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Recovery of Copper from Waste Printed Circuit Board

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ABSTRACT

This generation can't be imagined without copper, the most used metal element in electrical and electronic appliances due to its efficient electric conductivity. That causes high yield of copper in the waste stream too. As energy resources are limited, so alternative methods should be developed to recover those energy resources for keeping the ecosystems balanced. The waste printed circuit board (PCB) is the main source of value metals like gold, silver, copper etc. In the present study recovery of copper from waste PCBs using hydrometallurgical route was studied.

1. Introduction

During the last few decades, consumer electronics revolutionized the way people communicate, entertain themselves, and retrieve information. From healthcare to communication to harnessing resources to obtaining and sharing knowledge, electronic equipment plays a crucial role in the basic function of society. However, as electronic equipment grows in numbers, so does electronic waste (E-waste). Electronic waste is one of the biggest buzz words and concerns about environmental science in recent years. Electronic wastes contain several metals, many of which are valuable, and some of which are hazardous. Thus, managing e-waste is imperative to recover the precious components and to reduce the environmental impact by handling the hazardous substance properly. According to Feldman (1993), there are so many prominent metallic elements in the printed circuit board.

Over the years, the e-waste managers are trying to bring sustainable solutions for it. However, most of the developing countries even don't know about the issue. People even don't bother to keep their waste electronic appliance for years which can cause radiation itself. On the other hand, recovery of value metals can reduce the loss of resources. Extracting metals from e-waste costs 13 times less than mining ore (Environmental Leader 2018).Metals can be recovered from waste PCBs by mechanical (Shigeki et al. 1997, Zhang et al. 1998, Veit et al. 2006, 2007), pyro metallurgical (Hennie et al. 1994, Chiang et al. 2007) and hydrometallurgical (Baba et al. 1987, Macaskieet et al. 2006, Vegliò et al. 2003) methods. The mechanical methods aren't that efficient, pyro metallurgy is responsible for high toxic gases that cause a more detrimental impact on health and the environment. Hydrometallurgy is the most efficient and friendly with the environment.

In the current research hydrometallurgical process was used for effective recovery of the valuable metal copper from waste printed circuit boards since this is more suited to lab-scale experiments and much more environmentally friendly than pyrometallurgy.This study aims for the comparative study of two hydrometallurgical recovery procedures of copper from mobile phone printed circuit board. The methodology of this research work comprised of a systematic laboratory experimental research performed in the following sequence: i) Collection of e-wastes from local market and local industries; ii) Characterization by AAS/XRF of elements present in the selected e-wastes(PCBs), iii) The e-wastes were subjected to an acid leaching process for Copper recovery using various process parameters.

2. Sample Collection, Selection and Characterization

E-waste samples such as mobile phones PCBs have been collected from Nimtoli and Elephant road area. According to observed recycling practices and the need of recovery solutions, Mobile PCBs were selected for extraction of Copper. Two major instruments were used in the analysis of the elements in e-wastes in the present study. One was

Atomic Absorption Spectroscopy (AAS), (Model: Varian AA 240 FS) which determines the concentration of elements in a liquid phase i.e in mg/liter. The analysis has been performed by dissolving the PCBs in the aqua regia solution. The other characterization method was performed using X-ray fluorescence spectroscopy (XRF) (Shimadzu Lab Center XRF-1800). This measures the concentration of elements in a powder sample which results in percentage of the composition.

Initially the samples were weighed and dissolved in strong acidic solution of aqua regia. Conducting the dissolution under the fume hood is a must, as extremely toxic gases evolve during the reactions. Figure 1. shows acid digestion of PCB samples under the fume hood.

