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Physical and chemical processing of printed circuit boards waste

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Abstract

A recycling process for PCB's is being studied, based on physical processing and hydrometallurgical treatment. PCB's waste was shredded in a lab cutting mill, resulting a grinded material with 90% (weight) with particle size less than 2.1 mm and an average particle diameter of 1.2 mm. Chemical analysis of granulometric fractions showed that the base metals like Cu, Zn, Pb and Sn concentrated mainly in intermediate size fractions (0.4-1.7 mm) being fines very rich in epoxy resin composite. About 80-90% of the principal metals were recovered in that size range.
The first step of chemical treatment was the acid leaching of metals. The use of nitric acid solutions at appropriate conditions allowed the efficient solubilization of base metals like Cu, Ni, Zn, Pb and Ag. More than 90% recovery of Cu, Zn and Ni were achieved at 90ºC using 1 M HNO_3. Dissolution of silver required higher concentrations (only 70% yield using 2 M HNO_3). Tin leaching was inefficient in nitric media, being always lower than 20%. The leaching conditions here reported were adequate to the base metals solubilization, allowing further processing of leachates for separation and recovery using hydrometallurgical operations. Precious metals recovery would be attained in a subsequent leaching step using highly concentrated acidic solutions.

Introduction

Recycling of electronic waste is nowadays a major issue due to the rapid expanding of the electronic goods market which gives consequent generation of respective waste. Metals recovery from such residues can lead to economic benefits due to their commercial value. In electronic waste, recycling of printed circuit boards (PCB's) is specially attractive due to the high metal content of these components (up to 40% w/w), containing valuable non-ferrous metals such as copper, lead, tin, zinc, nickel, aluminium, and also very interesting levels of precious metals. Most common processing routes used for electronic scrap are smelters, but alternative processes are encouraged, particularly for treating lower quantities in a more versatile way.

The hydrometallurgical treatment of PCB's allow the recovery of contained metals. In a first step, acid leaching with nitric acid under moderate conditions is suitable to dissolve some base metals like copper, lead and tin, and also some silver. The remaining residue can be further leached in a second step using more strong reaction conditions to dissolve and recover the precious metals. In this paper, some results concerning the physical and chemical treatment of PCB's waste are presented, including shredding, materials characterization and leaching of base metals with nitric acid solutions.

Results and Discussion

The PCB residues used in the laboratory work were discarded mother-boards from personal computers. The plaques were previously cut with a guillotine in about 5x5 cm fragments and then shredded in a lab cutting mill using a discharge grid of 4 mm. The grinded PCB material resulted from this treatment had an average diameter of 1.2 mm and characteristic diameters d_{10}=0.48 mm and d_{90}=2.1 mm. The ganulometric distribution can be observed in Fig. 1a. Concerning chemical composition, Fig. 1b shows the evolution of metal content with particle size, where it can be seen that higher concentrations occur in intermediate fractions (0.4-1.7 mm). The fine and coarse fractions are very concentrated in resin composite and other non-metals. The distribution of species presented in Fig. 1c was calculated combining weight and composition in each fraction. It can be seen that about 80-90% of metals can be recovered in the size range previously referred (0.4-1.7 mm).

