Extraction of Metals from Disposed Fragmented Portable Telephones by Various Leaching Solution

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The extraction Au, Pd, Ag and Cu from electronic disposed portable telephone fragmented by explosive in water using several leaching solution was studied in this investigation. The metals extraction by three kinds of leaching solution, thiosulfate, iodine, and aqua regia, were compared. The best metals extraction was obtained from a 30 mass% aqua regia solution. The efficiency of metals extraction from the samples fragmented in different extents was compared with the 10 mass% aqua regia solution. The recovery of 91.97% Au, 97.69% Pd and 90.87% Cu could be achieved by a 30 mass% aqua regia solution at the retention of 54 h.

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1. Introduction

At present, most of precious metals, such as Au and Pd, are used in electronic equipments and electrical appliance. As the products are often being updated, the old models are usually discarded and become waste. It was reported in Japan that there was 11893×10^3 units of portable telephone were discarded in 1996. The discarded telephone was increased to 19263×10^3 units in 1997 and 26442×10^3 units in 1998. The trend was increasing year to year up to date. Due to the natural resources are getting exhausted and lower graded, it is important in present day and future to conduct the research projects on recovering the high-priced metals from the disposed electronic and electrical products.

In this investigation, the disposed portable telephone was fragmented in different extents by explosive in water, followed by metals extraction using three different leaching solution. The effect of variables on the metals extraction was studied. Based on the findings of this study, a new fragmentation method (explosion in water) may be suggested to give an optimal overall metals recovery. This may lead to reduce the high cost of material fragmentation.

2. Experimental Material and Procedure

NOF Corporation supplied the disposed portable telephone used in this investigation. After fragmented by explosive in water, the metals extraction from the disposed telephone was conducted as in the following procedure.

Firstly, the efficiency of metals extraction from three leaching solution, *i.e.*, iodine and KI (Potassium Iodide), aqua regia and ammonium thiosulfate, was studied and compared. Secondly, the metals extraction by using ammonium thiosulfate leaching solution from the mechanically fragmented telephone was investigated. Finally, the extraction of Au, Ag, Pd and Cu from the disposed portable telephone fragmented by

explosive in water was investigated.

The metals value of the experimental solution was determined by ICP (Inductively Coupled Plasma Spectrometry). The material balance was calculated.

The disposed portable telephone used in this study was the general model produced in 1996. Net weight excluded battery is 87.85 g per unit telephone. The metals content for each unit are 0.021 g Au, 0.034 g Pd, 12.53 g Cu and 0.018 g Ag. Prior to metals leaching, the disposed portable telephone was fragmented by different amount of explosive and procedure in water into five different types of products, which was identified as S-1, S-2, S-3 and S-4 (details shown in Fig. 4).

For comparing the metals extraction efficiency of different leaching solution, the sponge gold was used. The sponge gold has the purity of 99.92% and particle size smaller than 5 mm.

3. Experimental Results and Discussion

3.1 Metals extraction by various leaching solution

To find the metals extraction efficiency of different leaching solution, the sponge gold was used in the initial study. The solution composition of the leaching solution are: $0.2 \text{ mol} \cdot \text{dm}^{-3}$ iodine + $1.0 \text{ mol} \cdot \text{dm}^{-3}$ KI (Potassium Iodide); 10% aqua regia; 30% aqua regia; $1.0 \text{ mol} \cdot \text{dm}^{-3}$ thiosulfate solution (pH 10.2, $0.03 \text{ mol} \cdot \text{dm}^{-3}$ Cu^{2+} , $3.0 \text{ mol} \cdot \text{dm}^{-3}$ NH_3 , $1.0 \text{ mol} \cdot \text{dm}^{-3}$ $(\text{NH}_4)_2\text{S}_2\text{O}_3$). The metals extractions by the leaching solution in 24 h are shown in Fig. 1. Results indicate that the best Au extraction was obtained by using both $1.0 \text{ mol} \cdot \text{dm}^{-3}$ ammonium thiosulfate and 30% aqua regia. It was reported that Pd was not dissolved in ammonium thiosulfate solution.¹⁾ About 100% of Au was dissolved by these two leaching solution in 12 h. The 10% aqua regia has the worst Au extraction efficiency. Only 30% of Au was extracted by 10% aqua regia in 24 h. The iodine solution has the fastest Au leaching kinetic. 80% of Au was extracted by $0.2 \text{ mol} \cdot \text{dm}^{-3}$ I_2 + $1.0 \text{ mol} \cdot \text{dm}^{-3}$ KI solution in 4 h. However, the AuI_4^- complex is not stable. If the oxidizable iodine is not

