ISSN: 0975-766X
CODEN: IJPTFI
Available Online through ***Research Article***
www.ijptonline.com

WEALTH FROM WASTE PCBS - ENTREPRENEURSHIP OPPORTUNITIES IN E-WASTE MANAGEMENT

Dr. N. Gomathi[1], Sandhya. P[2]*
[1]Computer Science and Engineering, Veltech Dr. RR & Dr. SR University, Chennai-600062, India.
[2]*Department of Science and Humanities, Veltech Dr. RR & Dr. SR University, Chennai-600062, India.
Email: sandy.spk22@gmail.com

Received on: 11-02-2017 *Accepted on: 31-03-2017*

Abstract

Aim: Worldwide increasing demand to electronic also increases its demand to the electronic waste called as E-waste. The extraction of useful materials from E-waste and reusing is called as E-waste management. But in most countries the E-waste management is a very expensive, energy consuming or non environmental friendly technique. In this paper we aim for a complete process to extract metals efficiently without causing any environmental hazards.

Methods: The process starts by an Automatic line process which gives an effective extraction of metals and non metals. This process can be followed by a halide leaching for extracting precious metals. In halide leaching iodide leaching is expected to be of best results due to its non corrosive, easy regeneration and fast leaching rate. This is followed by the electrogenerative process and purification by HCl for pure gold, silver and platinum recovery from waste PCBs.

Results: The iodide leaching is to be performed with an iodide leaching reagent and is expected to give 80 – 95% of gold recovery. The precious metal lechate solution undergoes another process of electrogenerative process where a 90% recovery of gold and silver is expected. In the same electrogenerative process with the same crude material by increasing the HCl concentration and by increasing the effective temperature a platinum recovery is expected.

Conclusion: The Eco-friendly leaching process can be used for higher leaching rate of metals and precious metals. This method is also important for energy and cost saving future of the developing countries.

Keywords: E-waste, PCBs, Automatic line, Leaching, Electrogenerative process.