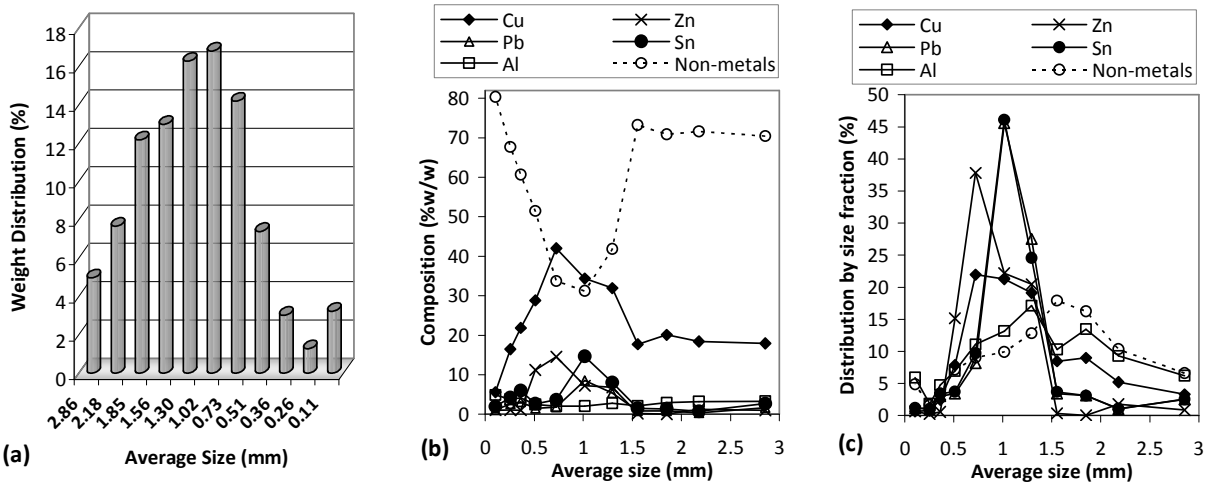

Fig. 1 – Characterization of shredded PCB material. (a) Particle size distribution; (b) Chemical composition vs. size fractions; (c) Distribution of species by size fractions.

The leaching tests of shredded PCB material were carried out in orbitally shaken glass vessels, for 4 hours of residence time and at a liquid/solid ratio of 25 L/kg. Leaching with nitric acid was very efficient for the dissolution of most of the base metals present (Fig. 2). Only tin dissolution was scarce due to probable oxidation to insoluble Sn(IV) species. The effect of temperature on leaching yields was very significant (Fig. 2a) mainly for copper and zinc (maximum yields of about 90% attained at 90ºC) being less important for the other metals (in the range 50-90% yield). The acid concentration was also an important factor on leaching efficiency (Fig. 2b), but for most of metals a stabilization in leaching yields occurred at 1M HNO_3. Silver dissolution was particularly dependent from leachant concentration, changing the recoveries attained from 3% for 0.5M to 70% for 2M of acid.

The leach liquors obtained can be subsequently treated by hydrometallurgical operations (such as selective precipitation, solvent extraction or ion exchange) in order to separate and recover the metals in pure forms. The residue coming from the leaching operation can be again leached using more aggressive acid/oxidant conditions to recover noble metals.

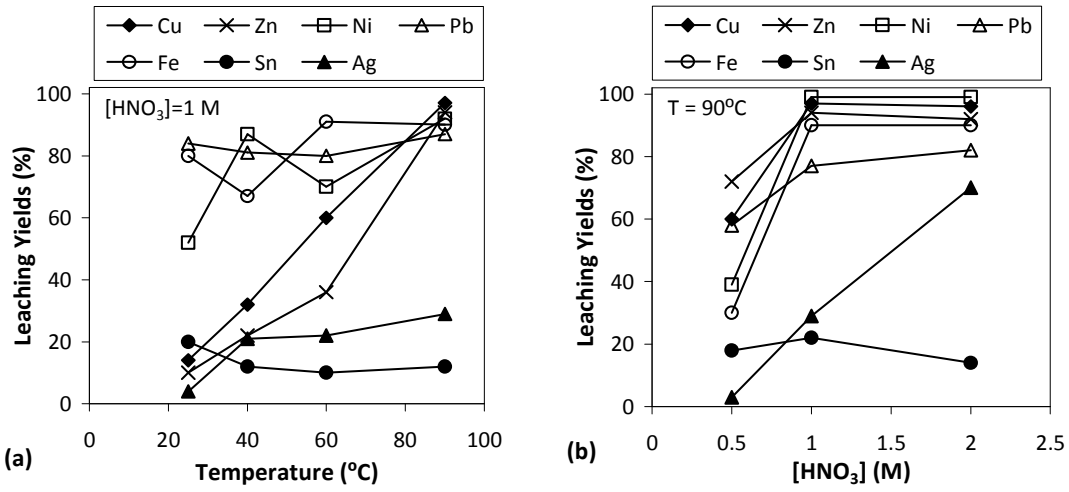

Fig. 2 – Leaching yields of shredded PCB's, with HNO_3 solutions, for 4h and L/S=25L/kg. (a) Influence of temperature; (b) Influence of acid concentration.

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