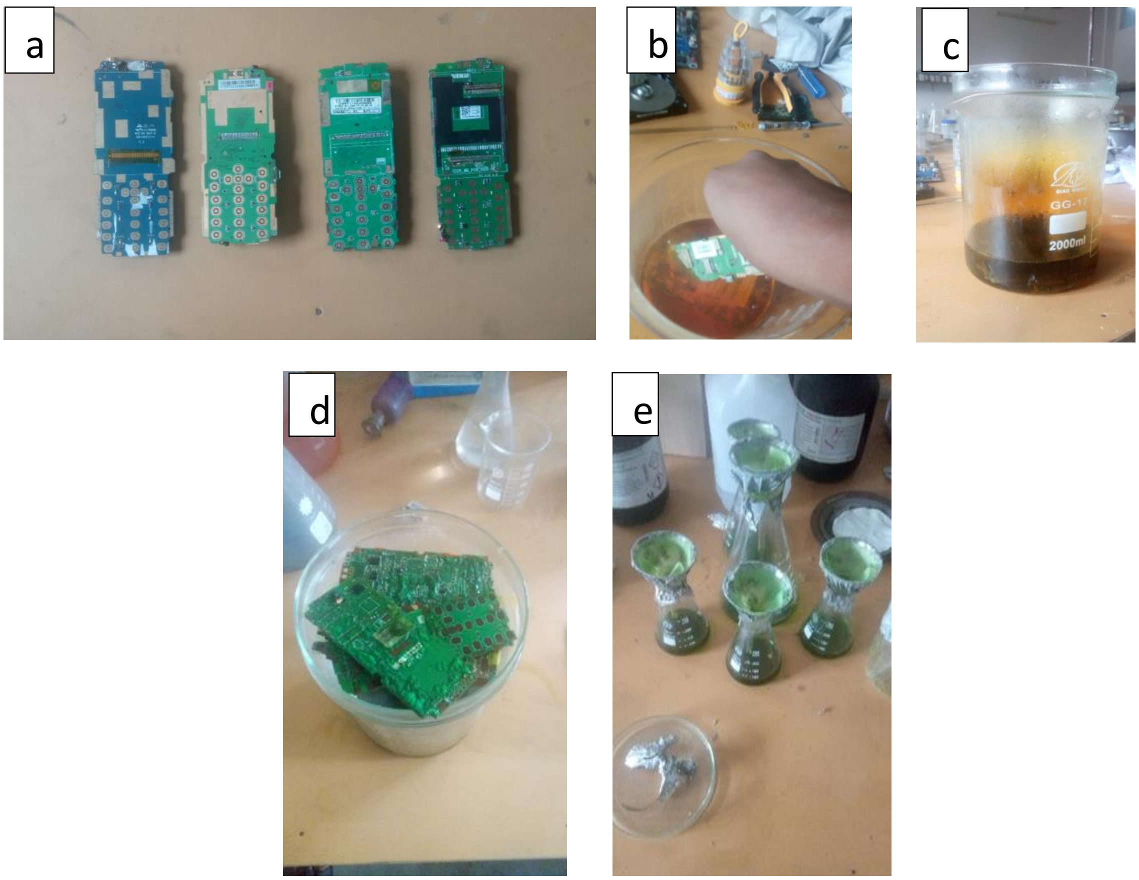

Fig. 1. (a) Dismantled PCBs (b) dissolving PCBs into aqua regia (c) solution after complete dissolution(d) PCB taken out after dissolution (e) filtering the solution

Table 1. shows the concentration of elements in the chosen samples analyzed by AAS techniques.

Table 1. AAS analysis of Chinese mobile PCBs

Sample	Element	Concentration (mg/L)
	Aluminium (Al)	**753 mg/L**
	Arsenic (As)	**Less than 0.05 mg/L**
	Cadmium (Cd)	**0.18 mg/L**
	Chromium (Cr)	**278 mg/L**
	Cobolt (Co)	**9.04 mg/L**

	Copper (Cu)	**12823 mg/L**
	Calcium (Ca)	**79.9 mg/L**
Chinese Mobile PCBs	**Iron (Fe)**	**1528 mg/L**
	Lead (Pb)	**193 mg/L**
	Manganese (Mn)	**33.4 mg/L**
	Mercury (Hg)	**1.67 mg/L**
	Nickel (Ni)	**733 mg/L**
	Molybdenum (Mo)	**3.59 mg/L**
	Silver (Ag)	**33.3 mg/L**
	Tin (Sn)	**1150 mg/L**

3. Methodology of Copper Extraction

Two batches of mobile PCBs (weighed 60gm) were taken, washed and dried. Then they were cut in an identical size and one batch was introduced in a mixture of 300 mL 98% H_2SO_4 and 100 mL 30% H_2O_2. Since the mixing process is exothermic, the acid was slowly added to prevent overheating. The temperature of the mixture was stabilized at 20°C by keeping the beaker in an oil bath. The HCl-H_2O_2 mixture was similarly prepared, maintaining the same volumetric ratio, by slowly adding fuming hydrochloric acid. Another batch of PCBs was slowly added to the solution as well. The acid dissolves the solder joints and the welded components of the PCB, while the hydrogen peroxide dissolves the Copper in solution as it is oxide. The seething beakers were kept under a fume hood for 2 – 3 hours for the reaction to complete. Electrolysis was done after filtering the solution. Graphite was used as both cathode and anode. 3A current was applied at 10V voltage. Electrolysis was carried out for 15-20 minutes.

