

## Research on Refining Gold from Electronic Waste

Xia HUO

Environmental Protection Bureau of Liupanshui City  
Liupanshui, Guizhou, 553004, China  
e-mail: 1019126131@qq.com

Ronghua LU

Renewable Resource Utilization Engineering Center  
Liupanshui, Guizhou, 553004, China

Mingzhe HU

Renewable Resource Utilization Engineering Center  
Liupanshui, Guizhou, 553004, China

Yue YIN

Renewable Resource Utilization Engineering Center  
Liupanshui, Guizhou, 553004, China

**Abstract**—Due to the fast development of electronic waste and the gradually deficient of the modern resources, the environment is deteriorated seriously. Thus, the recycling and utilizing of electronic waste becomes an important research area in modern scientists. In the present paper, the authors employ  $H_2SO_4$  acid and  $H_2O_2$  blend solution and  $C_2H_5OH$ - $KBr$ - $K_2SO_4$  extraction solution to gradually departure the gold from electronic waste. What's more, the authors use atom absorption spectra and XRD methods to analyze the gold solution extracted using the above method. It is concluded that using  $H_2SO_4$  acid and  $H_2O_2$  blend system is a 40% higher efficiency compared with the traditional method.

**Keywords**-*electronic waste; recycling; gold; atomic absorption spectrum; extraction; precipitation*

### I. INTRODUCTION

In the middle of the twentieth century, with the rapid development of science and technology as well as the rapid development of heavy industry, light industry, aerospace industry, nuclear industry and electronic industry, a very serious electronic waste has been generated as a result (Waste Electrical and Electronic Equipment, WEEE) [1-4]. Under this kind of circumstances, it is the main development request to carry on the resources disposal to the electronic waste. At home and abroad at present, the processing method can be divided into: land filling [5], heat treatment [6], Physical methods [7], wet chemical process [8], biological methods [9-10] as well as supercritical water oxidation method [11]. Among these methods, the method of cyanide can be used to realize economy and industrialization, but it can not reach the requirement of green production, secondly, urea sulfur method, multi sulfide method and iodide method can achieve green production and industrialization, but the economic benefit is low and the production cost is high. Finally, super-critical water oxidation method and biological method are both very high green standard, however, they need high investment and long production cycle, thus, they can not achieve industrialization as well. Therefore, the recycling process with economy, industrialization as well as green process at the same time is still a great challenging task.

In the present paper, the mechanical crushing separation assistant with wet chemical separation in electronic waste

recycling and utilization to refined gold metal, is not only with a high metal recovery efficiency, but also has high purity metal recycling without excessive processing, which can achieve most of the other production needs. Therefore, this method is selected to study the recycling of electronic waste in the present paper.

### II. EXPERIMENT

In the experiment, gold, copper and other metals in the waste computer main board are studied. Atomic absorption spectrometer principle is to measure a specific wavelength through sample atomic vapor absorption (resonance absorption), based on which it can determine the measured elements. The basic parameters of the atomic absorption spectroscopy used in this study are as follows: source power 220V/50Hz, power 150W, volume 1000mm×350mm×390mm, weight 70kg. Working environment temperature between 10~35°C, working environment humidity ≤80%. Planet ball mill (XQM-L), electrochemical workstation (CHI860D), constant temperature vacuum dryer (DZF-6050). Experiments need to be formulated with different concentrations of chemical reagents and solution system, they are aqua regia (AR) and sulfuric acid (GR) and hydrogen peroxide mixed acid (AR) and high concentration alkali solution (AR) and different concentrations of acid and salt solution (AR). The experimental flow chart is as follows:

Firstly, the CPU board was broken by the mechanical crushing method, then we used the 20 mesh screen to mesh the powder. Then filtered powder was weighed ( $m=16.5g$ ) and was put in the planet ball mill for ball milling. Finally, extracting metal with the repeated washing method until we got 5.0g metal at last. The metal was put into a 200ml beaker after separation, 60mL 2mol/L sulphuric acid was added into the beaker under the magnetic stirring by 30 r/min and heated to 50°C for reaction for 30min. After filtering the sulfuric acid solution, the remaining metal was put into a 300ml conical flask and 50mL 1:1 sulfuric acid hydrogen peroxide solution (the concentrations were both 9mol/L) was added to the conical flask, keeping the reaction temperature at 50°C for 90 min, the solution became dark green. After the solution was filtered, 6mol/L 60ml nitric acid was added to

the remaining metal mixture under the heating and stirring with 50°C and 30r/min for reaction for 60min. After reaction the color of the solution became blood red. After filtering, 80mL aqua regia was added to the residue for reacting 30min in the room temperature, till the solution became blood red again, however, after the heating by alcohol lamp for 60min, the solution became canary yellow, which was actually the gold bearing solution.

