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Studies on Metal (Cu and Sn) Extraction from the Discarded Printed Circuit Board by Using Inorganic Acids as Solvents

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Abstract

This Project deals with the experimental results of the leaching of metal like Cu and Sn from Printed Circuit Boards (PCB) from obsolete electronic devices by means of leaching using different combinations of acidic mixtures followed by precipitation. Printed circuit boards were dismantled, cut into small pieces, and fed into a Ball mill. The powder obtained was leached by using the aqueous solutions H_2SO_4, H_2SO_4+HCl, HCl, and HCl+HNO_3. The lowest values for the percentage of metal extraction were obtained with H_2SO_4 while the HCl+HNO_3 mixture exhibited an extraction of Sn and Cu in a maximum percentage. Precipitates were obtained at different pH values by neutralizing the leach liquors using NaOH. The HCl+HNO_3 leach system presented the highest recovery values from the powder feed as well as from the leach liquor. Comparing the results for Sn and Cu extraction after 120 minutes obtained with the various leach systems, 3.0 N HCl+1.0 N HNO_3 exhibited the highest percentage values for simultaneous Sn and Cu extraction (93.3%Sn and 92.7% Cu).

Keywords: Tin; Copper; Recycling; Electronic scrap; Extraction.

Introduction

More than millions of electronic devices have been installed over the past two decades. As new and more efficient electronic devices come onto the market, significant numbers of old electronic devices are being scrapped. Likewise, the number of obsolete electronic devices has also been growing. Due to the lack of specialized companies working with the recycling of obsolete electronic devices, such equipment is commonly scrapped in inappropriate disposal areas, together with domestic garbage, with no specialized recycling processes [1].

Printed circuit boards used in electronic devices are composed of different materials, such as polymers, ceramics, and metals, which render the process of scrappers even more difficult. The presence of metals, such as tin and copper, encourages recycling studies from an economic point of view. The Average Percentage availability of metal in PCB is shown in table 1. However, the presence of heavy metals turns this scrap into dangerous residues. This, in turn, demonstrates the need for solutions to this type of residue so as to dispose of it in a proper manner without harming the environment. The recycling of printed circuit boards from obsolete electronic devices is, at present, a fairly new activity, although opportunities are available for expansion in this area. For instance, gold, silver, tin, and copper, among other metals, can be recovered by means of the hydrometallurgical treatment of printed circuit boards [2]. The E-waste can be treated by thermal and non-thermal methods.

The Non-thermal method of treatments uses leaching as one of the main stages. Leaching is the process of extracting a soluble constituent from a solid by means of a solvent. In extractive metallurgy, it is the process of dissolving minerals from an ore or a concentrate, or dissolving constituents from metallurgical products.

Metals	Percent Availability
Copper	17-19
Aluminium	7-8
Zinc	0.1
Tin	3.25
Nickel	0.05
Iron	2.9
Lead	4.0
Silver	Traces

Table 1: Composition of PCB.

Lead, tin, and Copper were successfully recovered from alloy wire electronic scrap through acid/alkali leaching and a NaOH solution was added to the leach liquor for metals precipitation. Some researchers have also been working on the recycling of electronic scrap [3].

Recycling

The Recycling process can be done by two methods

Thermal processing

In Thermal processing the printed circuit boards can be recycled by applying enormous amount of heat. In this process technique three stages are involved. They are as follows

- Pyrolysis
- Hydration
- Metallurgy

Non-thermal processing

This is another way of recycling the printed circuit boards. This method is simple and easy to handle the feed materials. This process includes

- Dismantling or Disassembly
- Grinding or Crushing

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- Separation
- Chemical Treatment

Materials and Methods

In this Project we have handled the non-thermal processing technique as shown in figure 1. The Printed Circuit Board was crushed in a ball mill and sieved to separate according to size of 0.2 mm. The undersized particle was separated which is feed to the Leaching mixture. The powdered PCB was dissolved in a leaching mixture of acids in different combination. Copper and Tin present in the PCB are allowed to dissolve in the acidic solutions. The amount of metals dissolved in the solution can be determined by using the AAS or by the volumetric analysis method. The concentrations of inorganic acids used in these tests are determined by volumetric analysis. The use of high concentrations of acids was allowed to control the experimental costs. About 10 gms of PCB powder was allowed to react with the 100ml of the leach solution of different concentration [4].

The experiments were carried out at 60 ± 2 °C. Samples of the leach liquor were collected at intervals of 10, 30, 60, and 120 minutes during the experiment. Leach liquor samples were collected, filtered and sent for chemical analysis to determine tin and copper concentration in aqueous solution [5].

Results and Discussions

Table 2 shows the percentage of copper and Tin Extracted from different leaching agents. The objective of the experiment is to determine the leaching ability of the inorganic acids at low concentration. Since the concentration of the acid is low, we can use the commercial grade as quite efficiently. Figure 2 and 3 shows the graphical representation of percentage metal (Cu and Sn) extracted versus reaction time. It was found that the leach liquor of concentrations 3.0 N HNO_3 and 3.0 N HCl+1.0N HNO_3 leach systems were the most efficient to recover Tin and Copper (93.3% and 92.7%) simultaneously.

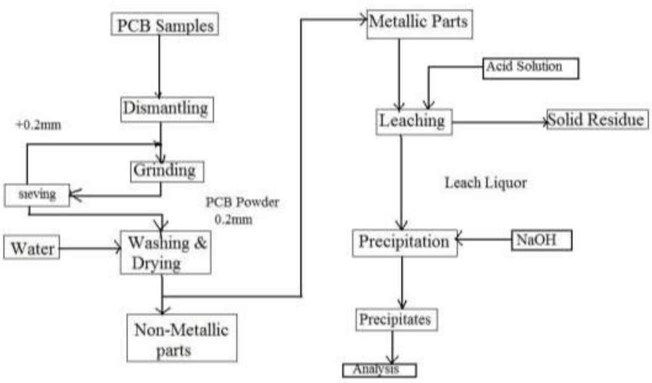

Figure 1: The block diagram of the process used in this work.

