Electrochemical dissolution behavior of several metals from WPCBs in different bromide-based electrolytes

S. Varvara[1], S.A. Dorneanu[2], R. Bostan[1], M. Popa[1], R. Truță[2], P. Ilea[2,*]

[1]Department of Exact Sciences and Engineering, "1 Decembrie 1918" University of Alba Iulia, 15 -17 Unirii St., 510009 Alba-Iulia, Romania

*[2]Department of Chemical Engineering, "Babes-Bolyai" University, 11 Arany Janos St., 400028 Cluj-Napoca, Romania, *e-mail: pilea@chem.ubbcluj.ro*

INTRODUCTION

Waste printed circuit boards (WPCBs) are the most valuable components of the electrical and electronic equipment wastes, which contain various metallic materials, including precious metals. The concentration of the noble metals, particularly Au, Ag, Pd and Pt is higher than in their primary resources, which makes WPCBs potential sources of recyclable metals. WPCBs contain different hazardous elements, including heavy and toxic metals that may cause significant environmental pollution during the conventional waste treatments by landfilling or incineration. Therefore, the WPCBs recycling is necessary not only for resource recovery, but also for the environmental protection.

In an attempt to develop an innovative and eco-friendly technology for metals recovery from WPCBs, electrochemical dissolution behaviour of Ag, Au, Cr, Ti was investigated in different bromide-based electrolytes, using electrochemical techniques.

EXPERIMENTAL

Corrosion test solutions:

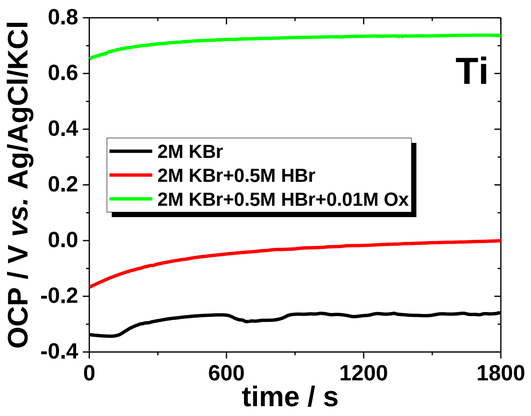
- Sol. A: 2 M KBr
- Sol. B: 2 M KBr + 0.5 M HBr
- Sol. C: 2 M KBr + 0.5 M HBr + 0.01 M Br_2

Electrodes:

- Au (1mm); Ag (1.7mm); Cr (3.5mm) and Ti (3mm) disks as working electrodes
- $Ag/AgCl/KCl_{SAT}$ as reference electrode (Ref.)
- Pt wire (ϕ = 0.5 mm, L 10 cm) as counter electrode

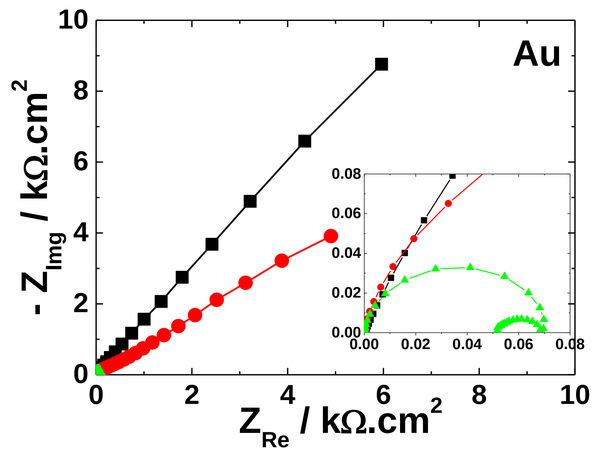
RESULTS AND DISCUSSIONS

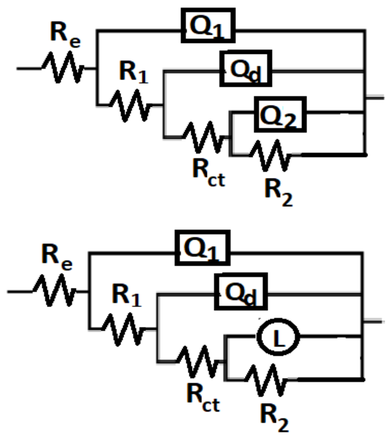
Open-circuit potential (OCP)



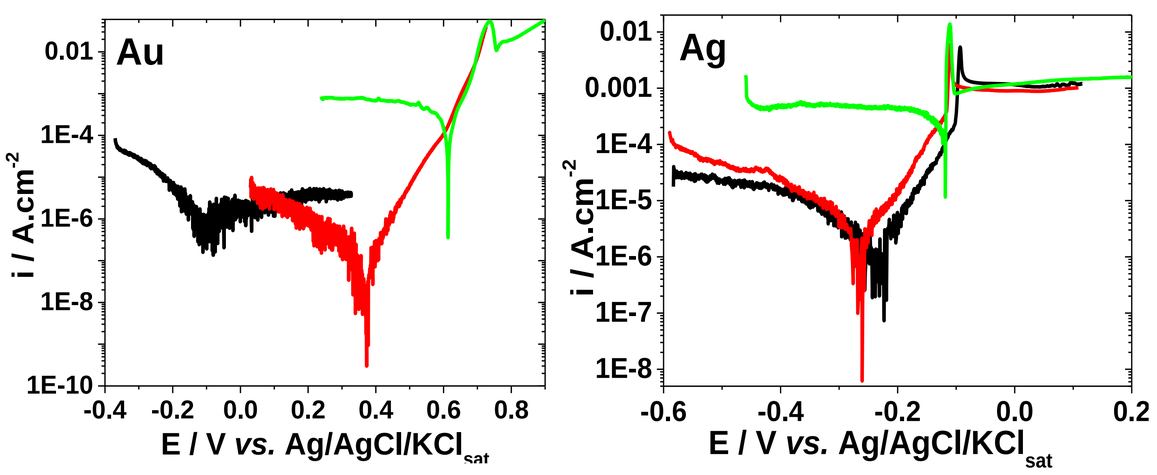
Metal	OCP / V *vs.* $Ag/AgCl/KCl_{SAT}$		
	Sol. A	Sol. B	Sol. C
Au	+0.036	+0.450	+0.614
Ag	-0.236	-0.230	-0.113
Ti	-0.262	-0.002	+0.738
Cr	-0.232	n.d.	+0.103

