Environmentally friendly recovery of valuable metals from e-wastes

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Background

E-waste is considered a potential resource. However, the current e-waste recycling is only 17.4%. E-waste management and recycling are crucial to environmental sustainability and carbon emissions reduction. Printed circuit boards (PCBs) are a valuable sub-system of e-waste. Although PCBs account for 3−6 wt.% of the total e-waste, they contain lots of valuable metals such as Cu, Zn, Ag, and Au, especially compared to natural ores. It was estimated that the cost of mining natural oral is nearly 7 times that of recycling PCBs to produce the same quality of Au, Ag, Cu, Al, and steel. However, the main used methods for PCBs treatment, landfill and pyrometallurgy, cause serious environmental and health concerns.

Objectives

- To create an efficient method to remove ECs from PCBs.
- To recover critical materials from waste PCBs to minimize military logistic tail.
- To improve the environmental friendliness of the e-waste recycling process.
- To enable the technology transfer to industry.

Design Principle

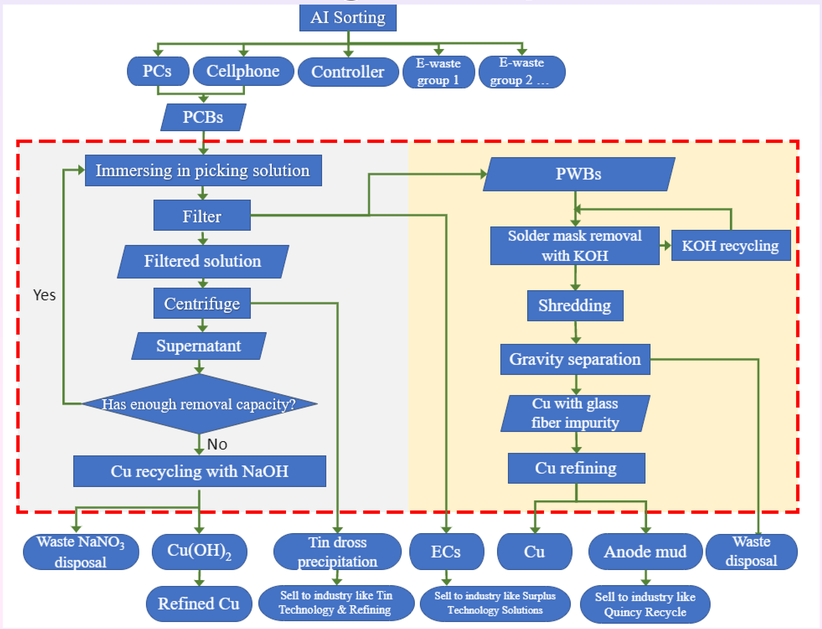

Figure 1. PCBs recycling process

Experiment Procedure

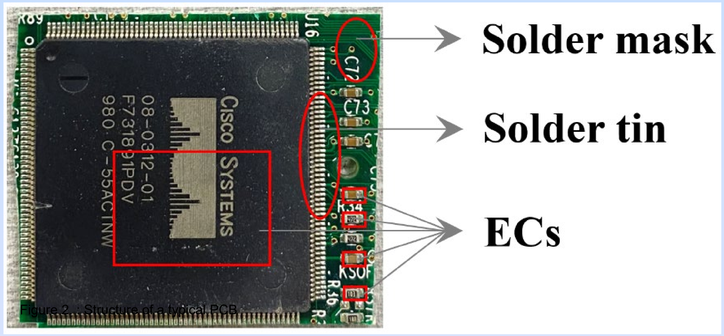

Figure 2. Structure of a typical PCB

Figure 2 shows a typical PCB. ECs are fixed and connected on the surface of PCBs by solder tin. In our approach, solder tin is removed by pickling solution to release the ECs from PCBs. To remove tin, a typical pickling solution reported in the literature (Tang et al., 2021) was used as the starting point with 40% (v/v) HNO_3 and additives (40 g/L $Fe(NO_3)_3$, 5 g/L $FeCl_3$, 5 g/L NaCl, 5 g/L sulfamic acid and 10 g/L benzotriazole). The pickling solution is commonly used in the PCBs manufacturing industry. The main reaction is the reaction between nitric acid and tin. Different dominant reactions between nitric acid and tin occur at different conditions.

