RESEARCH ARTICLE

Electrochemistry during efficient copper recovery from complex electronic waste using ammonia based solutions

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Abstract Leaching selectivity during metal recovery from complex electronic waste using a hydrochemical process is always one of the generic issues. It was recently improved by using ammonia-based leaching process, specifically for electronic waste enriched with copper. This research proposes electrodeposition as the subsequent approach to effectively recover copper from the solutions after selective leaching of the electronic waste and focuses on recognising the electrochemical features of copper recovery. The electrochemical reactions were investigated by considering the effects of copper concentration, scan rate and ammonium salts. The diffusion coefficient, charge transfer coefficient and heterogeneous reaction constant of the electrodeposition process were evaluated in accordance with different solution conditions. The results have shown that electrochemical recovery of copper from ammonia-based solution under the conditions of selective electronic waste treatment is charge transfer controlled and provide bases to correlate the kinetic parameters with further optimisation of the selective recovery of metals from electronic waste.

Keywords copper recovery, electronic waste, end-of-life products, selective leaching, electrodeposition

Supplementary Information

1. Selective leaching of copper from complex electronic waste

The reactions between copper and the leaching solution are

$$\mathrm{Cu}+\frac{1}{2}\mathrm{O_2}\rightarrow\mathrm{CuO}, \quad \text{(S1)}$$

$$\mathrm{CuO}+2\mathrm{NH_3}\cdot\mathrm{H_2O}+(\mathrm{NH_4})_2\mathrm{X}\rightarrow\mathrm{Cu(NH_3)_4X}+3\mathrm{H_2O}. \quad \text{(S2)}$$

where X represents an anion from the ammonium salt (carbonate or sulphate for instance).

2. Electrodeposition of copper from leach solution

Table S1 Pure copper electrodeposited directly from leach solution (with ammonium carbonate) comparing with the composition of the ICT waste

Elements	Cu	Sn	Fe	Al	Pb	Zn	Ni	Ag	Cr	Au

Original ICT waste /wt-%	49.66	2.27	4.03	2.30	1.99	2.65	2.20	0.064	1.37	0.012

Elements	Al	Cu	Fe	Ni	Pb	Zn	Sn
Leaching solution /g·L^{-1}	0.01	57.01	0.02	0.10	0.13	1.75	0.06

Elements	Cu	Al	Si	Ni	Pb
Electrodeposited copper /wt-%	99.78	0.019	0.008	0.023	0.069

3. Nucleation model

As responses to the applied potentials, maximum current densities appear, i.e. the i_m, t_m which are related to the copper nucleation and growth processes and a decaying in the current density converging to the limiting current density in correspondence to the diffusion of copper amine complex.According to the model by Scharifker and Hills [1], the experimental data can be simplified into two limiting nucleation mechanisms, i.e. instantaneous and progressive. Instantaneous nucleation (equation (S3)) corresponds to a slow growth of nuclei on a small number of active sites and all the nuclei are formed prior to the growth. The progressive model (equation (S4)) describes that the nuclei forms progressively.

$$\frac{i^2}{i_m^2}=\frac{1.9542}{t/t_m}\left\{1-\exp\left[-1.2564\left(\frac{t}{t_m}\right)\right]\right\}^2 \quad \text{instantaneous (S3)}$$

$$\frac{i^2}{i_m^2}=\frac{1.2254}{t/t_m}\left\{1-\exp\left[-2.3367\left(\frac{t}{t_m}\right)^2\right]\right\}^2 \quad \text{progressive (S4)}$$

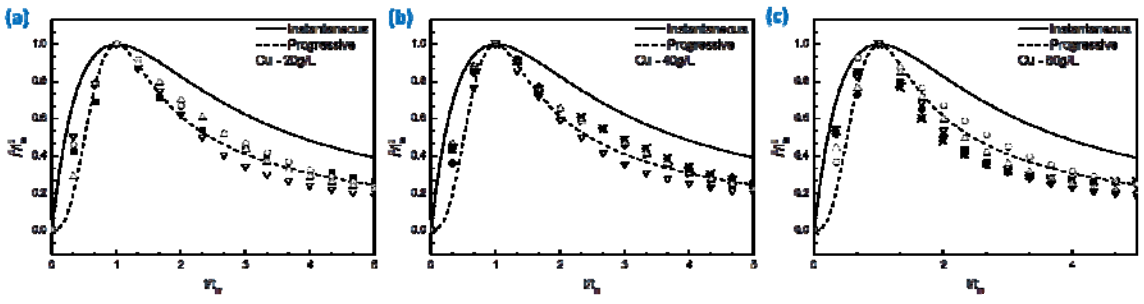

Fig. S1 Nucleation mechanisms for solutions with different copper concentrations using chronoamperometry

Reference

1 Zoski C G. Handbook of Electrochemistry. Elsevier, 2006