Gold Leaching from Printed circuit Board Scrap with Thiosulfate

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Abstract. Metals, such as Au, Ag, Cu, Sn and Ni can be found in the printed circuit boards (PCB). According to this, the aims of this work investigates gold leaching from the PCBs of mobile phones using thiosulphate gold leaching.The effects of various factors on the leaching such as leaching time,, and so on in thiosulfate leaching system were discussed. The optimum leaching conditions were as follows; leaching time was 4h, leaching temperature was 25 ℃, thiosulfate concentration was 0.5moll^{-1}, ammonia concentration was 1.2moll^{-1}, copper ion concentration was 0.04moll^{-1}, slurry pH was 10, stirring speed was 300rpm, Na_2SO_3 concentration was 0.1moll^{-1} respectively. The gold leaching ratio of 95.3% was achieved.

1. Introduction

With the acceleration of information equipment updating, a large number of discarded printed circuit boards have been produced [1]. the analysis results show that the printed circuit board generally contains rare metals gold, silver, palladium, etc., the gold content of discarded printed circuit boards is much higher than general gold grade of gold which can be extracted by different hydrometallurgical routes [2]. Do not recycle the precious metals contained in the printed circuit board which not only cause serious pollution to the environment, but also cause a lot of waste of precious resources. Jing-Ying L and Zhong F dealed with the leaching of gold and silver from the printed circuit boards of waste mobile phones using a thiourea leaching process [3-4].Thiosulphate gold leaching has received considerable attention as an alternative technology to the cyanidation of gold ores due to environmental reasons [5]. In the presence of oxygen, thiosulfates and gold can form stable $Au(S_2O_3)_2^{3-}$, the reaction equation of thiosulfate in alkaline solution is as follows [6]:

$$Au + 2S_2O_3^{2-} = Au(S_2O_3)_2^{3-} + e^- \quad (1)$$

$$2Au + 4S_2O_3^{2-} + H_2O + 0.5O_2 = 2Au(S_2O_3)_2^{3-} + 2OH^- \quad (2)$$

$Cu(NH_3)^{2+}$ was formated by Cu^{2+} and NH_3 in the process of gold leaching which play a catalytic role as oxidant. The reaction is as follows [7]:

$$Au + 5S_2O_3^{2-} + Cu(NH_3)_4^{2+} = Au(S_2O_3)_2^{3-} + 4NH_3 + Cu(S_2O_3)_3^{5-} \quad (3)$$

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The solution must also be kept pH 10.0 by adjusting ammonia concentration, the aim of this paper is to investigate gold leaching from the PCBs of mobile phones using thiosulphate gold leaching, the effects of sulfite concentration, copper ion concentration, ammonia concentration and reaction time on the gold leaching rate were studied.

2. Experimental

2.1. Materis

The water used was deionized and distilled, all chemicals used were of analytical reagent grade. All experiments were performed at the given temperature.

2.2. Analytical techniques

The contents of the metallic ions (Au, Cu) in the sample solutions obtained from the leaching experiments were analyzed by atomic absorption spectroscopy(AA320),The contents of the thiosulphate ions in the sample solutions obtained from the leaching experiments were analyzed by pH measurements were made using pH/Eh meter (PHS-25 ,Shanghai Precision & Scientific Instrument Co, Ltd).

2.3. Methods

The PCBs of mobile phones was provided by a environmental protection company in Kumming. It was crushed into 80-100 mesh size of particles, heating up to 500 ℃, burning 2 h to remove organic matter; After cooling, the base metal was treated by H_2O_2 and H_2SO_4. The content of gold in raw materials was 0.91‰ by atomic absorption analyzer.Leaching is in the three-necked flask containing a certain volume of leaching liquid under the given condtion as follows: solid-liquid ratio is 1:4, the proper pH is 10.00, stirring speed is 300rpm, Na_2SO_3 concentration is 0.1mol/l .

3. Results and discussion

3.1. Effect of 1 thiosulphate concentration

Under the experimental conditions (leaching time was 4h, leaching temperature was 25 ℃, ammonia concentration was 1.2moll^{-1}, copper ion concentration was 0.025moll^{-1}, slurry pH was 10, stirring speed was 300rpm, Na_2SO_3 concentration was 0.1moll^{-1}),the effect of thiosulphate ion concentration on gold leaching rate is shown in Fig. 1.It was noted that the leaching rate of gold increased with the increase in thiosulfate concentration. High thiosulfate concentration is beneficial to leaching according to the equation (1)-(2), the leaching rate of gold slightly decreased when thiosulfate concentration is beyond 0.5moll^{-1},then the appropriate thiosulfate concentration is 0.5 moll^{-1}.

