Study on Gold Extraction Process of Printed Circuit Board Based on Thiourea Method

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Abstract. The printed circuit board is rich in recyclable metals Cu, Au, Ag, Pt, Pb, etc. The precious metals such as gold are extracted from it, which is in line with the concept of resource recycling. In this paper, the theorem method was used to extract gold from waste circuit boards. The effects of reaction time, reaction temperature, theorem concentration, and Fe³⁺ mass concentration on gold leaching rate were investigated. The results showed that the pH was controlled at about 1, the theorem concentration was 0.12 mol / L, FeCl₃ was 0.024 mol / L, the stirring speed was 300 r / min, and the leaching time was 2 h. Under the above conditions, the gold leaching rate reached 90.37 %. The theorem gold extraction method has certain potential application values due to its rapid gold dissolution, low toxicity during leaching, low price, high efficiency, and environmental protection.

1. Introduction
Waste circuit boards contain a large amount of copper, aluminum, iron and other base metals, trace amounts of precious metals such as gold, silver, platinum, and heavy metals such as lead and cadmium, but the highest mass content of the metals contained in waste circuit boards is copper, which has the highest recycling value. It is gold [1-2]. The traditional gold immersion method is the cyanide method, but the acute toxicity of the cyanide method seriously endangers the environment. The theorem gold extraction method has become a green gold extraction method that replaces cyanide gold extraction due to its fast gold dissolution speed, low toxicity during leaching, and environmental protection. Its leaching principle is as follows [3]:

\[
\text{Au} + 2\text{TU} + \text{Fe}^{3+} = \text{Au(TU)}_2^{2+} + \text{Fe}^{2+}
\]

As can be seen from the above equation, the leaching environment is acidic, because iron will be precipitated in the alkaline range, but for printed circuit boards, it contains copper, aluminium, iron and other base metals, and trace amounts of gold, silver, and palladium. Precious metals, such as platinum, platinum, and heavy metals, such as lead and cadmium [4]. Therefore, the leaching process in this paper first uses nitric acid to digest the printed circuit board powder, and after filtering, the leaching slag is subjected to gold leaching, and the filtrate is separately processed to obtain copper and other metals. The reason why nitric acid is needed before leaching is that copper, aluminium, silver and other metals will complex with theorem to increase the consumption of theorem; the metal oxides
generated after roasting will consume acid and reduce the acidity; metals in waste circuit boards. The elementary substance will displace the leached gold ions, reducing the gold leaching rate.

In this study, the theorem immersion gold method was used to conduct experimental research on the recovered circuit boards, in order to obtain precious metal gold from industrial waste, and provide a certain theoretical and practical basis for the recycling of resources.

2. Experimental

2.1. Raw materials and reagents
Waste computer circuit boards were purchased at the waste purchase station, HNO$_3$ (AR), theorem (AR), FeCl$_3$·6H$_2$O (AR), H$_2$SO$_4$ (AR), distilled water.

2.2. Instrument
Electrochemical Analyzer (630E, shanghai chenhua), Atomic Absorption Spectrometer (TAS-990, pu xi tong yong), Muffle Furnace (Luoyang chun qing)

2.3. Waste computer circuit board pretreatment
The waste circuit board is shredded, and then calcined in a muffle furnace at high temperature for 5 hours. After cooling, the ash and slag are put into a closed prototype to be crushed into powder. The residue after calcination is bare metal or its oxide.

2.4. Leaching method
Weigh out 5g of the processed waste computer circuit board powder, first digest with nitric acid (1 +3), leaching copper, zinc and other metals to obtain the filter residue, collect the filter residue in a conical flask, add a certain amount of FeCl$_3$, theorem, Stir with a glass rod, add distilled water, and adjust the pH of the solution to about 1 with sulfuric acid. Stir with a stirrer at a stirring speed of 300 r / min. After the time required for leaching is reached, the solution is obtained after filtering the reaction, and the volume is washed and fixed. The volumetric solution was measured for concentration with an atomic absorption spectrophotometer, and the leaching rate was calculated.

3. Results and discussion

3.1. Effect of pH
The use of FeCl$_3$ as the oxidant determines that the solution can only be carried out in an acidic environment. Usually, when the pH is greater than 2.5, FeCl$_3$ starts to precipitate. Therefore, the pH examined in this paper is in the acidic range to ensure the stability of the system. Under the conditions of 0.08mol/LFeCl$_3$ and 0.05mol/LTU, the stirring speed was 300r/min, the leaching temperature was 20°C, and the leaching time was 2h. The influence of acidity on leaching was examined. The results are shown in Figure 1. Figure 1 shows that when the external conditions are constant, a high leaching rate can be obtained with a pH range of 1.
3.2. Influence of temperature