Introduction

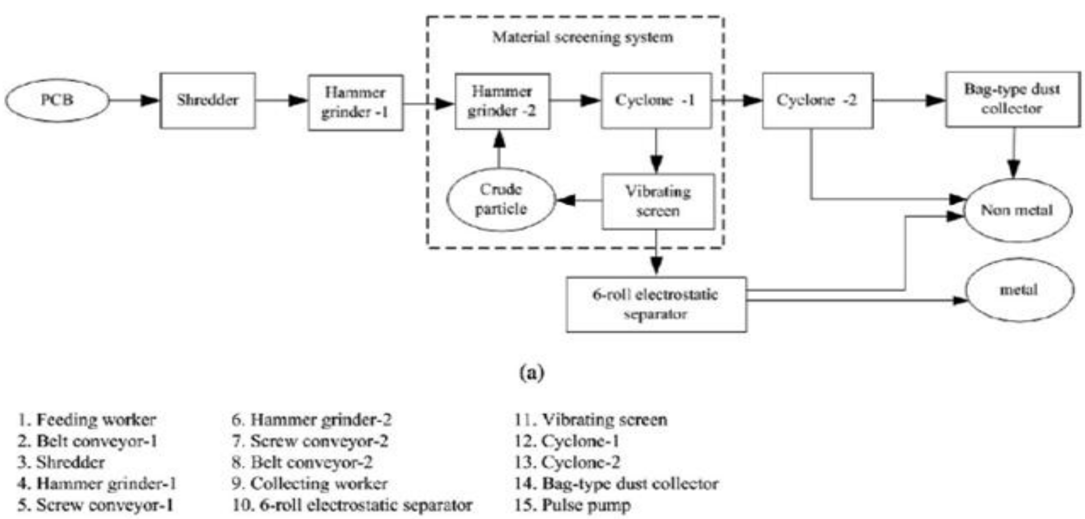
Electronics has become part of human life, without which no step in daily life happens. Due to the increasing demand to electronic items the electronic waste called as E-waste has also progressively increased in the world. Recent articles say that china has been facing the maximum problem of E-waste and every year the E-waste present there crosses a limit of 100 million tons [1]. Among which the maximum electronic waste is the Printed Circuit Boards (PCB) [2]. Already in market there are several E-waste recycling methods available but all those methods increase pollution in the environment and consume more cost. The common by-product of PCB waste management are polychlorinated dibenzo-*p*dioxins (PCDD) and polybrominated diphenyl ethers (PBDEs) [3]. Due to the hazardous waste that is produced commonly different methods were introduced to save their environment from pollution and make their city effective in E-waste management process. But due to the expensive pollution free processes followed in developed countries [4] these methods are of no use to the developing and under developing countries [5]. The infancy in the research proceeding and the high demand in the present world for a pollution free E-waste management is a major reason to find a new solution to this dangerous disease causing problem. Normally the traditional method of metal separation from PCB is done by separating the metal and non metal from a crude material where 30% of metals will not be recovered [6]. That 30% of metals undergo a second process manually for more metal and nonmetal separation. But here maximum of metals and non metals are lost due to erosion in rain and wind where all this is passed to the surrounding environment causing most hazardous dangers [7&8].In finding a solution to this major problem energy utilization and production capacity in industries are also to be taken into account. The continuous process that can be adapted is called as an automatic line process where it is observed to be of no negative cause to the environment [9, 10, 11]. After the copper recovery is done the metal and the non metal components of the byproduct was completely reused [12]. The automatic line technology is a four step process with: (i) multiple scraping, (ii) material screening, (iii) multiple-roll CES, and (iv) dust precipitation from which a 95% of copper recovery can be obtained [13]. As a next step to the traditional metal leaching methods we can also extract precious metals like silver, gold and platinum from waste printed circuit boards (PCBs) [14]. For precious metal extraction cyanide leaching [15] was the most commonly used technique but this technique was not environment friendly technique [16]. The environment safe precious metal extraction method is a thiourea leaching. It is a three step analytical process with an initial pretreatment of PCB is performed and then the usual metal and nonmetal extraction process followed by pneumatic separation, magnetic extraction, screening, eddy current extraction and electrostatic separation to obtain the specific metals [17]. The solution to this problem is halide leaching. The halide leaching and electrogenerative method using a chloride media was expected to be more effective. In halide leaching the iodide leaching is the most preferred due to its high leaching rate. This gives a perfect result of faster leaching, easy regeneration, reduction of iodine while gold recovery and less corrosion and toxicity [18].With these promising technologies such as four part metal and nonmetal leaching technique and Iodide leaching makes extraction of metals, nonmetals and precious metals in an eco friendly and safe manner. The halide leaching and electrogenerative method gives an output of lechate solution which is loaded with 95% of precious metals. This lechate solution is taken into an electrogenerative process with a chloride media to obtain an effective gold and silver extraction. In this system an external power is not needed and it is cost effective [19].The gold deposition takes place on the Reticulated Vitreous Carbon (RVC) and Porous Graphite (PG). The use of RVC is due to the less density and high corrosion resistance observed during leaching process [20]. This process of leaching is adopted to extract gold from ores by the use of several lixiviants. From the PCBs recovery of gold and silver can be achieved by electrogenerative approach. In the same process by a small adjustment in the temperature [21] platinum deposition also can be achieved by the same electrogenerative process.

Methodology

Automatic line process

The metal recovery process can be processed. For a 4500 kg of waste PCBs an approximate maximum size of 600 * 100 * 5 mm and a minimal size of 200*20*2 mm largest size material can be obtained. The following are the four step process (Figure 1) that can be performed for recovery of metals, media, nonmetal and dust [22].

Fig. 1: Four step automatic line process [23].