Table 2. Procedures of Cu Extraction for Two Samples

Sample	Procedures
1	**Mobile PCBs, Electrolysis, $H_2SO_4+H_2O_2$**
2	**Mobile PCBs, Electrolysis, $HCl+H_2O_2$**

The recovery process is shown briefly in figure 2.

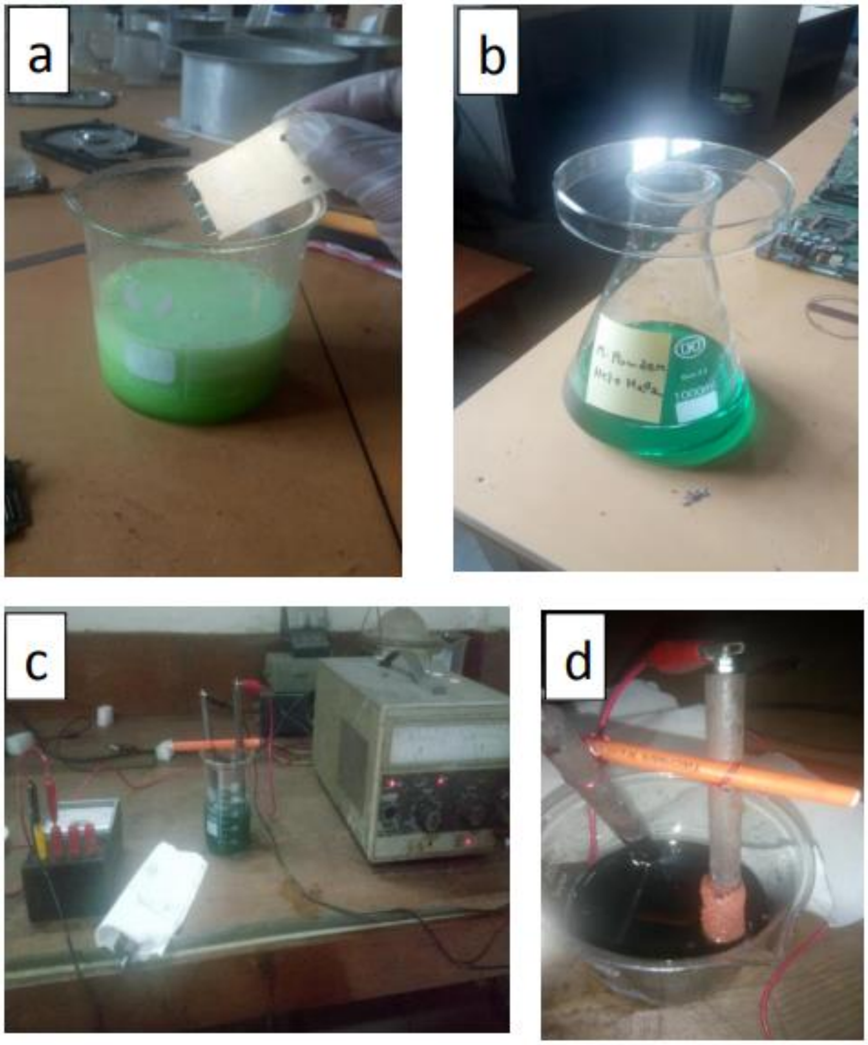

Fig. 2. (a) PCB dissolved in Acid media (b) Filtered solution (c) Electrolysis (d) Deposition of copper

Cu deposited on the cathode as can be seen in figure 2(d). Deposited copper was separated and dried. Then the powder was characterized by X-Ray Fluorescence. Figure 3 summarizes the process flow for Cu extraction.