Electrochemical impedance spectroscopy (EIS)

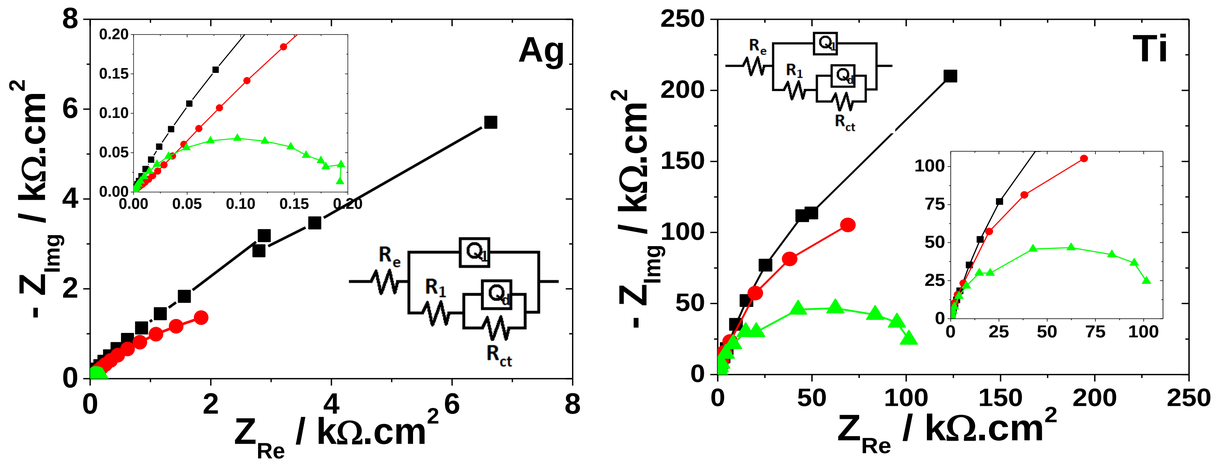




Potentiodynamic polarization measurements



Polarisation curves in different electrolytes: (—) Sol. A; (—) Sol. B;(—) Sol. C (scan rate, 10 mV/min)



Nyquist diagrams corresponding to metals corrosion in different bromide-based electrolytes: (—■—) Sol. A; (—●—) Sol. B; (—▲—) Sol. C.

Electrochemical parameters as function of metal and electrolyte

Metal	E_{corr} (V *vs.* Ref.)	i_{corr} ($\mu A.cm^{-2}$)	β_a ($mV\ dec^{-1}$)	$\lvert\beta_c\rvert$ ($mV\ dec^{-1}$)	v_{corr} µm/hour
Sol. B					
Au	+0.376	0.14	75.2	200.3	0.00055
Ag	-0.260	2.35	68.7	129.6	0.009
Sol. C					
Au	+0.614	267.34	73.9	210.9	1.02
Ag	-0.118	169.16	n.d.	94.7	0.65
Ti	+0.727	0.64	99.8	158.6	0.00064

The results of the regression calculation with the electrical equivalent circuits

Metal	R_e Ω cm²	R_1 Ω cm²	C_1 µFcm⁻²	R_{ct} Ω cm²	C_d mFcm⁻²	R_2 Ω cm²	C_2 mFcm⁻²	L H cm²	R_p Ω cm²
Sol. A									
Au	0.17	1501	272.5	76960	1.7	-	-	-	78461
Ag	0.30	629.7	274.0	28020	3.7	-	-	-	28649.7
Sol. B									
Au	0.20	113.1	27.3	1576	0.18	35360	2.1	-	37049.1
Ag	0.19	12.4	55.2	5668	7.2	-	-	-	5680.4
Sol. C									
Au	0.04	6.1	49	9.1	0.03	4.6	-	20.0	19.8
Ag	0.02	0.4	771.9	20.3	2.7	--		-	20.7

$Q = Z_{CPE(\omega)} = 1 / [C(j\omega)^n]$ $\quad R_p = R_1+R_{ct}+R_2$

CONCLUSIONS

- Except for Cr, which passivates in all studied electrolytes, the corrosion of Au and Ag is significantly enhanced in highly acidic bromide solution, especially in the presence of the oxidizing agent. It allows the generation of the $Br_2 – Br^-$ system in the $HBr-Br_2$ solution, which favors the dissolution of Au and Ag at greater rates, as compared to Br_2 -free electrolytes.
- Ti dissolution rate was also slightly accelerated in the bromide-based solution containing Br_2, as proved by EIS measurements.

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