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Fig. 1 Change of the Au leaching in 24h by the different Au leaching processes and conditions. ((◆) $(\text{NH}_4)_2\text{S}_2\text{O}_3$: $1.0 \text{ mol}\cdot\text{dm}^{-3}$, CuSO_4 : $0.03 \text{ mol}\cdot\text{dm}^{-3}$, NH_4OH : $3.0 \text{ mol}\cdot\text{dm}^{-3}$, pH10.2; (▼) $\text{I}_2 + \text{IK} = 0.2 + 1.0 \text{ mol}\cdot\text{dm}^{-3}$; (▲) $\text{HCl}/\text{HNO}_3 = 3/1$: 30 mass%; (●) $\text{HCl}/\text{HNO}_3 = 3/1$: 10 mass%; stirring speed: 2.5 s^{-1} , sample: sponge gold).

replenished continuously, the Au leaching reaction would be reversed.²⁾ That was why that Au extraction was slightly below 80% at 24 h leach as shown in Fig. 1.

3.2 Metals extraction from disposed telephone by using mechanical fragmentation method

There were many investigators reported the Au extraction by using ammonium thiosulfate.³⁻⁵⁾ But, there was few investigation being conducted on the Au extraction from the circuit board by using ammonium thiosulfate. In this study, both ammonium thiosulfate and 30 mass% aqua regia leaching solution were used to extract the metal value from the electronic circuit board, which was fragmented by mechanical method. The result is compared with the board fragmented by explosive in water. The base board was cut by scissor into a size of $2 \text{ mm} \times 5 \text{ mm}$. A 5 g of base board is leached with a 100 mL leaching solution. Result of Fig. 2 shows that ammonium thiosulfate solution could dissolve Au, Ag and Cu but the Pd was un-touched. Using the solution combination of $1.0 \text{ mol}\cdot\text{dm}^{-3} (\text{NH}_4)_2\text{S}_2\text{O}_3$, $0.03 \text{ mol}\cdot\text{dm}^{-3} \text{Cu}^{2+}$, $3 \text{ mol}\cdot\text{dm}^{-3} \text{NH}_3$ and pH 10.2, 100% of Ag was extracted in 24 h, while 90% of Cu and 85% of Au were respectively extracted in 36 h. Result also indicates that Au extraction from the base board was much slower than the Au extraction from the sponge gold. The reason could be due to that the metal structure on the base board is more compact. It is more difficult to extract the metals unless the metals surface is fully exposed.

3.3 Metals extraction from disposed telephone by using explosive fragmentation in water

In this series of test, all metals extractions were conducted by using 30% aqua regia solution.

3.3.1 Gold extraction results

The disposed portable telephone was being fragmented in different extents, S-1, S-2, S-3 and S-4, by explosive in water as seen in Fig. 4. All metals attached electric circuit was detached from the mother board. The Au extraction with 30 mass% aqua regia solution from those fragmented telephone is shown in Fig. 3. It can be seen that S-2 has the best Au extraction kinetics due to its highest degree of destruction. The electric circuit was bent and interior parts were separated. The leaching solution could easily contact with the metallic

Fig. 2 A plot of the leaching percentage of Au, Cu and Pd varying with time for the base board of portable telephone ($(\text{NH}_4)_2\text{S}_2\text{O}_3$: $1.0 \text{ mol}\cdot\text{dm}^{-3}$, CuSO_4 : $0.03 \text{ mol}\cdot\text{dm}^{-3}$, NH_4OH : $3.0 \text{ mol}\cdot\text{dm}^{-3}$, pH10.2, stirring speed: 2.5 s^{-1} , sample: base board, ammonium thiosulfate solution: $0.1 \text{ mol}\cdot\text{dm}^{-3}$, base board 5 g) (Au(◆), Cu(■), Pd(●), Ag(▲)).