Metal Scrapping

First step of treating waste PCB is a mechanical method called metal scrapping. Here the parts from PCB such as woven glass along with metals and resins are present. There is presence of high toughness and hardness in the general mechanical stripping process and it gives out a large number of water energy. To reduce the energy wastage a multi step crushing method is used. The crushing method is performed with a feed conveyer to load the input materials then a shredder to perform the crushing mechanism then two hammer grinders to perform the breaking mechanism.

The shredder and one grinder placed in a vertical position [24]. This position is maintained in the scrapping method to have a better dust free delivering of the product. The energy consumption of hammer grinder was reduced by maintaining the screen hole diameter based on an eq (1).

$$A = 2340 \cdot m\left(\frac{1}{D_2} - \frac{1}{D_1}\right) \qquad (1)$$

Here,

m = mass of PCBs waste

D_1 = Before scrapping average size of PCB particle

D_2 = After scrapping average size of PCB particle

A = Average size of particles

Following the shredder both the hammer grinders are to be placed so the size reduction can be effectively performed. For the size reduction two square knives of various rotation is expected to be in an average size of 50 x 50 mm. The rest of the materials are scrapped by a hammer grinder 1 to an average size of 5 x 5 mm. The reduction of size 50 x 50 mm can be achieved by a shredder then further reduction to an average size of 5 x 5 mm by the first hammer grinder. The following grinder can reduce the particle size to approximately half of the size achieved by hammer grinder 1 approximately to 2.5 mm.

Due to these process performed there is always high possibility of increased temperature leading to abrasion and PCB pyrolysis. To reduce abrasions inside the system the speed of knife rotation is to be reduced but when the speed reduces below a limit the reduction of size will not be achieved. So the knife rotation was optimized to 1800 rpm and the water system flow inside was maintained at 80 ° C [25].

Material Screening

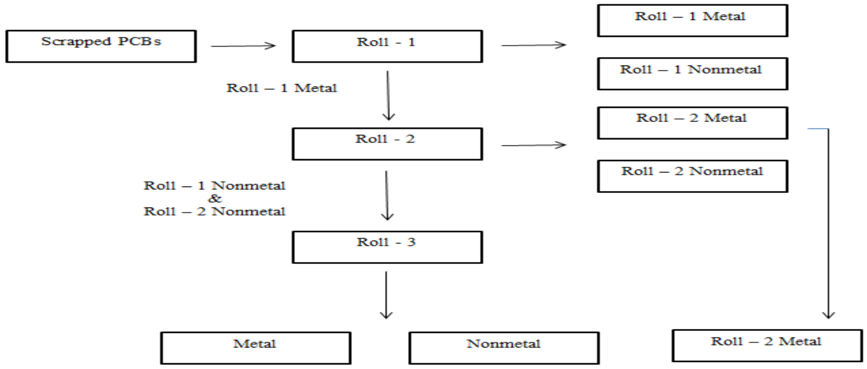
As a process of screening the control of hammer grinder 2 screen hole is to be maintained at Φ 2.5 mm. To achieve a high metal recycling ratio in this continuous process a suitable particle size of +0.6-1.2 mm is expected to be maintained before the particles are fed into the electrostatic separators. The optimized sized particles are fed into the two cyclone followed by the vibrating screen. The connection from hammer grinder to the cyclone is through a rectangular shaped pipe where the materials undergo a circular motion when it passes into the cyclone. First the fed particles from the continuous hammer grinder are passed into the first cyclone maintained by a 3000 pa blast volume high speed air. When the circulatory motion is taking place inside the cyclone the larger particles are theoretically supposed to be thrown towards the outer wall and get collected at the bottom of the cyclone. And the tiny particles undergo the rotary motion in the centre pipe. From this the fine nonmetal particles are passed on to the cyclone 2 and the rest of the particles which is of + 1.2 mm and + 0.6 – 1.2 mm will be connected to the vibrating screen. Here the screen is made up of a wire mesh with a size range of 1.2 × 1.2 mm. From here the size reduced particles are delivered into the hammer grinder-2 by conveyor 2. From the particles that are not reduced yet the metal and nonmetal particles can be separated by passing them into the 6-roll electrostatic separator. The dust particles are collected by the bag type collector [25].