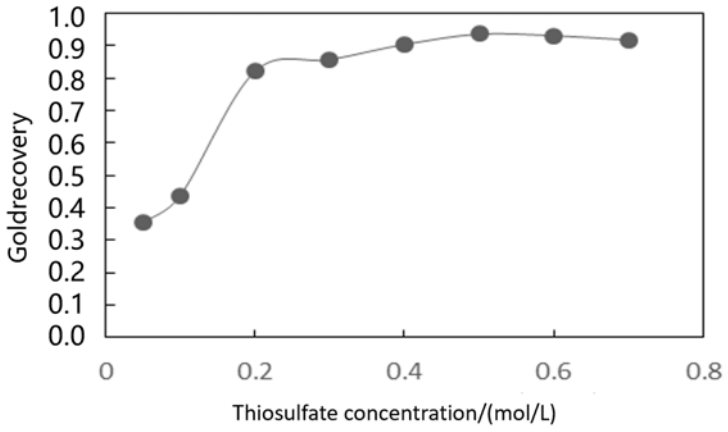


Fig. 1 Effect of thiosulfate concentration on goldr recovery

3.2. Effect of copper ion concentration

Under the experimental conditions (leaching time was 4h, leaching temperature was 25 ℃, thiosulfate concentration was 0.5moll^{-1}, ammonia concentration was 1.2moll^{-1}, slurry pH was 10, stirring speed was 300rpm, Na_2SO_3 concentration was 0.1moll^{-1}), the effect of copper ion concentration on gold leaching rate is shown in Fig.2.It was noted that copper play a important role in thiosulfate leaching. The work had proved that the leaching rate of gold was close to zero.

In the absence of copper ion ,the leaching rate of gold increased with the increase in copper concentration, the reason is the addition of ammonia can play a catalytic role in the reaction.the gold leaching rate increase is not obvious when the copper ion concentration is beyond 0.04 mol/l, the gold leaching rate decreases, the reason may be that copper ions can oxide thiosulfates. As a result, the copper ions play an advantageous and unfavorable role in the process of leaching, which can catalyze the leaching of gold and the consumption of sodium thiosulfate. In order to prevent the large consumption of sodium thiosulfate, it is necessary to control certain copper ion concentration [8] .the appropriate copper ion concentration is 0.025 moll^{-1}.

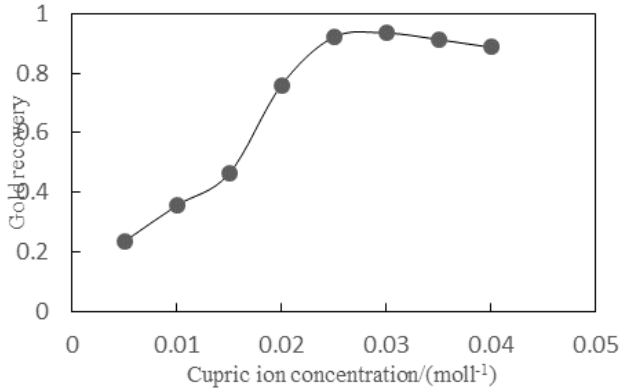


Fig. 2 Effect of cupric ion concentration on gold recovery

3.3. Effect of ammonia concentration

Under the experimental conditions (leaching time was 4h, leaching temperature was 25℃, thiosulfate concentration was 0.5moll^{-1}, copper ion concentration was 0.025moll^{-1}, slurry pH was 10, stirring speed was 300rpm, Na_2SO_3 concentration was 0.1moll^{-1}), the effect of ammonia ion concentration on gold leaching rate is shown in Fig.3,It can be seen from Fig.3 that the addition of ammonia has a great influence on the leaching rate of gold. The leaching rate of gold is only 29.4% when ammonia concentration is 0.2moll^{-1} .With the increase of ammonia concentration, copper ions and ammonia can form $Cu(NH_3)_4^{2+}$ which greatly increased gold leaching rate according to the equation,but high concentrations of ammonia concentration had disadvantage influence on gold leaching and increased the hydroxide ion which prevented the dissolution of gold.high concentrations of ammonia concentration results in decrease concentration of $Cu(NH_3)_4^{2+}$ which decreased catalytic capability,As shown in Fig.4,As a result of sulfite decomposition on the surface of the gold particles, the accumulated sulfur film passivated gold with thiosulfate[10]. At the same time, copper ions in solution exist in Cu $(S_2O_3)_3^{5-}$ form, so that copper ions do not have catalytic effect. When ammonia concentration is greater than 1.2 moll^{-1}, the leaching rate of gold decreased, the reason may be that Cu $(NH_3)_4^{2+}$ less with NH_3/NH_4^+ decreases, its catalytic ability also decreased. At the same time, excessive ammonia will increase the hydroxide ion and prevent the dissolution of gold [11]. Therefore, the appropriate ammonia concentration is 1.2 moll^{-1} .

