instances, sampling of heavy metals and toxic organics sediments in e-waste recycling sites such as Guiyu (China) and Bangalore (India) showed that heavy contamination from backyard recycling brings severe damage to the local environment and leads to human health risks (Huo X *et al.* 2007) [6] (Ha, N.N. Agusa *et al.* 2009). Air pollution around the e-waste processing area was also found in China (Li H. Yu *et al.* 2007) [8]. Thus, technology on the E-waste handling, managing as well as recovering and recycling is very much essential in order to reduce the environmental impact brought by the E-waste.

There are several methods for the metal recovery from waste materials or by-product. Oishi *et al*. conducted research on recovery of copper from printed circuit board (PCB) by hydrometallurgical techniques (Oishi T. *et al.* 2007) [10]. Frey and Park performed research for recovery of high purity precious metals from PCBs using aqua regia as leachant (Y. J. Park, D. Fray., 2009) [12]. According to DOE Malaysia, the main technology employed to recover ewastes in terms of precious metals in Malaysia is still limited to wet chemical processes and electrolysis. There are still very limited literatures on the e-waste management, handling and recovery process of hazardous materials in Malaysian e-waste industry. In our previous study, the re-utilization of industrial waste had been investigated (Hisyamudin, M.N.N. *et al.* 2009) [4] (Yokoyama S. *et al.* 2010a) [10] (Yokoyama S. *et al.* 2010b) [10]. Thus, the current study is to investigate the recycling process of E-waste through the manual dismantling process and hydrometallurgical process. The E-waste that been used is waste dc motor due to the massive amount of it in the E-waste industry in Malaysia.

2. Characterization of the PCB

Table 1 shows the material composition contained in the PCB. A typical PCB composition is 30% plastics, 30% refractory oxides and 40% metals. The most abundant metal is copper with a concentration between 10% and 30%. Metal compositions in PCBs are different according to the manufacturer and the year of its manufacturing and technology (Montero R. *et al.* 2012) [9].

Table 1: Material composition (Montero R. *et al.* 2012) [9]

Element	Composition
Cu	10-26.8 (%)
Pb	0.99-4.19 (%)
Zn	0.16-2.17 (%)
Au	80-1,000
Au	110-3,301
Pt	.6-30 (g/t)
Pd	10-29 (g/t)

3. Material and Method

Figure-1 shows the waste PCB from a desktop computer used in the study. It is a common PCB that can be easily found at the e-waste disposal area or second hand electronic shops. The computer was manually dismantled and the time required to dismantle all parts was measured. The dismantled parts were then categorized into ferrous, non-ferrous, PCB and plastic parts, and composition of each types of part was measured. Then, in order to investigate the leaching behaviour of PCB parts, the PCB parts were collected from one single desktop computer and the leaching test of the PCB parts was conducted.

In this project we have implemented the non-thermal processing technique. The PCB is firstly cut into the small parts by the help of plier then these parts of PCB are dissolved into a leaching mixture of an acid named as nitric acid ($2NHNO_3$).

Fig 1: Waste PCB sample.

Copper and other metals that are present in the PCB are allowed to dissolve in the acidic solution. The amount of metal dissolve in the solution can be determined by the help of Atomic Absorption Spectroscopy (AAS). About 10 gm. of PCB was allowed to react with the 100 ml of the leach solution of nitric acid (2N HNO_3).

The experiments were carried out at 60±2 ˚C. Sample of leach liquor were collected at 60 minutes

Leach liquor sample were collected, filtered and then performed chemical analysis to determine metal concentration in aqueous solution.

Table 1: Amount of metal determined.

Cu	19000 mg/l
Fe	2.036 mg/l
Zn	5.5 mg/l
Pb	0.467 mg/l
Ni	ND
Co	ND

4. Conclusion

Fundamental study of waste computer circuit board was melted out to research the dismantlement processes and dissolution behaviour of the waste. Dissolution of every part within the waste desktop PCB was discovered. It is observed that after dissolving the PCB parts into a leaching mixture of nitric acid removes the metals from the PCB and the metal which is obtained in the large amount is copper. By this process 19000 mg/l Copper is obtained.

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