SOLVING A WEEE PROBLEM:
Electrochemical Recovery Of Metals From End-of-life Electrical &
Electronic Systems

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BACKGROUND

Nearly a million tonnes (93 million items) of waste electrical and electronic equipment (WEEE) and two million automotive, containing many electronic systems, are discarded in the UK each year. Furthermore, only about 20 % of the UK’s 350,000 tonnes p.a. waste IT equipment is being reprocessed, the remainder being sent to landfill (Figure 1).

Implementation of the European Directive on WEEE imposed producer responsibility and 75% recycling targets in the UK in January 2007. The EU End-of-life Vehicles Directive also requires the recovery/re-use of materials in end-of-life vehicles to be increased from the present 85 % (mostly metallic) to 95 % by Jan 2015. These will require new processes to be developed and applied, to recover metals from WEEE and EESs.

PROCESS OVERVIEW

A flow circuit for the proposed two step process is shown schematically in Figure 3.

In a leach reactor, metals (copper, tin, lead, gold, silver, and platinum etc.) are dissolved from shredded EESs and WEEE using chlorine in acidic aqueous chloride solutions. The metals are then recovered from solution by electrodeposition at the cathode of a membrane divided electrochemical reactor, the anode of which is used to re-generate the chlorine. In principle, with the input of electrical energy, the process produces de-metalised polymers, metals, and no additional waste or effluent streams. The process chemistry is summarised below.

Leach reactor:

\[
M_{scrap} \rightarrow \{n-z\}C\,^\rightarrow + \frac{z}{2}2Cl^- \rightarrow MC\,^{(n-z)}
\]

Electrochemical reactor:

Anode (e.g., Ti/ RuO\textsubscript{2}):

\[
z(2Cl^- + \text{anolyte}) \rightarrow Cl_{2}(g) + 2e^-
\]

Anion-exchange membrane:

\[
zC\,^\rightarrow + 2C\,^\rightarrow \rightarrow zC\,^{(n-z)}
\]

Cathode (e.g., Carbon felt):

\[
MC\,^{(n-z)} + z2e^- \rightarrow M_{\text{new}} + zC\,^{(n-z)}
\]

Overall:

\[
\text{Overall process reaction: } M_{\text{scrap}} \rightarrow M_{\text{new}}
\]

However, electrical and electronic systems (EESs) contain both valuable (copper, precious metals) and hazardous (lead, chromium) metals. Removing these metals (Figure 2) from the landfill stream has consequential environmental and economic benefits.

STEP 1 - DISSOLUTION OF METALS

Leaching experiments have shown that, for the base metals (copper, tin, lead), a leaching conversion of greater than 99 % can be achieved in about three hours. The dissolved precious metal concentrations (gold, platinum) increased more slowly, 80-95 % being dissolved after eight hours, as shown in Figure 4.

A model of the reactor has been developed, using leaching kinetics measured with a rotating disc electrode, to predict the effects of factors such as particle size, flow rate and direction. Larger scale experiments (Figure 5), to process 1-2 kg of shredded electronics, are also being performed in a packed bed column reactor to optimise the process.

STEP 2 - METAL RECOVERY BY ELECTRODEPOSITION

As shown in Figure 6, complete recovery of copper, tin, lead, silver, gold and palladium from the leachate solution is possible by electrodeposition at greater current efficiencies; at higher pHs, aluminium hydroxide can be precipitated and recovered.

A circulating particulate bed electrode (CPBE) reactor or a titanium mesh cathode in a fluidised bed of glass beads, Figure 7, enable continual recovery of most of the metals by electrodeposition, at rates depending on the particular metal and electrode potential.

The electrical energy cost of recovering the metals from solution is about £250 per tonne of scrap, compared with a metal value of over £2000 per tonne of scrap.

CONCLUSIONS

Research at Imperial College London has demonstrated the feasibility of removing a high percentage of both the hazardous and valuable metals from electronic scrap, at low cost, enabling them to be re-used, rather than posing an environmental hazard in a landfill.