After the initial treatment, the above solution was treated with a certain amount of sodium hydroxide (analytical reagent) to adjust the pH of the solution, because the best working condition of the extraction agent, ethanol potassium bromide ammonium sulfate system, is in the range of pH=2~4. Additionally, when the solution concentration of absolute alcohol (analytical reagent), potassium bromide (analytical reagent) and ammonium sulphate (analytical reagent) were 30vol%, 0.04g/ml and 0.3g/ml, the agent possesses the highest extraction efficiency for Au. Firstly, after the addition of anhydrous ethanol 75ml, we adjusted the solution to about pH=3, then 13g potassium bromide was added to the solution and the solution changed from pale yellow to orange yellow, as illustrated in Fig.1(a). Finally, 97.5g ammonium sulfate was added to the solution together with 3min stirring to make it completely dissolved, and the solution changed back to pale yellow again and it appeared salting out reaction after resting for 5min, as illustrated in Fig. 1(b). The organic phase and the precipitated salt phase were separated by a liquid separating funnel and 10ml gold containing organic phase solution is taken out for further analysis.

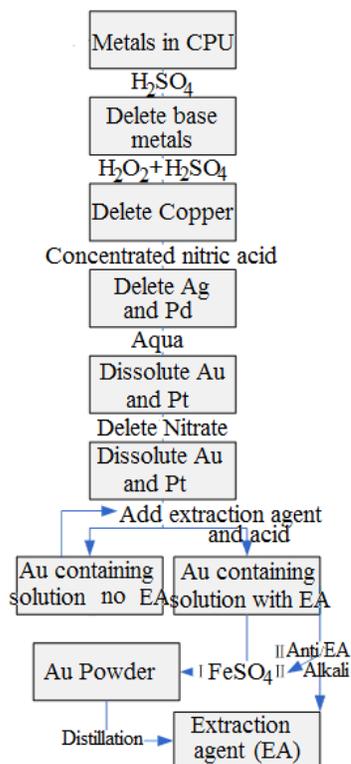


Figure 1. The experimental flow chart

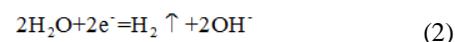


Figure 2. The extraction of ethanol-potassium bromide-ammonium sulfate system

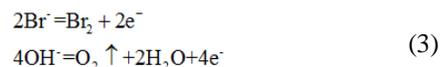
The solution was loaded into the beaker for electrolysis. We employed 2mol/L, 5ml hydrochloric acid for surface treatment. After surface treatment, the copper was used as negative electrode, while platinum was used as anode. Electrochemical workstation (CHI860D) was used for electrodeposition. When the pH was about 3, the settlement potential was scanned as -1.1V. Finally, the current - time curve was used for electrolysis and the settlement potential and electrolysis time were set firstly. After about 30mins, a yellow material vaguely appeared on the surface of the copper and a small amount of air bubbles appeared on two electrodes surface. The first 10 minutes stage in the current time curve is exhibited in Fig. 2.

The reaction of the electrolytic can be expressed as in Equ.(2) and (3):

cathode:



anode:



From Equ(2), we can know that the sedimentation potential of Au is -1.1V. And the amount of electricity in the deposition process can be obtained by using the time current scanning method. Thus, the concentration of gold ions can be calculated theoretically. The gold electroplated copper was analyzed by the TD-3500X ray diffraction, copper was used as the target with its diffraction wavelength being 1.54056 Å, the result is illustrated in Fig.4.

### III. DATA ANALYSIS AND DISCUSSION

Sulfuric acid hydrogen peroxide system was employed to dissolve the metal mixture, and the hydrogen peroxide solution was added in batches with equivalent time. Using this method the dissolution time can be contracted by less than 60 minutes compared with that in literature 12, which in turn increases the production efficiency by 40%.

