INVESTIGATION INTO FROTH FLOTATION FOR THE BENEFICIATION OF PRINTED CIRCUIT BOARD COMMINUTION FINES

by

Iyiola Olatunji Ogunniyi

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Supervisor: Prof. Thys (MKG) Vermaak

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Ololito ni iwo Olorun mi,

Ko si ayida ojiji lodo re,

'Wo ko yi pada, aanu re wa titi

Ololito l'Olorun je si mi.

James 1.17

. . . 'Behold, I come quickly'.

- *Jesus the Christ.*

UNIVERSITEIT VAN PRETORIA
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Abstract

In resource recovery from end-of-life printed circuit board (PCB), the physical processing route is considered most environmentally friendly. The −75 µm fraction generated during the comminution assays well above many precious and base metal deposits, but contributes overall drop in value recovery. This investigation was aimed at exploiting the versatility of froth flotation for beneficiation of the PCB comminution fines.

Chemical composition characterisation work shows wet assay of constituents in the sample vary with digestion condition. Absolute assays as for hazardous constituents thus require comparison of data from more than one digestion condition. Comparative assaying of samples from beneficiation treatments can use aqua regia digestion which gives a less hazardous procedure compared to hydrogen fluoride combined with microwave and nitric acid treatments. It also gives leach liquor from which all constituent elements can be analysed, compared to that from total digestion via sodium peroxide fusion. For this sample total digestion will therefore not always give better results compared to partial digestion. Findings also show that thermogravimetric analysis may not be recommended in PCB characterisation. It gave no distinct inflexion point to characterize any constituent. This is due to the very diverse material constituents of the sample.

Further on characterisation, the sample gave a loose bulk density lighter than water, and true sample density of 3 g/cm^3. This coupled with surface hydrophobicity observed necessitates that pulping the sample must be done under water. Light optical and scanning electron microscopy showed particle liberation was very high, but not total. Morphology of the metallic particles was very diverse, with average circularity shape factor of 0.63. This coupled with the material diversity is a major constraint in sub-sieve size analysis of the sample. As shown by scanning electron microscopy energy dispersive X-ray spectroscopy, the liberated particles themselves contain more than one chemical element, being alloys. Beneficiation operation therefore cannot attempt to separate such particles into constituent elements but some bulk collection of metallic values into a concentrate.

Reverse flotation of metallic values based on a scheme described as natural hydrophobic response (NHR) was found successful. Favorable kinetics under the scheme gave about 500 rpm and 500 ml/min aeration rate, at 300 g sample in a 3.5 *l* Leeds cell. Without the use of a collector, natural hydrophobic response was observed. The system also gave a stable froth without the aid of a frother. Investigations (surface tension and dynamic froth stability height measurements, combined with general literature) show the NHR froth is a fine particle stabilised froth, and not surfactant stabilised. Au and Pd, were among the elements best enriched into the sink; 64 % recovery for Au at enrichment ratio of three. Flotation over narrower and coarser fraction (+106 – 75 µm) shows the NHR scheme can be successfully applied at this size.

Chemical conditioning schemes investigated shows very minimal responses to reagents. Potassium amyl xanthate (PAX) did not condition the metallic particles for flotation remarkably as it does with native metals. Sulfidation with sodium hydrogen sulfide shows a little improvement in response to PAX. Sodium mercaptobenzothiazole – a very selective collector for tarnished copper and lead minerals – did not show such selectivity in the PCB comminution fines pulp. Some cationic pull with tetrabutyl ammonium chloride towards selective pull of non-metallic values after NHR pull has subsided was observed, although very little also. Macromolecular depression with carboxyl methyl cellulose did not subdue the natural hydrophobic response up to profuse percentage dosages. Depression by lowering surface tension, described as gamma depression, using Betamin 127A (active constituent: ethoxy nonyl phenol)

was effective to wet hydrophobic particles, but still not helpful for selective pull after chemical conditioning. At the lowered surface tension, frothing sets in coupled with entrainment.

Probable causatives for the poor response to reagents are surface oxidation of the metallic particles and depression by calcium ions in pulp. Surface studies with field emission scanning electron microscope and auger electron spectroscopy composition depth profiling, show presence of organic layers on the surface of the metallic particles. The surfaces were also found to be oxidised down to about 340 nm depth profiled. None of the surfaces is a pure alloy, but occurring in forms that will be relatively inert to reagents. Beside these, from aqua regia wet assaying, the sample contains about 7 % calcium by mass, and ICP-MS trace element analysis of the process water confirms calcium presence up to 7 ppm equilibrium concentration in the pulp.

Judging from the responses, the natural hydrophobic response scheme can be well recommended for PCB comminution fines flotation. Optimisation of the performance of the scheme responds remarkably well to kinetic parameters variation. With the generally low impeller energy and aeration rate found favourable for PCB CF flotation, and the zero reagent cost (no collector, no frother) of the NHR scheme, PCB comminution fines flotation shows good prospects.

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'Tunji OGUNNIYI.
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