SELECTIVE LEACHING FOR THE RECOVERY OF COPPER FROM PCB

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Abstract

This paper reported on the leaching behavior of printed circuit board (PCB) using a new leaching agent of ammonia-ammonium persulfate, to recover copper. Cu and Zn leaching were found to be fast and reached equilibrium in 6h whereas for Ni, prolonged leaching time was needed. The best leaching efficiency was found to be around 99% Cu, 60% Zn and 9% Ni with 5M ammonia, 0.5M ammonium persulfate concentration, which suggested a technological viability of Cu recovery from PCB. Finally the leached solution was subjected for electrowining to recover Cu. The Cu metal with purity of 99.97% was obtained by electrowining.

Keywords: *Printed circuit board, Leaching, ammonium persulfate*

1. Introduction

The amount of electro-electronics waste produced nowadays is very high, and it has been increasing for the short life time of these equipments [1]. Printed circuit board is the majority of these equipments which generally contains 10-30% Cu as well as other metals like Ni, Zn, Fe, Ag, Cd, Au, Pb, Sn etc, depending on the source and types of circuit board [2]. The recycling of printed circuit board is still quit limited due to the material content in PCB is heterogeneous. Leaching is one of the processes for the recovery of metals from PCB. To recover Cu from waste PCB using mineral acid as leaching agent has been studied extensively [3-5]. However, these acids can dissolve many types of metals from waste but these types of mineral acids are corrosive and poisonous, difficult to handle. Compared with acid as leaching agent a potential alternative to the environmental benign process is alkaline leaching where ammonia is used as a leaching agent. Recently, very few studies have been carried out using ammonia as leaching agent to selectively leach Cu from solid waste [6, 7].In the present study, a suitable hydrometallurgical process for the recovery of Cu from PCB was studied using ammonia-ammonium persulfate media.

2. Experimental

PCB was crushed using a crusher (Mikasa Machinery Pt. Ltd., Singapore) and sieved with a screener. The metal content of PCB was measured by dissolving it in aqua regia and determined by AAS (Perkin-Elmer, AAnalyst 700). Leaching solution was prepared using aqueous ammonia (33%, w/w). Leaching experiments were carried out by shaking a fixed amount of dried PCB with 100 mL of leaching solution. Then the solid residue was filtrate out and the metal concentrations in the filtrate were determined by AAS. The following equation was used to compute the percentage of leaching

% Leaching = $\frac{A_e}{A_i} \times 100$, where A_e = Amount of metal in leached solution and A_i = Initial amount of respective metal in PCB.

3. Results and discussion

3.1. Metal content in PCB

To determine the metal contents in PCB requires the complete dissolution of the metals in PCB. This was confirmed in aqua regia. A typical analysis of PCB metal contents after aqua regia digestion is shown in Table 1. The metal content were 277.40 mg/g Cu, 4.13 mg/g Ni, 11.25 mg/g Fe and 20.36 mg/g Zn whilst other metals like tin, aluminum, led, silver, cadmium etc were less than 0.10 mg/g. PCB contains significant amounts of Cu, Ni, Zn and Fe. The selective separation and leaching efficiency of these metals are focused on here in after.

Table 1: Element contents in the PCB, mg/g

Cu	Ni	Zn	Fe	Pb	Al	Sn	Mg	Mn	Ag	Co	Cd	As	Sb
277.4	4.1	20.3	11.2	1.8	0.6	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1

3.2. The leaching tests

3.2.1. Effect of leaching agent

The aim of this study is to find out the optimized leaching condition. For this purpose leaching performance of various leaching agents including acidic and alkaline solution were studied. Table 2 shows the leaching percentage of metals obtained from the versatile leaching solution. PCB treated with ammonia showed lower solubility of Ni and Fe but higher solubility of Cu and Zn. On the other hand PCB treated without ammonia showed high solubility of Fe and Ni, especially with organic acid; whereas the solubility of Cu and Ni was not sufficient. Among all leaching solutions ammonia-ammonium persulfate showed highest selectivity and leachability of Cu and Zn. In terms of Cu recovery from leached PCB, Cu with fewer impurities is needed. To get high selectivity, alkaline leaching is better than acidic leaching which leached out fewer impurities.

