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Current status and future perspective of recycling copper by hydrometallurgy from waste printed circuit boards

Yan Xu[a]，Jinhui Li[a,*], LiliLiu[a]

State Key Joint Laboratory ofEnvironment Simulation andPollution Control, School ofEnvironment, Tsinghua University, Beijing, 100084, China

Abstract

The current replacement of electronic products is speeding up, resulting in a growing number of e-waste. Electronic waste, especially waste print circuit boards contain large amounts of copper, which not only bring greater ecological threat, but also cause a serious waste of copper resources. Therefore, the study on clean, effective copper leaching technology has a very important practical significance to reduce environmental hazards of waste print circuit board and resources recycling. Hydrometallurgical is a better technology for recycling copper from waste print circuit boards. In this article, hydrometallurgical copper recovery system is divided into four categories: acid leaching, ammonia - ammonium leaching, chloride leaching, as well as other ways of leaching. The advantages and disadvantages of leaching of copper system are analyzed in the process of copper resource utilization. Studies abound on recycling copper from copper-containing waste with citric acid and other complexing agents as the leaching reagent, but studies on recycling copper from waste print circuit boards are rarely reported, which can be used for reference. The trends of the research are using environmentally friendly reagent as leaching agent, selecting the appropriate leaching solution at a certain temperature and pressure and optimizing the subsequent separation procedure. Recycling of waste gas and waste leachate generated in the hydrometallurgical processcan further reduce chemical costs and meet increasingly exacting environmental requirements.

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*Keywords:*Waste printed circuit boards; Copper; Leaching; Recovery; Hydrometallurgy

1. Introduction

The amount of global e-waste - discarded electrical and electronic equipment - reached 41.8 million tonnes in 2014, according to a new United Nations University report. According to the report, just two countries - the US and China - discarded nearly one-third of the world's total e-waste in 2014[1].

* Corresponding author. Tel.: +86-10-6279 4143; fax: +86-10-6277 2048.
E-mail address: jinhui@tsinghua.edu.cn

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The discarded e-waste contained about iron, (16,500 kilotons), copper (1,900 kilotons), and gold (300 tonnes) also significant quantities other metals such as silver, aluminium, palladium, and other potentially reusable resources, and estimated value about US$52 billion. It may also contains amounts of health-threatening metals and substances such as mercury, cadmium, chromium, and ozone-depleting chlorofluorocarbons [2].If not properly disposed of, it will cause great harm to environment and human health. The metal content in the waste circuit board is much higher than the metals in the ore. For example, the average grade for copper in China is 0.8%，while the content of copper in waste circuit board copper taste is more than 20%. As an important nonferrous metals，because of its unique physical and chemical properties：good ductility, high thermal conductivity， electrical conductivity and corrosion resistance，copper is widely used in electrical, light industry, machinery manufacturing, construction industry, defense industry and other fields. With the continuous development of society and increasingly demand for copper, although China's copper reserves is more, but on the whole, copper resources, especially rich copper is still poor. Therefore, no matter for environmental protection, or for resources recycling, the comprehensive recycling of waste printed circuit boards has important social and economic significance[3,4].

Recently different recycling methods are used for circuit boards such as mechanical [5], pyrometallurgical [6], hydrometallurgical[7,8] and biological treatment[9], etc. Besides, supercritical fluid[10], microwave pyrolysis[11] and plasma melting[12]are also reported, but in other hand these process have their own certain limitation such as level of research at laboratory scale, small recycling capacity. Although, mechanical recovery method can effectively separate the metal and non-metal, but can't get the pure metal products at last and the following must be combined with hydrometallurgy process. In addition, this method is become an important step in terms of pre-treatment of electronic waste recycling. In another hand, pyrometallurgy technological process is short, but the equipment investment is large, metal recycling cannot achieve at significant level. In addition , high possibility for secondary pollution. However, biological metallurgy with environmental protection, small investment, is a potential way of recycling, but less strain, hard to cultivate and long leaching cycle limiting its large-scale application. It also has some drawbacks, including leaching agent consumption and greater pollution. But by optimizing the process, choosing less toxic leaching agent and leaching leachate recycling process, these problems can be better solved. It is a viable method for large-scale processing[13.14].

Recovery of metals from electronic waste by hydrometallurgical technology began in the western developed countries in the late 1960s[15.16]. The basic principle is to scrap printed circuit board in an acidic or alkaline leaching solution, so there is a separation of valuable metals and other materials. Then by using solvent extraction, precipitation, displacement, ion exchange, distillation, filtration to recovery of precious metals and other base metals from the liquid phase[17].The processing steps are as follows: (1) Heating the waste printed circuit board to a certain temperature, when organic matter of the substrate part occurs pyrolysis in high temperature，in order to reduce the consumption of acid and simplify the subsequent process.(2)Leaching the waste printed circuit boards in strong acid or strong oxidizer solution can obtain acid solution containing copper and other lower value metals and sediment containing precious metal strip.(3) Treating stripping sediment containing precious metals by using aqua regia or other caustic acid to recycling platinum, gold, silver and other precious metals.(4) Adopting ion exchange, solvent extraction or chemical precipitation method processing metal leaching solution can extract metal or metal compounds[18].

The value of electronic waste is the largest component of precious metals. While, with the reduction in precious metal content in electronic products, as well as the increasingly stringent environmental requirements, research on hydrometallurgical method is not only limited to the extraction of precious metals, but also turned to the precious metals and common metals recycling[19].

Because of the obvious advantages in recycling metal from waste printed circuit boards, a large number of hydrometallurgical leaching are carried out at home and abroad. Due to the highest content of copper in the waste printed circuit board, the base metal recycling is mainly for hydrometallurgical leaching of copper[20].

In hydrometallurgy, the disposal of waste printed circuit board of the leaching process is critical, the current method of hydrometallurgical leaching of waste printed circuit board can be divided into four types: acid leaching, ammonia leaching, ammonium salt leaching, chloride leaching, and other ways of leaching, some of the leaching methods have had certain industrial applications in different ranges[21].

2. Leaching of copper from waste print circuit boards

2.1Acid leaching method

2.1.1Nitric acid leaching method