Selective electroextraction of Sn-Pb from Cu free leaching solution obtained during the recycling of waste printed circuit boards using the KBr-HBr system

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INTRODUCTION

Worldwide, the Waste Electrical and Electronic Equipment (WEEE) is among the largest categories of dangerous waste, which grows with 3-5% per year [1]. Waste Printed Circuit Boards (WPCBs) are a metal-rich fraction of WEEE streams and their recycling to recover metals promotes the preserving of the natural resources [2], being recognized as multi-metal urban ores [3]. Their recycling by electrochemical processes have high environmental compatibility and energy efficiency [4, 5].

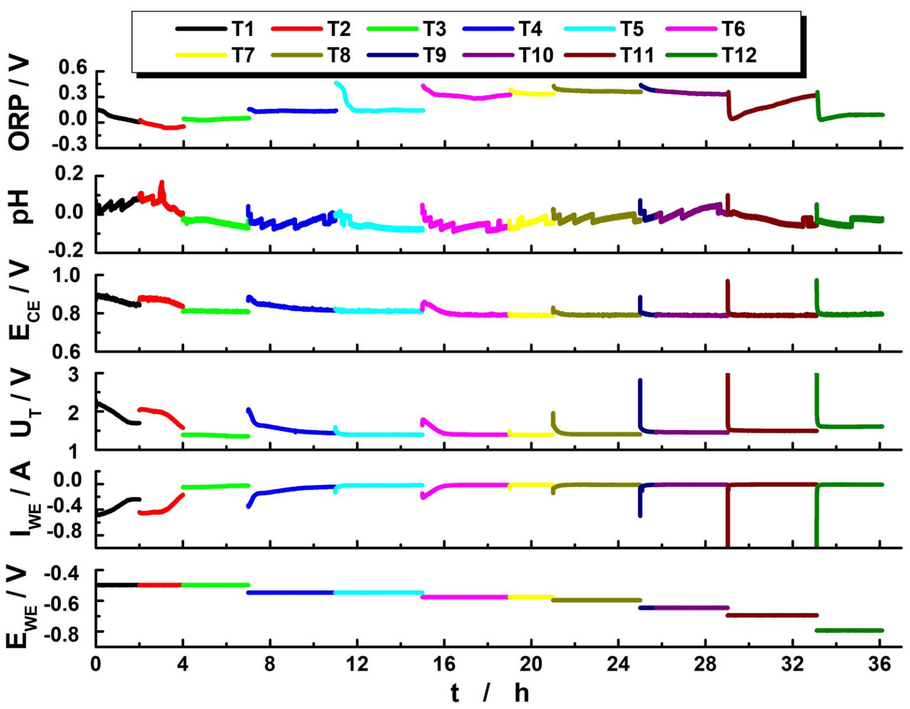
The present work aims to study the process of potentiostatic selective electroextraction of Sn and Pb from a Cu-free real leaching solution (RLS) based on the KBr/HBr/Br_2 system.

EXPERIMENTAL

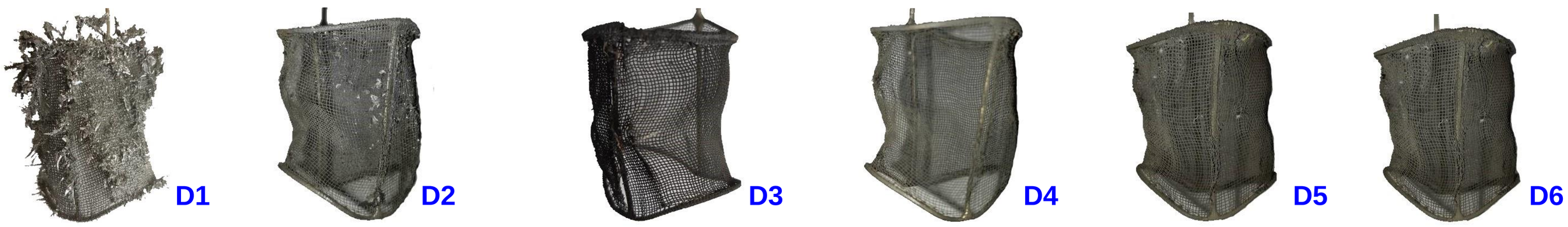
- ✓ **Electrochemical cell:** 1 L polypropylene electrochemical cell divided by a ceramic membrane;
- ✓ **Anode & Counter-electrode (CE):** Graphite bloc of 71.5 cm^2 active area;
- ✓ **Cathode & Working electrode (WE):** Fisher-type Pt electrode;
- ✓ **Reference electrodes (Ref.):** Ag/AgCl/KCl_{SAT};
- ✓ **Anolyte:** 2 L of 2 M KBr aqueous solution recirculated at 150 mL/min;
- ✓ **Catholytes:** 0.5 L of stirred RLS containing Sn, Zn, Al, Fe, Pb, Ni and Cu of 7.9, 7.5, 6.9, 5.9, 4.0, 0.62 and 0.008 g/L, respectively;
- ✓ **Equipment:** DXC236 P/G-stat (Datronix Computers, Romania); TC peristaltic pump (Medorex, Germany); 2 C863 laboratory multimeters (Consort, Belgium); Spectro CIROS CCD ICP-AES (S.A.I., Germany).

