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Leaching studies for metals recovery from printed circuit boards scrap

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Abstract

In this paper, the leaching behavior of the major metals present in printed circuit boards waste is evaluated, aiming at its recycling by hydrometallurgy. Several leachants were compared (sulfuric, hydrochloric and nitric acids, at 2 M H^+ concentration), at temperatures of 25ºC and 90ºC and 4 hours of reaction time. Sulfuric acid leaching was not very promising concerning metals dissolution being only effective for iron. Hydrochloric acid allowed the leaching up to 60% of tin and about 50% of lead, as well as the iron. Nitric acid was the most efficient leachant due to its oxidizing properties. Recoveries of 90% or more for copper, iron, nickel and zinc were achieved at the higher temperature. Lead was also dissolved (up to 80%), as well as silver (more than 70%). These results show that the hydrometallurgical recovery of most of the metals present in PCB's scrap is a technically feasible alternative that shall be considered and evaluated.

Introduction

Printed circuit boards (PCB's) are electronic components with special interest due to its high potential economic value and environmental concern. The management of end-of-life PBC's involves its removal from electronic devices during the dismantling phase, and treatment in process units for metals recovery. Usually PCB's are shredded being the metal fraction separated by physical methods and then sent to secondary copper smelters. The alternative technology is the hydrometallurgy, in which metals are dissolved, purified in aqueous media and recovered.

Due to the high complexity of PCB´s, which contain numerous chemical elements in their composition, selective leaching using different agents is a possible approach to be considered, since can allow to extract selectively some groups of metals in successive leaching stages, improving and simplifying the following separation steps. In this sense, the solubility of metal ions in the various media (e.g. sulfate, nitrate, chloride) is the starting point for the development of the selective leaching process. As example, silver is practically insoluble in chloride media while lead is very insoluble in sulfate media. Noble metals such as Pd, Pt and Au would be only soluble under extreme conditions such as in *aqua regia*.

Taking in consideration the chemical stability of different species, a multistep efficient leaching process could be developed. In this paper, results of laboratory studies on the leaching of basic metals contained in printed circuit boards in different aqueous acid media are presented and discussed.

Results and Discussion

Leaching experiments were carried out in lab stirred vessels, at controlled temperature (25 and 90ºC), for 4 hours of reaction time, with liquid/solid ratio L/S=25 L/kg and using 2 M H^+ leaching solutions (with sulfuric, hydrochloric and nitric acids).

The use of nitric acid allowed achieving higher leaching yields since this leachant has simultaneously acid and oxidizing properties. Weight loss of solids was up to 40% with HNO_3 and was substantially lower with the other two acids (Fig. 1a). Most of the metals in PCB's reacted efficiently with HNO_3 (Fig. 1b), mainly in hot conditions, achieving recovery yields of 80-100% for Cu, Fe, Ni, Zn, Pb and Ag. Solubilization of copper with sulfuric or hydrochloric acid, for the conditions tested and without an auxiliary oxidant was negligible, as well as for other metals such as Ni, Zn and Ag. The use of chloride media seems more adequate for metals such as tin and lead. Tin behavior is quite complex, since was much more soluble in chloride than in sulfate media; moreover, tin leaching was depressed with nitric acid under hot conditions, probably due to the formation of oxidized Sn(IV) species which can precipitate as hydroxide even under low pH conditions. Aluminium leaching was always low, because a substantial part of this metal is present in PCB's as ceramic materials, very refractory to chemical attack.

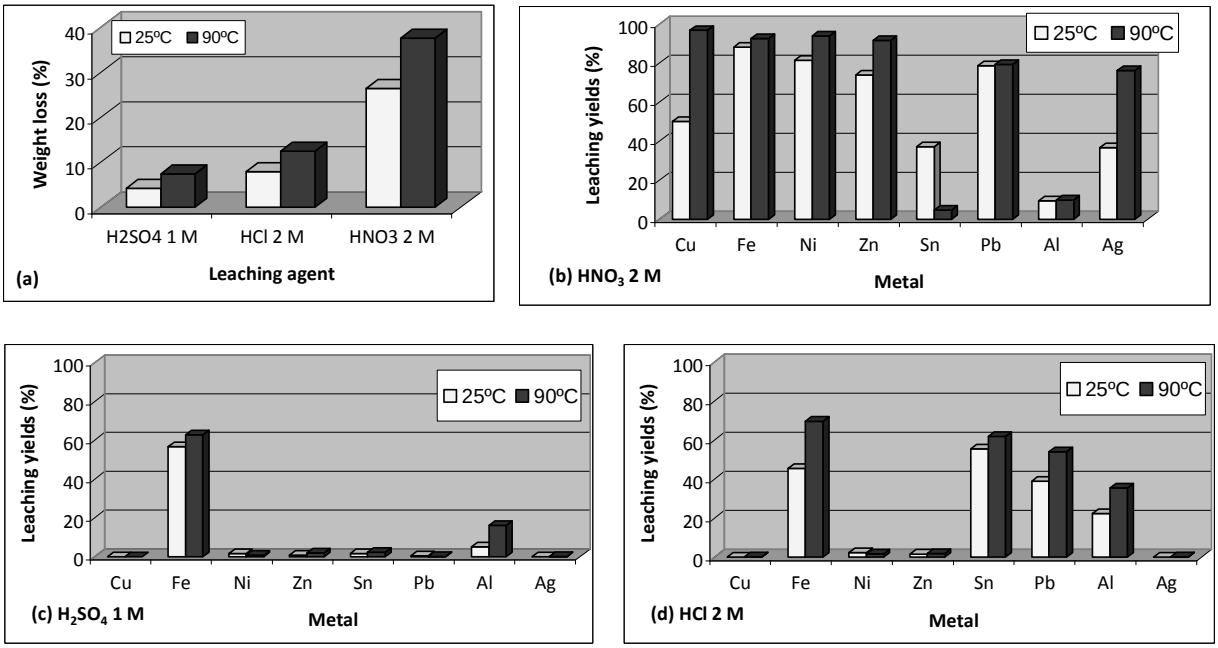

Figure 1 – Results of leaching tests: (a) weight loss; (b), (c) and (d) leaching yields for the several metals with different acid leachants.

Results obtained confirmed most of the theoretical predictions about behavior of metals in different acid media. Several treatment options can be withdrawn from the results, combining successive leaching steps to solubilize selectively groups of metals. As example, a first leaching step with HCl, in optimized conditions, can allow the recovery of most of Sn and Pb; a second leaching step with HNO_3 can recover most of the other metals (Cu, Zn, Ni, Ag). The solutions generated can subsequently be processed for metals separation by hydrometallurgical operations (e.g. precipitation of silver as AgCl and copper recovery by solvent extraction).

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