Multiple – Roll CES

There is a 3 step 6 roll electrostatic separator in which the rolls are equally separated to two parts. The first 3 rotating rolls are placed in a vertical position and the other 3 rolls follow few other parameters. The construction of electrodes which helps in increasing the purity of metal, position of separator board can be adjusted to get different purity levels of metals, and rotating speed roll are the three major influencing factors to separation process. These parameters are set to solve the major problems of the traditional separation process [26, 27].

Roll – 1 has a higher feeding rate than the roll – 2 and the output of the whole system is based on the feeding rate of roll – 1. Here a crude material separation takes place where the nonmetals are transferred to the roll – 3to reduce the effect of fine nonmetal particles. The metal content from roll – 1 was fed into the roll – 2. From the roll – 2 a separator board was set to collect the metals and media and nonmetals were transferred to roll – 3. All the nonmetal particles from the roll – 1, roll – 2 and media from these are passed on to the roll – 3. The rotating speed of roll- 3 electrodes is to be reduced to increase metal loss and improve the metal collection. The roll-1 receives media from the roll – 3 continuously (Figure 2).

Fig. 2: Electrostatic triple separator – Flow chart.



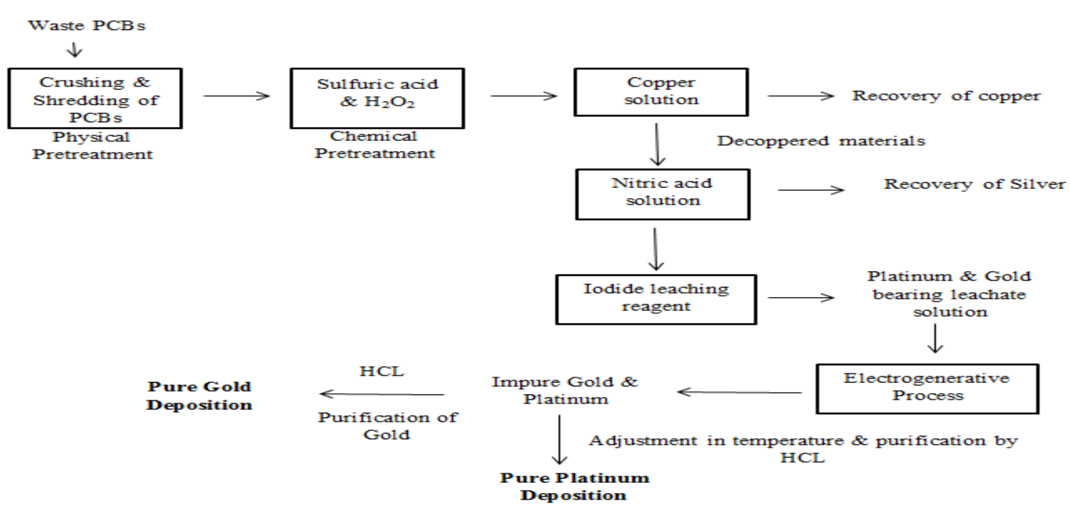
Dust Precipitation

The last and final process of the automatic line is the dust precipitation where this dry process produces a lot of dust in environment so the bag type dust collector is proposed to precipitate the dust. The dust is moved to the collector using a pulse pump [28].

Iodide leaching

The waste PCBs that are shredded and crushed are passed to the leach reactor. Here the extraction of precious metals can be carried by dissolving gold and silver using Iodine in aqueous acidic Iodide solution. At the end of each leaching process the sample that are eluted are filtered and undergo a volumetric analysis. The volumetric analysis gives the percentage of metal dissolution that can be achieved. All the precious metals can be obtained from the lechate solution by 8 hours of process [29]. This lechate solution is again to be treated by an electrogenerative process for a complete gold and silver recovery (Figure 3).

