Gold Electrowinning from Acidic Aqueous Chloride in a Packed Bed Electrode

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A novel process[1] is being developed to recover metals from waste electrical and electronic equipment (WEEE) using an acidic aqueous chloride electrolyte. Chlorine, anodically generated in a membrane-divided electrochemical reactor (Fig. 1), dissolves metals (Ag, Au, Cu, Pd, Sn, Pb, etc.) from shredded WEEE in an external leach reactor, and the metals are electrodeposited at the cathode[2,3], enabling their subsequent recovery and refining. Hence, the overall process involves inputting electrical energy to move the metals from WEEE to cathode and, in principle, additionally produces only de-metallised WEEE, for further processing.

As the precious metals (Ag, Au, Pd, Pt) are present at low concentrations, cathodes with high specific surface area and mass transport rate coefficients are required for their selective electrodeposition at economically viable rates. Fig. 2 shows results for the depletion of $AuCl_4^-$ and $AuCl_2^-$ ions to concentrations well below 1 g m^{-3}, at high current efficiencies, in a packed bed electrode of carbon chips with specific surface area a in contact with a Ti/Pt feeder electrode and operated in batch recycle mode.

Atomic absorption and UV spectrophotometric analyses of the electrolyte established that, depending on the potential and flow rate, Au(I) species could be produced as intermediates in the reduction of $AuCl_4^-$ ions, as implied in Fig. 2, though the decay in total dissolved gold concentration (c) in catholyte volume V followed approximately the exponential decay with time t expected for mass transport controlled processes, with rate coefficient k_m at volumetric flow rate u:

$$c_t = c_o \exp\left\{-\frac{ut}{V}\left[1 - \exp\left(-\frac{\bar{k}_m A a L}{u}\right)\right]\right\} \qquad [1]$$

This suggests a more complex reaction mechanism than two parallel mass transport controlled reductions of $AuCl_2^-$ and $AuCl_4^-$ ions initially present in the 1 kmol HCl m^{-3} electrolyte. The results will be interpreted in terms of the sequential reactions:

$$AuCl_4^- + 2e^- \rightleftharpoons AuCl_2^- + 2Cl^- \qquad [2]$$

$$AuCl_2^- + e^- \rightleftharpoons Au + 2Cl^- \qquad [3]$$
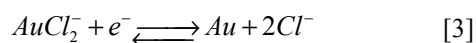
with time / concentration / current density dependent potential profiles in the packed bed cathode. This enabled some $AuCl_2^-$ intermediates to desorb into the electrolyte without immediate further reduction, for the particular potential applied between the feeder electrode and a reference electrode at the bed / membrane interface.
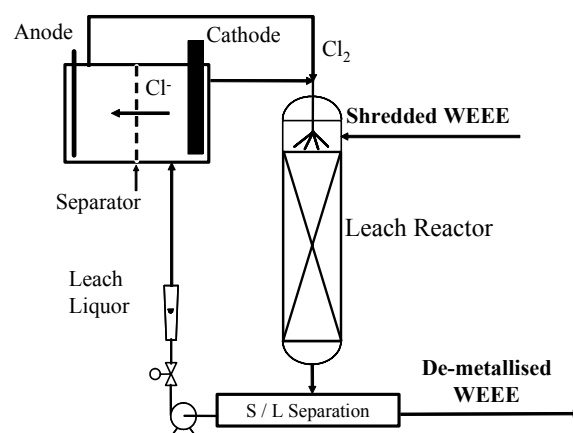

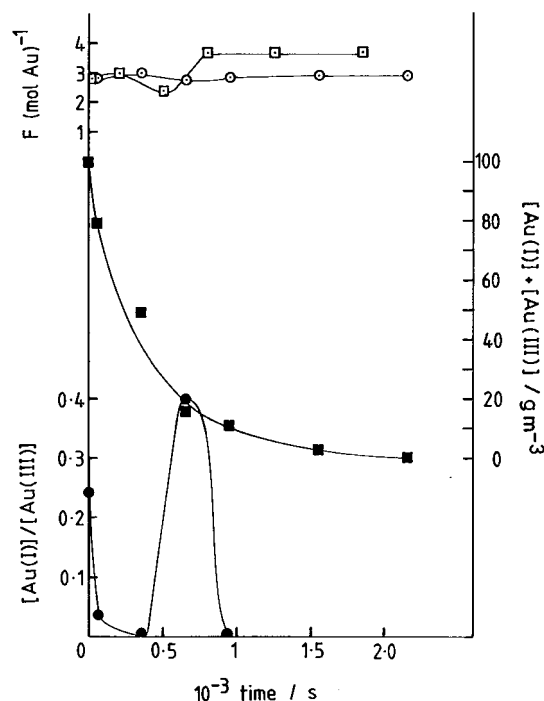Fig. 1. Process flow diagram of electrochemical and leach reactors for recovering metals from WEEE.

Fig. 2. Time dependences of total dissolved gold concentration (■), [Au(I)]/[Au(III)] molar ratio (●), and incremental (⊙) and cumulative (□) Faradays per mole of gold deposited in the packed bed electrode of 2-3 mm graphite chips, with dimensions 0.145×0.046×0.01 m^3, and estimated particulate area ca. 0.094 m^2, operating with a feeder-membrane potential difference of 0.53 V (SHE), electrolyte superficial flow rate 3.5×10^{-2} m s^{-1}.

ACKNOWLEDGEMENTS

REFERENCES

1. N.P.Brandon, G.H.Kelsall, T.Müller, R.Olijve, M.Schmidt and Q.Yin, in Proc.Electrochem.Soc. Vol.2001-23, C.Comninellis, M.Doyle and J.Winnick (Eds.), Electrochem.Soc., N.J., 2001, pp.323-338.
2. D.Pilone and G.H.Kelsall, *Electrochim.Acta*, in press, 2005.
3. D.Pilone and G.H.Kelsall, *J.Electrochem.Soc.,* in press, 2006.