The solution obtained by the treatment of sulfuric acid and hydrogen peroxide solution was analyzed by atomic spectrometry and the obtained concentration of copper and other metal is listed in Table I, from which the recovery of copper by this method can be calculated to be as high as 98.35%.

TABLE I. THE ATOMIC SPECTROMETRIC DETERMINED CONCENTRATION OF METALS IN THE SOLUTION (mg/L)

	Cu	Fe	Pb	Zn
CPU solution	1807.33	161.29	810.6	31.29

In the subsequent extraction of gold bearing solution, potassium bromide was added in order to increase the extraction rate, since bromine ion can produce more stable  $AuBr_4^-$  substance with trivalent gold ion compared with  $AuCl_4^-$ . And the addition of ammonium sulfate is to make precipitation reaction in the system, so that other metal ions in the solution can be separated from the organic phase by the form of salt [13]. Finally, the phase analysis of Au films obtained by electroplating was analyzed by XRD patterns, as illustrated in Fig. 3. There are two peaks in the XRD pattern and their coordinates are (43.45, 1194) and (50.55, 52462) respectively. Jade5 software was introduced for comparison analysis in the XRD pattern, from which, it is found there are 5 peaks, of which the 3 peaks indicate the presence of copper and the 3rd peak at  $44.444^\circ$ , whose FWHM is 2.0360 Å, is the finger diffraction peak of Au 200 index, indicating the existence of Au.

The precipitated powder is also analyzed by XRD, the results show that it contents cobalt, tin and lead metals, as illustrated in Fig. 5. From figure 5, it can be concluded that the cobalt, tin and lead metal correspond to the sixth, third and fifth peak in the XRD pattern, whose horizontal coordinate (the  $2\theta$  angle) are  $42.670^\circ$ ,  $30.8^\circ$  and  $31.555^\circ$  respectively.

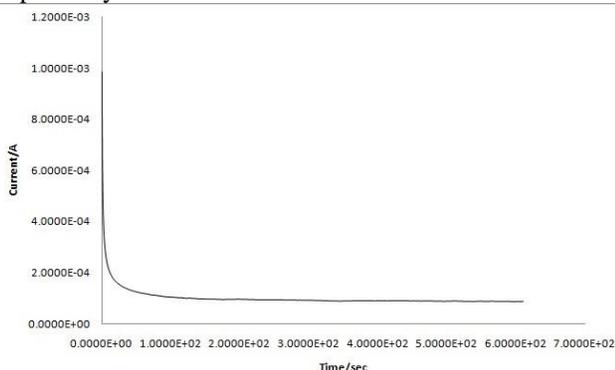


Figure 3. Electroplating current versus time curve

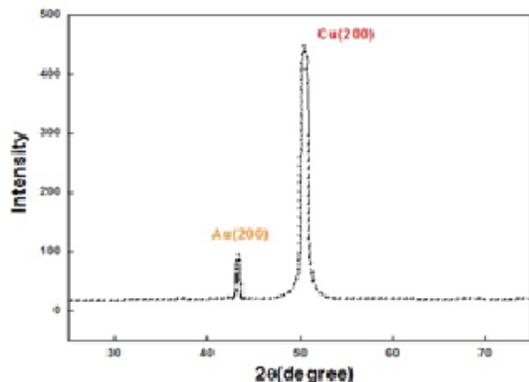


Figure 4. XRD diffraction pattern of the coated Cu plate

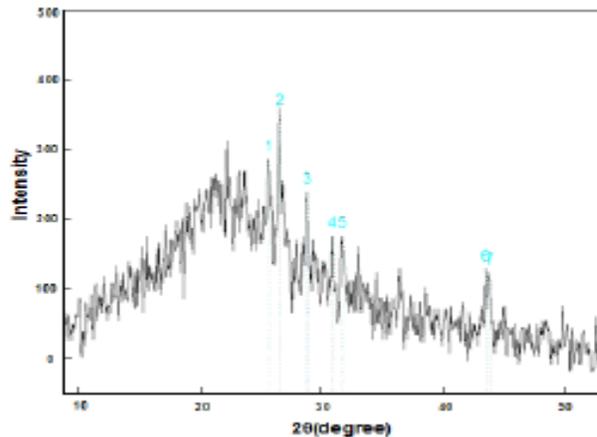


Figure 5. XRD diffraction pattern of the precipitated powder.