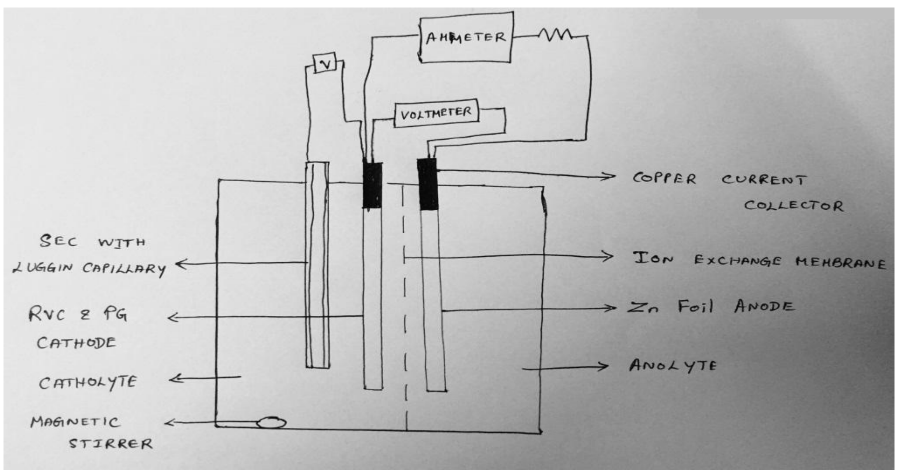
Fig. 3: Halide leaching mechanism.



Electro generative process

The effective electrogenerative process can be achieved in a 5.5 cm x 5.5 cm x 8.0 cm batch cell made with ion exchange membrane. The electrodes present in the batch cell helped as a current collector due to the copper sheet connections. The complete circuit can be obtained by connecting the electrode connection wire with an external circuit. A zinc foil was used as anode with 0.4 M NaH2PO4 0.1 M NaCl as anolyte solution. A RVC, porous graphite, copper plate and stainless steel plate as cathode with 0.4 M NaH2PO4 solution as in Figure 4. Cathode and the electrode connecting current collectors were covered completely with parafilm to avoid gold diposition.0.4 M Sodium di-hydrogen phosphate was used as a buffer with a pH of 7 [30]. The monitoring of AU (III) deposition was performed by an atomic absorption spectrometer [31]. With this spectrometer the percentage of gold recovery can be calculated.

Fig. 4: Electrogenerative process.



Results and Discussion

Automatic line process

The leaching of metals and nonmetals by an automatic line process gives an effective output of complete metal and nonmetal separation and metal leaching. The metals from roll – 2 and roll -3 will be metals with high purity and the non metals from roll -3 will be purely non metals without any impurity.

The main aim of this work is to get higher leaching rate and follow an environmentally friendly process for metal and non metal separation. Previously the metal and non metal separation was achieved by a traditional method where 30% of metal recovery was escaping to the environment and causing several hazardous problems (23-27). Here in automatic line process 90% recovery of metals and dust collection by a dust collecting bag is performed to avoid the small material escape to the environment.

Halide leaching

Automatic line process followed by a process of halide leaching 80 – 95 % of lechate solution with gold and silver can be obtained. Here the scrapped PCBs are treated chemically with copper solution to dissolve copper. From the de coppered material by treating with nitric oxide and silver nitrate silver can be extracted. Then by using a iodide leaching reagent lechate solution with 80 – 95% of gold and platinum can be leached.

The cyanide leaching commonly the poisonous leaching was a main reason to several health issues to a lot of people working in the leaching environment. As a solution to this hazardous leaching technique thiourea leaching was effectively performed. Even the thiourea leaching gave good results and was Eco-Friendly but this process in developing countries seemed to be leading to much larger energy consumption and not cost effective (28&29). So the iodide leaching was adopted in this process to obtain the best results of non corrosive environment, high leaching rate and cost effective leaching process.