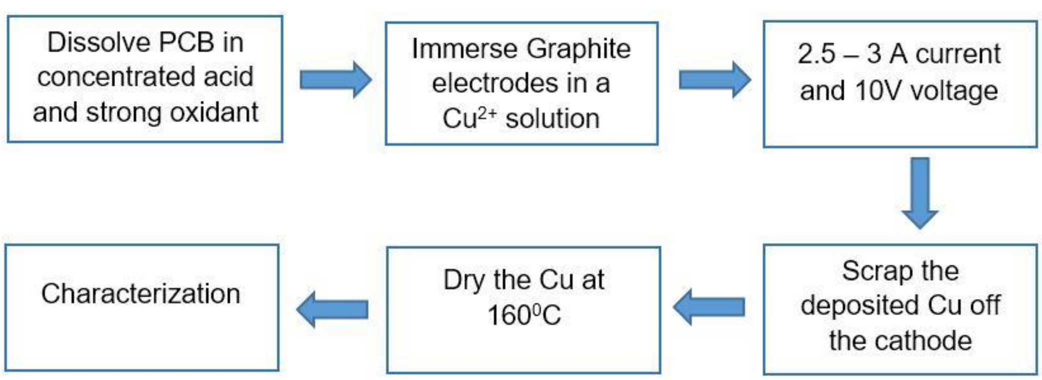

Fig. 3. Flow chart of the Copper recovery process from mobile phone PCBs

The X-Ray Fluorescence (XRF) results showed a very good recovery of copper from PCBs. The recovery percentage shows hydrochloric acid has better efficiency over sulphuric acid to dissolve copper in the solution. 99% pure copper was extracted from hydrochloric acid solution, when sulphuric acid has given 79% of copper. The results are shown in Table 3 & Table 4.

Analyte	Result %
Cu	99.7064
Si	0.1050
Fe	0.0891
Al	0.0565

Table 3.

Analyte	Result %
Cu	79.1275
Sn	6.3168
Si	6.0099
S	4.3687

Table 4.

Table (3). Copper recovered from HCl solution, **(4)** Copper recovered from H_2SO_4 solution

4. Findings

This study has successfully demonstrated the recovery of copper from mobile phone PCBs. Through hydrometallurgical process routes significant amount of copper were recovered. Copper showed corresponding metal recovery of 99.7%. Analysis by XRF has confirmed the recovery of this precious metal. The amount of metal obtained was used to approximate average yield of copper element from 1 tonne of waste PCBs. The result is summarised in Table 5.

Table 5. Comparison of yield value from experiment with reference value

Recovered Metal	1 ton PCBs (present study)	1 ton PCBs (Reference value)	Market Value (USD/gm)	Value Recovered (USD)
Copper	**136.35 kg**	**190.512 kg (Vidyadhar, 2016)**	**0.01**	**$1363**

5. References

Baba H. An efficient recovery of gold and other noble metals from electronic and other scraps, Conserv. Recycl. 1987; 10:247-252.

Chiang HL, Lin KH, Lai MH, Chen TC, Ma SY. Pyrolysis characteristics of integrated circuit boards at various particle sizes and temperatures, J. Hazard. Mater. 2007; 149:151-159.

Environmental Leader, Extracting metals from e-waste costs 13 times less than mining ore, 2018 [online] Available: https://www.environmentalleader.com/2018/04/extracting-metals-e-waste

Feldman, A.V. Method for Processing Scrap of Electronic Instruments. U.S. Patent 5,217,171, 8 June 1993

Hennie V, Bob S. Mining discarded electronics, UNEP Ind. Environ. 1994; 17:7-11.

Macaskie LE, Creamer NJ, Essa AMM, Brown NL. A new approach for the recovery of precious metals from solution and from leachates derived from electronic scrap, Biotechnol. Bioeng. 2006; 96:631-639.

Vegliò F, Quaresima R, Fornari P, Ubaldini S. Recovery of valuable metals from electronic and galvanic industrial wastes by leaching and electrowinning, Waste Manag. 2003; 23:245-252.

Shigeki K, Hitoshi O, Shigehisa E, Hiroyuki I, Pavel D. Recovering copper from electric cable wastes using a particle shape separation technique, Adv. Powder Technol. 1997; 8:103-111.

Veit HM, Bernardes AM, Ferreira JZ, Tenório JAS, deF C. Malfatti, Recovery of copper from printed circuit boards scraps by mechanical processing and electrometallurgy, J Hazard. Mater. 2006; 137:1704- 1709.

Veit HM, de Pereira CC, Bernardes AM. Using mechanical processing in recycling printed wiring boards, JOM 2007; 54:45-47.

Zhang S, Forssberg E. Optimization of electrodynamic separation for metals recovery from electronic scrap, Conserv. Genet. Resour. 1998; 22:143-162.