#### IV. CONCLUSION

In this paper, we combined two methods of physical separation and chemical separation to extract the Au in the waste CPU boards, where the chemical separation is to employ dilute sulfuric acid, sulfuric acid, nitric acid, aqua regia and hydrogen peroxide system, ethanol ammonium sulfate potassium bromide system as the research object so as to achieve high purity gold solution. The sulfuric acid hydrogen peroxide system is used to oxidize the base metal with strong oxidation of hydrogen peroxide, and the metal is dissolved by sulfuric acid. We added the hydrogen peroxide solution in batches with the equivalent time in the present paper, which can enhance the reaction efficient by 40%. Extraction of gold from the solution by the ethanol ammonium bromide potassium bromide system, where employing potassium bromide can make solution more stable since gold bromate root is more stable than gold perchlorate root, using ammonium sulphate can realize salting-out reaction and using ethanol can generate phase separation and to realize extraction effect.

Atomic absorption spectroscopy indicates that the copper metal content in CPU boards can reach 1807.33 mg/L, the recovery rate of copper can reach 98.35% by employing sulfuric acid. From the gold solution electrolysis by using electrochemical workstation, we can verify that the solution is gold containing solution and CPU boards contain cobalt, tin, lead and other elements besides gold as well.

#### ACKNOWLEDGMENTS

The authors would like to appreciate the Construction of Science and Technology Projects in Guizhou Province (Guizhou Renewable Resources Utilization Comprehensive Research Engineering Center 52020-2015-H-12), Industry University Research Fund of Liupanshui Normal University, Research Foundation for Advanced Talents of Liupanshui Normal University (Grant No. LPSSYKYJJ201403 and LPSSYKYJJ201404), the Physical Electronic Key Discipline of Guizhou Province No. ZDXK201535, the Outstanding Young Scientist Cultivation Program of Guizhou Province No.201522, the Recruitment Program of Guizhou University granted 2012032, the MIT Creative Team of Liupanshui

Normal University No.LPSSYKJTD201402 and Huadong Recycling Resources Co., Ltd. for the finance support of the present paper.

#### REFERENCES

- [1] G. N. Sheng, Experimental study on recovery of copper from waste printed circuit board [D]. *Qingdao: Qingdao University of Science & Technology*, 2008.
- [2] X. Y. Wang. Recycling of electronic waste of precious metals [D]. *Changsha: Central South University*, 2012.
- [3] B. Liu. Study on the extraction of gold from waste printed circuit boards [D]. *Shanghai: Donghua University*, 2006.
- [4] S. Zhu. Recycling technology of waste home appliances [J]. *Journal of Liaoning Technical University: Natural Science Edition*, 28, 154 (2009).
- [5] Q. F. Zhou, W. Zhu. Recovery of gold from waste computers and their accessories [J]. *Journal of Comprehensive utilization of resources in China*, 7, 31 (2003).
- [6] P. Run, Y. Chi, Study on the transfer and transformation of bromine during high temperature combustion of waste printed circuit board [J]. *Energy Engineering*, 3, 59 (2013).
- [7] C. Liu, J. X. Liu, X. Y. Guo, Research progress of electronic waste treatment technology [J]. *Journal of Metal materials and Metallurgical Engineering*, 42, 44 (2014).
- [8] G. Xue, J. Ju, C. D. Yang. Experimental study on gold extraction from gold bearing electronic components [J]. *Gold*, 12, 52 (2010).
- [9] J. Y. Li, X. L. Xu. Research progress of bio metallurgy technology in electronic waste [J]. *Journal of Gold science and technology*, 6, 25 (2010).
- [10] X. J. Li, S. Liang, X. Y. Guo. Research progress on recovery of precious metals from electronic waste by biological adsorption [J]. *Noble metal*, 31, 64 (2010).
- [11] Q. C. Zhao. Engineering application of supercritical water oxidation [J]. *Materials science and equipment in China*, 9, 21 (2013).
- [12] Z. Y. Han. Recovery test of metal iron, copper and gold from waste printed circuit board [D]. *Kunming: Kunming university of science and technology*, 2010.
- [13] W. S. Ma, L. Zhong, S. Y. Gao. Extraction separation gold by employing ammonium sulfate and potassium bromide system[J]. *Journal of Analytical Chemistry*, 1, 56 (2004).