First, the electrochemical analysis was used to determine the leaching temperature. The pH of the leaching solution was 1, and the material conditions were: 0.08mol/LFeCl₃, 0.05mol/LTU. Tafie curves were used to study the polarization curves of gold at different temperatures. The electrochemical test uses a three-electrode system, using a saturated calomel electrode as the reference electrode, platinum wire as the auxiliary electrode, and gold electrode as the working electrode. The results are shown in Figure 1. The results show that the higher the temperature, the greater the corrosion potential of gold, indicating that the difficulty of gold corrosion increases. The reason may be that the thermal stability of theorem is poor. The temperature of the system is too high. The theorem will decompose. The product will passivate the surface of the gold electrode. At the same time, the oxidation and complexation of gold also need to be performed at a certain temperature. Otherwise, it will affect the full leaching of gold. The literature also shows [5-6] that theorem has a poor thermal stability. In the theorem leaching gold system, increasing the leaching rate and leaching rate of gold by increasing the reaction temperature is limited. Therefore, the leaching temperature selected in this paper is 20°C. From the process conditions, the results are shown in Figure 2. Figure 2 shows that the leaching rate is the highest at 20°C, which confirms the electrochemical results.
3.3. Effect of theorem concentration

Under the conditions of leaching temperature of 20°C, pH of about 1, 0.08mol/L FeCl$_3$, the effect of theorem with different concentrations on the leaching of gold was examined. From the principle of reflection, theorem acts as a complexing agent and synthesizes Au with gold complex. (TU)$_2^{2+}$, its concentration must have an effect on the leaching rate of gold. The results are shown in Figure 3. Figure 3 illustrates that as the theorem concentration increases, the leaching rate of gold increases. When the theorem concentration is 0.12mol/L, the gold leaching rate is 87.72%. Subsequently, the theorem concentration continues to increase and leaching. On the contrary, the rate began to decrease. This may be because the mass concentration of theorem was too high, and a large amount of dithiomethane was formed in the reaction, which then covered the surface of the leaching object, which led to the leaching passivation and the leaching rate further decreased [7].
3.4. Effect of FeCl$_3$ concentration

FeCl$_3$ is an oxidant during the theorem leaching process. The chemical reactions that occur during the leaching process are as follows:

$$\text{2Fe}^{3+} + 2\text{TU} = (\text{SCN}_2\text{H}_3)_2 + 2\text{Fe}^{2+} + 2\text{H}^+$$

$$(\text{SCN}_2\text{H}_3)_2 = \text{TU} + \text{NH}_2\text{CN} + \text{S}$$

The amount of FeCl$_3$ is too low, the gold is not oxidized and the leaching rate is low. When the amount of FeCl$_3$ exceeds a certain limit, the theorem will be oxidized to dithiomethane and other substances to reduce the mass concentration of theorem, and the leaching rate will follow. Decline. Therefore, the amount is selected appropriately, so that the oxidation potential of the solution can be maintained in a suitable range to ensure a high leaching rate. In order to determine the appropriate FeCl$_3$ concentration, the Tafel curve was used to investigate the effect of different concentrations of FeCl$_3$ on the corrosion of gold. The results are shown in Figure 3. Figure 3 illustrates that when FeCl$_3$ is 0.024mol/L, the corrosion potential of gold is minimal and the current this indicates that when FeCl$_3$ is 0.024mol/L, the leaching of gold is the most beneficial. Therefore, FeCl$_3$ is selected as 0.024mol/L in this paper. From the process conditions, the results are shown in Figure 4, which shows that when FeCl$_3$ is 0.024 mol/L. The leaching rate was highest.

![Figure 4. TAFE curves of of Fe$^{3+}$](image-url)
3.5. Effect of leaching time

When the pH is controlled to about 1, the concentration of theorem is 0.12mol/L, FeCl₃ is 0.024mol/L, and the stirring speed is 300r/min, the effect of leaching time on the leaching rate of gold is examined. The results are shown in Figure 6, which shows that with the progress of time, the leaching rate of gold first increased, remained stable after 2 h, and decreased slightly. This shows that under this condition, 2h is sufficient reaction time. After more than 2h, after a longer mutual reaction of the agents, more reaction products will inevitably appear, which will cover the surface of the reactants and cause passivation, which will reduce the Leaching rate. In order to obtain a large leaching rate and avoid wasting power, the leaching time was set to 2h. It can also be seen from Figure 6 that under the above conditions, the gold leaching rate reached 90.37%, and a relatively good leaching effect was obtained.
4. Summary

(1) The electrochemical method can be used to optimize the leaching conditions. The Tafel curve can be used to investigate the effect of different concentrations of FeCl\textsubscript{3} and theorem on the corrosion of gold. The results are consistent with the actual process.

(2) The main factors affecting theorem are the pH of the solution, the concentration of theorem, the concentration of Fe\textsuperscript{3+}, and temperature. With the increase of theorem concentration within a certain range, the leaching rate of gold increases, but when the theorem concentration is too high, the leaching rate of gold decreases instead; the leaching rate of gold increases with the increase of Fe\textsuperscript{3+} concentration, but when the concentration is too high, the leaching rate of gold also decreases.

(3) In order to obtain a better leaching rate, the process conditions are: control the pH to about 1, the concentration of theorem is 0.12 mol/L, FeCl\textsubscript{3} is 0.024mol/L, the stirring speed is 300 /min, and the leaching time is 2h under the above conditions, the leaching rate of gold reached 90.37%.

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