Following are some possible mechanisms:

- $3Sn + 4HNO_3 + H_2O \rightarrow 3H_2SnO_3\downarrow + 4NO\uparrow$
- $Sn + 4HNO_3 \rightarrow H_2SnO_3\downarrow + 4NO_2\uparrow + H_2O$
- $4Sn + 10HNO_3 \rightarrow NH_4NO_3 + 4Sn(NO_3)_2 + 3H_2O$

To optimize the efficiency of tin removal, a range of pickling solution compositions have been experimented (Figure 3).

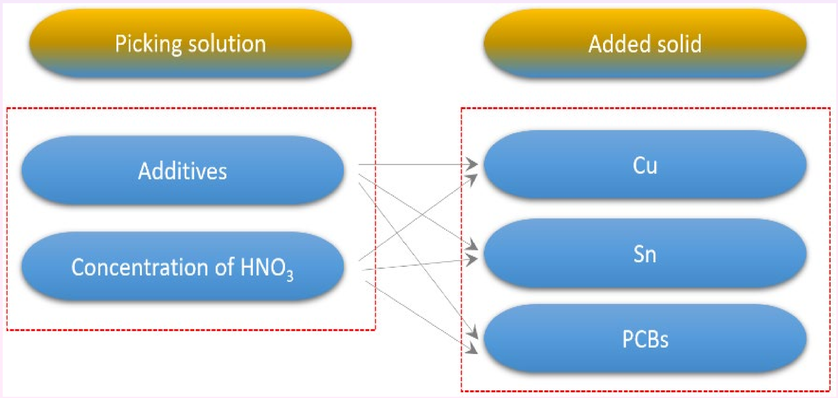

Figure 3. Different experiment conditions for pickling solution.

Results

Both reaction rates of Sn and Cu with the pickling solution increase with the increase of HNO_3 concentration. At 20% HNO_3, both Sn and Cu reaction rates were rather slow. It took overnight to remove the solder tin from PCBs. At 40% HNO_3, both Sn and Cu reaction rates were fast and resulted in low selectivity. 35% of HNO_3 was found to provide a good balance between selectivity and time needed to remove solder tin. Thus, an optimized pickling solution recipe was determined to be: 35% (v/v) HNO_3 and additives (40 g/L $Fe(NO_3)_3$, 5 g/L $FeCl_3$, 5 g/L NaCl, 5 g/L sulfamic acid and 10 g/L benzotriazole).

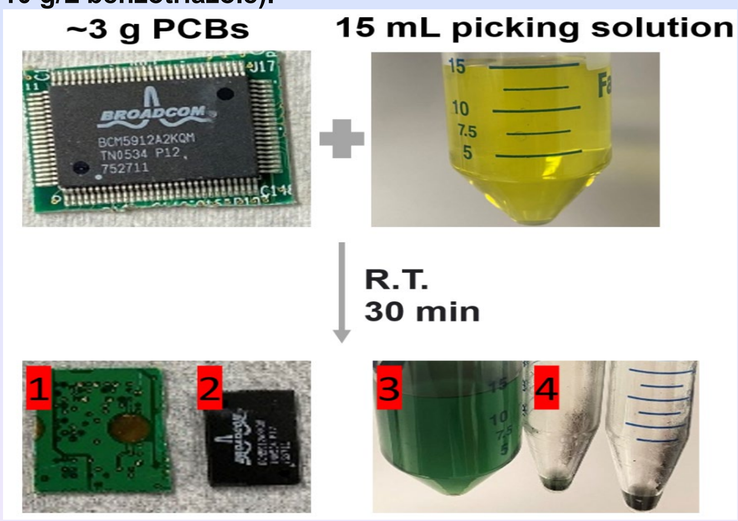

Figure 4: The process of removal of ECs from PCBs by pickling solution

Conclusions

In conclusion, the team developed an optimized pickling solution to remove ECs from PCBs and recycle tin in one step. This process is efficient, easily scalable, time-saving and cost-saving, especially compared to traditional manual dismantling. The pickling solution is recyclable which improves the environmental friendliness of the process.

References

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