Electrogenerative process

By a process of electrogenerative system the lechate solution with gold and platinum is fed to get impure gold and platinum using a chlorine solution. Here by using HCl we can purify the impure gold and obtain 90% of gold from waste PCBs. And also by increasing the concentration of HCl and by increasing temperature pure platinum of 90% can be obtained. This process is performed with chlorine solution giving the uniqueness to this process. Here the chlorine solution forms complexes with AU (III) and deposits the precious metals. This complex delivers the precious metal and the chlorine gas is being reused to form the chlorine solution in the same process. This regenerative method is highly effective, Eco-Friendly with 90% recovery rate. The HCl solution used in the process is a purifier and gives a product of 95% purity. By this process gold, silver and platinum can be extracted effectively with high purity.

Conclusion

The waste unconsumed iodide gas can be recycled again for leaching purpose which stands as a unique step for Eco-Friendly leaching process. In this work we suggest a novel method of iodide leaching for precious metals and HCL for purification in the electrogenerative process. This method also suggests the recovery to be 90% and recovery rate to be less than 2 hrs of operation time. With the Automatic line process the metals and nonmetal separation can be performed effectively without any dust to the environment and followed by iodide leaching to obtain a lechate solution of 80-95%

of precious metal in the 8 hrs elution. This lechate solution in an electrogenerative process with HCL for purification is expected to give a 90% pure gold and silver recovery. The same electrogenerative process with few adjustment of temperature gives a platinum deposition. Therefore a complete process of metal, nonmetal and precious metal recovery from waste PCBs can be performed in an Eco-Friendly manner.

Acknowledgments

This material is based upon the work supported by the Department of Science and Technology & Veltech technology Incubator, Certificate of Registration of societies. S.no. 488 of 2010.

References

1. T. Lehner, Integrated recycling of non-ferrous metals at Boliden Ltd”IEEE Int. Symp. Electron. Environ, 1998, 42–47.
2. J. Guo, S. Wang,Z. Xu, Asphalt modifiedwith nonmetalsseparated from pulverized waste printed circuit boards. Environ.Sci. Technol. 2009, 43 (2), 503–508.
3. A. Leung,W. Luksemburg, A. Wong, Spatialdistribution of polybrominated diphepyl ethers and polychlorinateddibenzo-p-dioxins and dibenzofurans in soil andcombusted residue at Guiyu, an electronic waste recycling sitein southeast China. Environ. Sci. Technol. 2007, 41, 2730–2737.
4. S. Chatterjee and K. Kumar, Review Effective Electronic Waste Management and Recycling Process Involving Formal and Non-Formal Sectors,International Journal of Physical Sciences, 2009, 4 (13), 893-905.
5. S. Schmelzer, W. Hoberg,New wet treatment for components of incineration slag,Aufbereit. Tech. 1996, 37, 149–157.
6. D. Sinha-Khetriwal, P. Kraeuchi and M. Schwaninger, A comparison of electronic waste recycling in Switzerland and in India, Environmental Impact Assessment Review, 2005, 25 (5), 492-504.
7. J. Cui,E. Forssberg, Mechanical recycling of waste electric andelectronic equipment: a review,J. Hazard. Mater. 2003, 99, 243–263.
8. Jing Feng He, Ya Qun He, Wen Sheng Ge, Chen Long Duan, Xiao Bing Wu, Research on the Recycling ofValuable Metals from Waste Printed Circuit Boards by Eddy Current Separation, Advanced Materials Research, 2010, 113-116, 367-371.

9. J. Guo, J. Li, Q. Yao, Z. Xu, Phenolic molding compound filled with nonmetals of waste PCBs,Environ, Sci. Technol,2008, 42 (2), 624–628.

10. J. Li, J. Xu, Z. Zhou, Application of corona discharge andelectrostatic force to separate metals and nonmetals fromcrushed particles of waste printed circuit boards,J. Electrostat 2007, 65, 233–238.

