

6- SUMMARY

The present study aims at making dual use of the spent printed circuit boards by recovering product values of the available metals and safe recycling of the polymer boards. Analysis revealed that copper, lead and tin are the common metals in the boards while gold strips may be detected in some special boards. The base material of the boards is a polymeric material coated with copper. Scoring of the goal was matched by two methods; a pyrometallurgical and hydrometallurgical routes.

Experimental facilities such as chamber and tube furnaces, gas purification system, glass ware, measuring appliances, chemicals and hardware tools for measuring temperature, pH, time and other parameters were prepared. Standard methods given in the literature for measuring the properties of the input, intermediate and end products were applied throughout the experimental study. The following experimental steps were then executed: visual inspection to get rid of foreign contaminants. Classification of the printed circuits scrap into: PCBs containing copper only, PCBs containing copper, tin and lead. PCBs containing copper and gold.

Part of the washed sample was fired at temperatures up to 850°C in normal atmosphere to achieve complete burning off of the polymeric material. The ash was dissolved in mineral acids to recover the respective metals.

Other part of the un-burnt PCBs was leached in hot solution of the respective acid having different molarity and filtered. The hot filtrate was cooled to $\approx 15^\circ\text{C}$ to help deposition of meta-stannic acid (basic tin oxide). Lead and copper ions were

separately recovered on cold by chemical precipitation as chloride and sulfide, respectively.

Gold strips in the PCBs sample remained un-dissolved. It was filtered, fluxed with boiling sodium persulfate in concentrated sulfuric acid for polishing. Polished gold strips were then washed with water and ethyl alcohol.

In the first method, the spent PCBs were heated at temperature up to complete burning off of the polymeric base material and oxidation of the metals. Ash left behind heat treatment was leached with nitric acid to achieve adequate dissolution. The main disadvantage of this method is that it was highly polluting and some of the metals escaped with the carbon fugitive emissions. The base material was fully decomposed and lost.

The other method to recover metal values from the spent PCBs was the hydrometallurgical treatment. The method started by washing the boards, dried in normal atmospheric conditions, and then immersed in the acid solution maintained at about 90°C for enough time (90 minutes) to attain complete dissolution. Three mineral acids were examined; sulfuric, nitric and HCl acids. The most acceptable acid was the nitric acid based on the following reasons:

All available metals dissolve without pollution hazards in hot conditions except gold.

The acid was aggressive so that low concentration can be used. Heating the leaching medium at relatively low temperatures (<90°C) was found satisfactory to

achieve successful leaching. Stirring the leaching reagents helped to attain complete dissolution of the metals of concern in shorter time.

The base material was in good conditions after leaching the metals. In other words, the acid did not decompose or attack the polymeric material under any leaching conditions.

Results showed that pyrometallurgical treatment was not suitable to achieve the goals. On the other hand, hydrometallurgical method is acceptable on basis of the high recovery extent and safety. The recovery extent amounted to 98.5% with copper, 96% with lead, 99.4 % with tin and 100% with gold. Different salts such as chloride, sulfate, carbonate and stearate of copper, tin and lead were also prepared in high purity conditions. The process economics showed that a high added value is achieved amounting to > 115 %.

7- CONCLUSIONS

The output conclusions of this work highly recommends the hydrometallurgical treatment of the useless printed circuit boards based on the following reasons.

1. The method is simple, safe, friendly and non polluting.
2. It also conserves the mineral resources, alleviates waste materials and saves money.
3. The extent of recovery is high and the products are technically pure.
4. The products are pure.
5. The base boards after removal of metals were found clean, smooth surface and can be re-used for the manufacture of new circuit boards.
6. The process economics showed that a high added value is achieved amounting to > 115 %.