S.No	Leaching mixture	% Copper	% Tin
1	2.18 N H_2SO_4 + 3 N HCl	8.5	58.2
2	3 N HCl +1 N HNO3	92.7	93.3
3	3N HCl	23.8	85.1
4	2 N HCl + 2 N HNO_3	75.85	76.7
5	3 N HCl + 2N HNO_3	46.71	89.48
6	3 N HNO_3	86.95	93.3
7	2.5 N HCl + 2.5 N HNO_3	52.42	92.21

Table 2: Percentage of Cu & Sn obtained from leached acidic solution after 120 min.

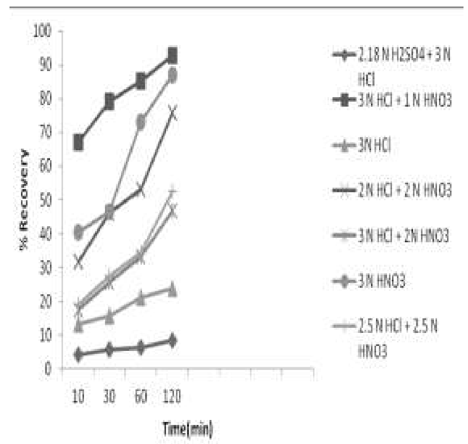

Figure 2: Cu recovery vs. reaction Time.

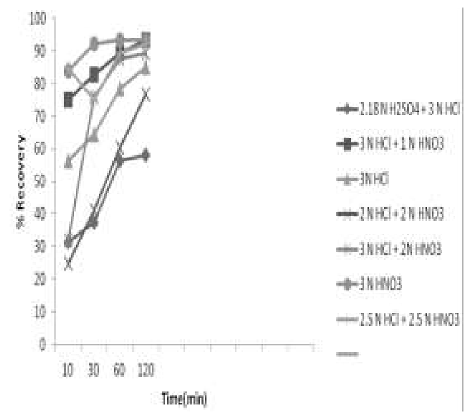

Figure 3: Sn recovery vs reaction Time.

Tin and copper content in the powder generated by the processing of PCBs from obsolete electronic devices is 3.25% Sn and 3.5% Cu. Thus the leach can be considered to be highly significant when compared to the content found in primary mineral sources.

The percentage of tin and copper extracted in the 2.18 N H_2SO_4+3 N HCl (58.2% and 8.5%) leach system showed the lowest results among the leach systems under study, while the 3.0 N HCl+1.0N HNO_3 (93.3% and 92.7%) system presented the highest results for simultaneous tin and copper extraction (using one stage leaching).

The precipitates obtained through the neutralization of the leach liquor from the 2.18 N H_2SO_4+3 N HCl systems exhibited the lowest results for tin and copper recovery from the powder feed and from the leach liquor. The 3.0 N HCl+2.0 N HNO_3 systems presented the highest values for simultaneous tin and copper recovery.

Concerning the morphology of the recovered copper, SEM images revealed dendritic growth of the deposits obtained from all three individual acid leaching solutions (Figures 4a, b, c). Specifically, in the case of the copper obtained from the sulphuric acid solution the recovered metal presented Fine dendritic structure with branches of about 80-100 μm (Figure 4a). On the other hand, copper deposited from nitric or hydrochloric acid

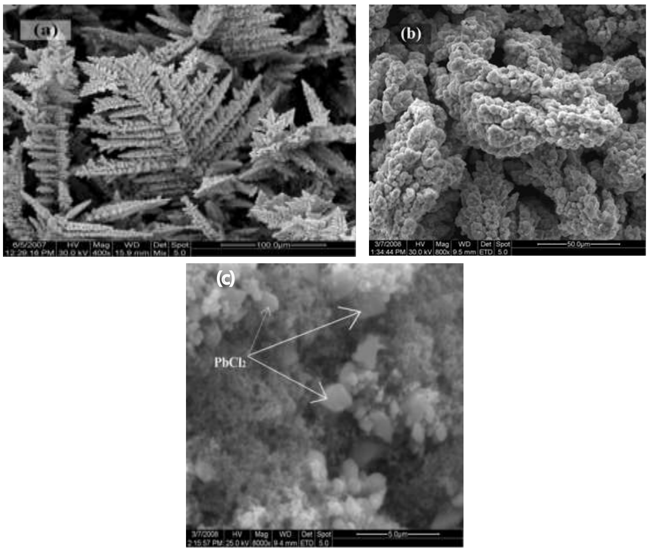

Figure 4: SEM images of recovered copper revealing the dendritic morphology from **(a) H_2SO_4 solution, (b) HNO_3 solution, (c) HCl solution.**

solutions demonstrated a more compact structure although a dendritic structure was conserved [6].

Conclusion

E-waste is an emerging issue, driven by the rapidly increasing quantities of complex end-of-life electronic equipment. The global level of production, consumption and recycling induces large flows of both toxic and valuable substances. Although awareness and readiness for implementing and Improvement is increasing rapidly, there are many obstacles to manage end-of-life products safely and effectively in industrializing countries [7]. Support securing economic efficiency and sustainability of e-waste management systems by optimizing the value added and improve the effectiveness of collection and recycling systems.

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