11. C. Hagelüken, Recycling of Electronic Scrap at Umi- core's Integrated Metals Smelter and Refinery,Pro- ceedings of EMC,2005, 59 (3), 152-161.

12. O. Osibanjo and I.C. Nnorom, The Challenge of Elec- tronic (e-Waste) Management in Developing Countries,Waste Management & Research, 2007, 25 (6) 489-501.

13. H. Y Kang, J. M. Schoenung, Electronic waste recycling: A review of U.S. infrastructure and technology options,Resources, Conservation and Recycling, 2005, 45,368-400.

14. J. Cui, L. Zhang, Metallurgical recovery ofmetals from electronic waste: A review, Journal ofHazardous Materials, 2008, 158, 228-256.

15. J.Ch Lee, B. Dh. Pandey, Bio-processing of solid wastes and secondary resource for metal extraction – A review, Waste management, 2012, 32 (3), 18.

16. S. Syed, Recovery of gold from secondary sources – A review,Hydrometallurgy, 2012,30 (51),115-116.

17. G. Hilson, A. J. Monhemius, Alternatives to cyanide in the gold mining industry: what prospects for the future?, Journal of cleaner production, 2006, 14,1158-1167.

18. J. S. J. Van Deventer, P. F. Van Der Merwe, The reversibility of adsorption of gold cyanide on activated carbon,Metallurgical Transactions B, 1993, 24B, 433-440.

19. P. M. H. Petter, H. M. Veit, A. M. Bernardes, Evaluation of gold and silver leaching from printed circuit board of cellphones,Waste management, 2014,34,475-482.

20. K. Koyama, M. Tanaka, Y. Miyasaka, Electrolytic copper depositionfrom ammoniacal alkaline solution containing Cu(I), MaterialsTransactions, 2006,47, 2076–2080.

21. C. Peng, Y. Liu, J. Bi, Recovery of copper and water fromcopper electroplating wastewater by the combination process of electrolysis and electrodialysis,Journal of Hazardous Materials, 2011,189:814–820.

22. P. C. Oliveira, F. C. Taborda, F. Margarido and C. A. Nogueira,Physical and Chemical Processing of Printed Circuit Boards Waste, Presented at the World Recycling Forum, Shanghai, China, Nov. 2009.
23. H. Yang, J. Lui, and J. Yang, Leaching copper from shredded particlesof waste printed circuit boards,Journal of Hazardous materials, 2011, 187 (1-3), 393-400.
24. Z. Gongming, L. Zhihua, and Z. Xulu, Experimental Study on MetalRecycling from Waste PCB, in Proc. Int. Conf. Sustainable SolidWaste Management, Chennai, India, 2007, 155-162.
25. R. Montero, E. de la Torre, A. Guevara, Recovery of gold, silver, copper and niobiumfrom processors of discarded computers using leaching column technique, in: 6th International Congress ofMaterials, Bogotá, Colombia, 2011.
26. J. Li, H. Lu, J. Guo, Z. Xu, Y. Zhou, Recycle technologyfor recovering resources and products from waste printedcircuit boards, Environmental Science and Technology, 2007, 6,1995-2000.
27. F. Yousse, Chehade, A. Siddique, H. Alayan, N. Sadasivam, S. Nusri, And T. Ibrahim, Recovery Of Gold, Silver, Palladium, And Copper From Waste Printed Circuit Boards, International Conference On Chemical, Civil And Environment Engineering (Iccee'2012), 2012, 24, 226-234.
28. J. Ficeriova, P. Balaz And E. Gock, Leaching Of Gold, Silver And Accompanying Metals From Circuit Boards (Pcbs) Waste, Acta Montanistica Slovaca Ročník, 2011, 16 (2), 128-131.
29. G. Senanayake, Analysis of reaction kinetics, speciation and mechanismof gold leaching and thiosulfate oxidation by ammoniacal copper(II)solutions. Hydrometallurgy, 2004, 75: 55–75.