Fig. 3 Extraction percentage of Au varying with time for the portable telephone. (30 mass% $\text{HCl}/\text{HNO}_3 = 3:1$, stirring speed: 2.5 s^{-1} , sample: portable telephone, aqua regia solution: 0.5 dm^3).

surfaces. About 80% of Au was extracted in 24 to 48 h and 95% of Au was extracted in 54 h. About 72% and 51% of Au were extracted respectively from S-4 and S-3 in 48 h. Their Au extractions reached 90% or higher at 54 h leach. The S-1 was not properly fragmented and the Au extraction from this part was less than 50% in 48 h and only 70% in 54 h.

3.3.2 Palladium extraction results

Figure 5 shows the Pd extraction under the same conditions as the Au extraction. Again, the Pd extraction from S-2 has the best result. Its extraction kinetics was faster than that of Au. About 95% of Pd was extracted in 36 h. The extraction from S-1, S-3 and S-4 at 36 h was 80%, 75% and 70% respectively. The extraction at 54 h, it was entirely 100% from S-2 and about 95% from other three samples.

3.3.3 Copper extraction results

The Cu extraction under the same conditions is shown in Fig. 6. Results indicate that the kinetics of the Cu extraction was faster than that of both Au and Pd at the initial stage. More than 50% of Cu was extracted from all four samples at the initial 6 h retention time. The Cu extraction rate was not varied very much. At 36 h retention time, 90%, 88%, 80% and 75% of Cu was respectively extraction from S-2, S-1, S-4 and S-3 samples. The Cu extraction reached about 90% for all samples at 54 h. It can be seen that the Cu surface was not fully exposed to the lixiviate and the Cu extraction did not reach a maximum.

Fig. 4 Photo of sample S-1, S-2, S-3, S-4 (portable telephone by explosive fragmentation in water).

Fig. 5 Extraction percentage of Pd varying with time for the portable telephone. (30 mass% $\text{HCl}/\text{HNO}_3 = 3:1$, stirring speed: 2.5 s^{-1} , sample: portable telephone, aqua regia solution: 0.5 dm^3).

Fig. 6 Extraction percentage of Cu varying with time for the portable telephone. (30 mass% $\text{HCl}/\text{HNO}_3 = 3:1$, stirring speed: 2.5 s^{-1} , sample: portable telephone, aqua regia solution: 0.5 dm^3).

Fig. 7 Extraction percentage of Cu varying with time for the portable telephone. (30 mass% $\text{HCl}/\text{HNO}_3 = 3:1$, stirring speed: 2.5 s^{-1} , sample: portable telephone, aqua regia solution: 0.5 dm^3).

3.3.4 Metals extraction from S-5 sample

The effect of fragmentation method on the metal extraction can also be seen from the S-5 sample, which was poorly fragmented. Figure 7 shows the metals extraction from S-5 sample under the same conditions. It is obviously that the metals extraction from S-5 sample was much lower than that of S-1, S-2, S-3 and S-4 samples. There were no metals being extracted after 24 h retention time. To examine the reason of poor metal extraction from the S-5 sample, the leached circuit board was removed and cut. It was seen that the interior Cu plat was still clean and the metals inside 5 mm from the edge were un-touched. It is obviously that the metals surface was not properly exposed and did not have chances to contact with leaching solution. Figure 8 shows that the interior portion of the electric board after 48 h leaching time. The metals surface was still clean.

Fig. 8 Photo of cross sections of leached base board of portable telephone (S-5).

4. Conclusion

- (1) The 30mass% aqua regia solution could effectively extract the valuable metals from the disposed portable telephone being fragmented by explosive in water.
- (2) Cutting the circuit base board of the disposed portable

telephone into a size of $2\text{ mm} \times 5\text{ mm}$ and leaching with a solution contains $1.0\text{ mol}\cdot\text{dm}^{-3}$ $(\text{NH}_4)_2\text{S}_2\text{O}_3$, $0.03\text{ mol}\cdot\text{dm}^{-3}$ Cu^{2+} , $3\text{ mol}\cdot\text{dm}^{-3}$ NH_3 and pH 10.2, the extractions of Au, Ag and Cu were 80%, 100% and 90% respectively. Pd was not leach able from this leaching solution.

(3) Extractions of Au, Cu and Pd from the disposed portable telephone being fragmented by explosive in water were all over 90%.

(4) The metals extraction depend upon the extent of fragmentation on the disposed portable telephone. It requires the good exposure of metal reface to give a good metals extraction.

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