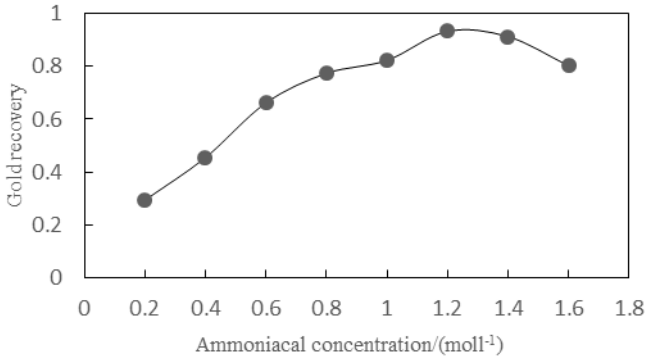


Fig. 3 Effect of ammoni concentration on goldr recovery

3.4. Effect of leaching time

Under the experimental conditions (leaching time was 4h, leaching temperature was 25 ℃, thiosulfate concentration was 0.5moll^{-1}, ammonia concentration was 1.2moll^{-1}, copper ion concentration was 0.025moll^{-1}, slurry pH was 10, stirring speed was 300rpm, Na_2SO_3 concentration was 0.1moll^{-1}),the effect of leaching time on gold leaching rate is shown in Fig.4, As seen in Fig.4,with the increase of time, the leaching rate of gold increased quickly and reached maximum almost 4 hours late.Extending leaching time won't improve gold leaching rate which increases the thiosulfate consumption rate and affects the leaching cost. Therefore, 4h was selected as leaching time in this process.

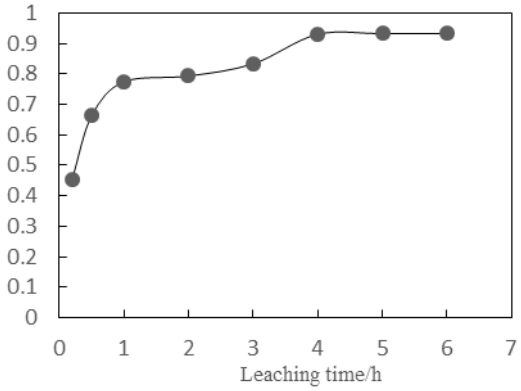


Fig. 4 Effect of leaching time on gold recovery

3.5. Comparison with gold ore leaching process

As shown in Tab.1 ,using copper–ammonia–thiosulfate solution, as an alternative to the conventional and toxic cyanidea has achieved higher leaching rates from PCBs and gold ore[12],under the same conditions(eaching time was 4h, leaching temperature was 25 ℃, ammonia concentration was 1.2moll^{-1}, slurry pH was 10, stirring speed was 300rpm, Na_2SO_3 concentration was 0.1moll^{-1}), PCBs achieved less thiosulfate consumption than gold ore ,The reason could be that PCBs leaching environment is relatively simple compared with gold ore. Thiosulfate can be adsorbed on the the surface of gold ore ; higher copper ion concentration in gold ore leaching solution results in more thiosulfate consumption. Above reasons can explain the reason that PCBs achieved less thiosulfate consumption than gold ore.

Tab. 1 Comparison between PCBs and Gold ore

Leaching object	Thiosulfate concentration ($moll^{-1}$) concentration	copper concentration ($moll^{-1}$) concentration	Ammonia concentration ($moll^{-1}$)	Leaching time (h)	Gold recovery (%)
PCBs	0.5	0.025	1.2	4	95.3%
Gold ore [12]	0.7	0.05	1.2	4	89%

4. Conclusion

1) The paper proved that copper–ammonia–thiosulfate solution, as an alternative to the conventional and toxic cyanide can deal with the leaching of gold from the printed circuit boards (PCBs) of waste mobile phones.

Thiosulfate method can effectively extract gold from discarded printed circuit board. The main factors affecting thiosulfate leaching are: reaction time, thiosulfate concentration, copper ion concentration and ammonia concentration. Copper ions and ammonia play an important catalytic role in thiosulfate leaching process. But they also plays a negative role in the process of gold leaching when their concentration reaches a certain concentration ,then,chosing a certain ammonia concentration and copper ion concentration are necessary.

The appropriate leaching conditions are as follows: solid-liquid ratio is 1:4, temperature is 25 ℃, reaction time is 4 h, thiosulfate concentration 0. 5 m ol/L,Copper ion concentration 0.05 m ol /L, ammonia concentration 1.2 mo L /L,the proper pH is 10.00, stirring speed was 300rpm, Na2SO3 concentration was 0.1mol/l respectively

Acknowledgments

The authors gratefully acknowledged the financial support by the Science Foundation of Yunnan education department (2018js377), * Corresponding author: LIU qiong, email: 285892335@qq.com.

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