RESULTS AND DISCUSSION

- The cathode potential (I_{WE}) was set to more negative values when the current through it (I_{WE}) decrease under 10% from its initial value.
- All obtained deposits were washed, dried and weighed. Further, they were removed from the Fisher WE using *aqua regia* and the resulting solutions were analyzed by ICP-AES.



Deposit codes	Tests	E_{WE} (V/Ref.)	$I_{WE, M}$ (mA)	m_D (g)	C_{EFF} (%)	W_S (kWh/kg)	Cu (%)	Sn (%)	Pb (%)	Fe (%)	Ni (%)	Zn (%)	Al (%)
D1	T1+T2	-0.50	-368.5	1.486	47.5	1.63	0.00	99.8	0.01	0.01	0.01	0.00	0.01
D2	T3	-0.50	-40.5	0.128	45.1	1.90	0.00	99.1	0.04	0.13	0.02	0.04	0.10
D3	T4	-0.55	-100.2	0.795	94.5	0.81	0.00	55.6	43.6	0.02	0.00	0.01	0.01
D4	T5	-0.55	-24.7	0.026	8.9	5.24	0.01	49.3	48.8	0.52	0.02	0.24	0.11
D5	T6	-0.58	-42.5	0.387	64.2	0.68	0.00	14.6	82.6	0.03	0.05	0.01	0.01
D6	T7	-0.58	-14.7	0.081	12.3	4.99	0.02	79.7	19.2	0.16	0.17	0.05	0.07
D7	T8	-0.60	-15.6	0.046	29.5	1.93	0.01	82.6	13.9	0.23	0.19	0.10	0.09
D8	T9+T10	-0.65	-17.0	0.019	16.2	6.07	0.01	89.1	8.65	0.70	0.91	0.54	0.05
D9	T11	-0.70	-9.7	0.010	11.7	6.38	0.02	92.3	5.61	1.04	0.36	0.58	0.20
D10	T12	-0.80	-12.0	0	-	-	-	-	-	-	-	-	-



- For each tested E_{WE}, the decrease of Sn and Pb concentrations reduces the mass (m_D) of the electrodeposited metals and favors the H_2 evolution, degrading the values of the current efficiency (C_{EFF}) and specific energy consumption (W_S).
- During the successive tests, depending on the applied E_{WE} and the remaining concentrations of Sn and Pb, the composition of the cathodic deposit changed, including Sn from 99.8 to 14.6% and Pb from 0.01 to 82.6%, while the Cu content did not exceed 0.02%.
- At high concentration of Sn (T1 ÷ T3), dendritic deposit of Sn of high purity (D1, D2) were obtained, after that smooth and compact deposits of Sn-Pb alloys (D3 ÷ D10) resulted, facilitating their extraction from the electrodeposition reactor.
- It is worth to note that the most susceptible impurities (Ni, Fe, Zn) start to be incorporated significantly in the cathodic deposit (Sn-Pb alloy) only at the E_{WE} values under -0.6 V/Ref.

CONCLUSIONS

- The results concerning the C_{EFF}, W_S and the composition of the obtained deposits prove that the selective electrodeposition of Sn-Pb alloys in potentiostatic mode from Cu-free RLSs is a feasible and cost-effective method to obtain good quality and valuable products.
- The process efficiency can be increased by the rigorous control of the main process parameters, such as $[Sn^{2+}]$, $[Pb^{2+}]$, I_{WE} or E_{WE}.
- Using this technology, the $[Sn^{2+}]$ and $[Pb^{2+}]$ in the RLS can be diminished from 7.9 and 4.0 g/L to 0.09 and 1.4 g/L, respectively.

REFERENCES

1. A. Otsuki, L. De L. Mensbruge, A. King, S. Serranti et al., *Waste Manage., 102*, 2020, 510–519.
2. T. Moyo, B.H Chirume, J. Petersen, *Resour. Conserv. Recycl., 152*, 2020, 1-7.
3. F. Moosakazemi, S. Ghassa, F. Soltani, M.R.T. Mohammadi, *J. Hazard. Mater., 385*, 2020, 1-11.
4. C. Cocchiara, S.A. Dorneanu, R. Inguanta, C. Sunseri, P. Ilea, *J. Clean. Prod., 230*, 2019, 170-179.
5. S.A. Dorneanu, A.A. Avram, A.H. Marincaş et al., *Studia UBB Chemia, LXIII, 4*, 2018, 147-158.

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