Table:2 Leaching of Cu, Ni, Zn and Fe with various type of leaching solution

Leaching agent, 1M	**NH_3, M**	**Cu, mg/g**	**Ni, mg/g**	**Zn, mg/g**	**Fe, mg/g**
Aqua regia	0	277.40	4.13	20.36	11.25
Leaching agent, 1M	**NH_3, M**	**Cu, %**	**Ni, %**	**Zn, %**	**Fe, %**
Sulfuric acid	0	29.74	26.15	42.93	24.26
Nitric acid	0	83.87	66.34	71.56	67.82
Hydrochloric acid	0	37.29	16.70	28.14	9.60
DL tartaric acid	5	0.28	0	1.72	4.62
	0	3.18	8.72	3.44	75.46
Oxalic acid	5	65.32	6.78	40.91	0
	0	2.47	14.28	3.43	65.77
Acetic acid	5	65.46	7.99	39.44	0
	0	0.04	0	0.73	27.11
Sodium chloride	5	69.74	19.85	58.98	0
	0	0	0	3.59	1.42
Sodium sulfate	5	75.41	12.35	49.36	0
	0	0.07	0	1.49	0.17
Sodium nitrate	5	80.45	17.43	72.34	0.44
	0	0.06	0	4.62	1.51
Ammonium thiocyanate	5	58.37	60.29	58.49	0
	0	2.44	5.32	1.27	0
Ammonium carbonate	5	92.62	18.64	67.70	0
	0	25.08	0	3.38	0.62
Ammonium nitrate	5	76.40	7.99	57.76	0

	0	28.64	4.60	4.12	0.53
Ammonium chloride	5	72.89	11.38	53.33	0
	0	23.58	4.60	5.89	0.53
Ammonium sulfate	5	64.31	2.20	48.14	0
	0	15.99	0	3.24	0
Ammonium persulfate (0.5M)	5	98.93	9.68	60.70	0
	0	27.14	54.70	10.90	65.60

3.2.2. Effect of contact time

Using a constant of NH_3 and $(NH_4)_2S_2O_8$ concentration, the leaching of Cu, Ni, Zn and Fe was studied up to the reaction time of 48 h at room temperature. The leaching percentage vs. time is plotted and presented in Fig. 1. The results demonstrated that the dissolution of Cu and Zn were fast and equilibrium were reached within 6 h comparer to Ni, which needed prolonged leaching time of 18 h to reach equilibrium. Whereas for the leaching of Fe, no effect of leaching percentage until 48 h leaching period.

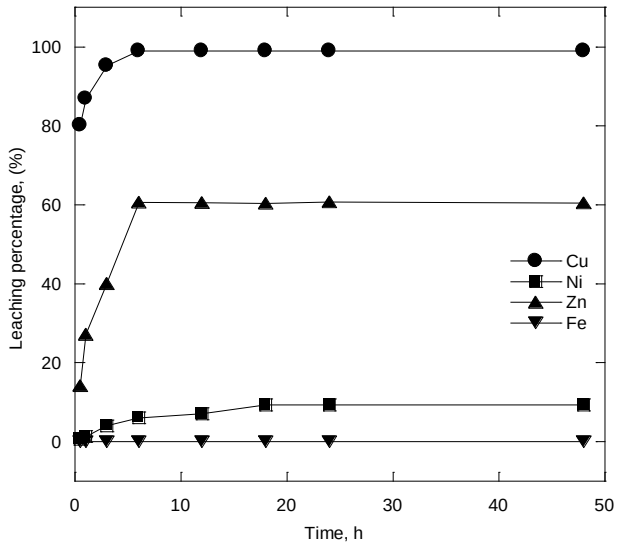

Fig.1. Effect of time on leaching percentage. $[NH_3]$= 5M, $[(NH4)_2S_2O_8]$ = 0.5M, PCB particle size = (-) 0.06mm, volume of leaching solution, V=100mL; weight of PCB, W=1g; temperature, T=25°C.

4. Electrowining

The solution obtained from the time parameter of 3h was treated by using an electrowining lab-scale operation, to verify the technical feasibility of the directly selective separation of these metals. After 14 h electrowinning process, a quantitative selective recovery of Cu was found. The deposits were analysis with AAS, after dissolution. The measures showed that the purity of deposited Cu was 99.97%. The experimental results showed that the good selectivity of the electrodeposition of the metals studied the technical feasibility of the process in the recovery of Cu from waste printed circuit board.

5. Conclusion

The investigation was demonstrated the technical feasibility of processing PCB by leaching in alkaline medium. At optimum condition, about 99% Cu was leached with 60% of Zn,

9% of Ni and not detectable amount of Fe. After electrowining the leached solution, 99.97% pure Cu was obtained at cathode. From this study it could be concluded that the metal leaching from waste PCB in alkaline solution is feasible and its merits could be expressed as: lower leaching agent cost, higher selectivity, higher recovery efficiency, less reaction time, safe operation, energy conversation and environmentally acceptable.

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