

**RECOVERY OF GOLD FROM  
ELECTRONIC WASTE THROUGH  
NON-CYANIDE BASED  
ELECTRODEPOSITION TECHNIQUE**

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**UNIVERSITI SAINS MALAYSIA**

**2016**

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THROUGH NON-CYANIDE BASED ELECTRODEPOSITION  
TECHNIQUE**

by

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Thesis submitted in fulfillment of the  
requirements for the degree of  
Master of Science

September 2016

## ACKNOWLEDGEMENTS

Alhamdulillah, all praises to Allah S.W.T for giving me such opportunity and strength to complete my thesis. Special thanks and appreciation wished to my supervisor, Dr. Muhamad Nazri bin Murat, for giving a non-stop supports and advice that build up my motivation on finishing this thesis. With his supervision, I managed to plan my tasks efficiently and as the results, the whole progress went smoothly as planned. Also not to be forgotten, my appreciation to En. Nur Irwin bin Basir, for his guidances in order to solve problems regarding this project.

Next, I would like to express my gratitude to all technicians and office staffs of the School of Chemical Engineering, Universiti Sains Malaysia (USM), especially to En. Shamsul Hidayat, En. Mohd Rasydan, En. Mohd Roqib, En Syed Nor Izwan, En. Che Nurnajib, and En. Muhamad Ismail for their technical supports during my laboratory works. Also, my gratitude to all the staff in the Science and Engineering Research Centre (SERC), USM Engineering Campus especially to En. Muhammad Fakhirul Izwan and En. Muhamad Yasier, as well as to En. Mohammed Nizam from the School of Civil Engineering, USM for all their efforts in analyzing all the samples for me.

Last but not least, special thanks to my lovely parents, En. Nazri bin Abu Bakar and Puan. Khamsiah binti Din, as well as my siblings, for their non-payable contributions and encouragement for me to further pursuing my dreams. Also, to my lovely fiancée, Nursyahira Nabila binti Zulkifli for her moral supports that help to bring me up to my feet and completing my study until the end. May Allah S.W.T bless us all and pays all of your kindness with His Jannah. Amin.

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## LIST OF SYMBOLS

<b>Symbol</b>	<b>Meaning</b>	<b>Unit</b>
\$	U.S Dollar	-
°	Degree	-
μm	Sample Size	Micro-meter or micron
A	Electrical Current	Ampere
C	Temperature	Celcius
C <sub>c</sub>	Allowance for Corrosion	-
cm	Length	Centi-meter
cm <sup>2</sup>	Area	Square centi-meter
e	electron	-
E°	Standard Potential	Volt
E <sub>final</sub>	Potential last to scan in cyclic voltammetry (Final positive potential)	Volt
E <sub>initial</sub>	Potential first to scan in cyclic voltammetry	Volt
E <sub>j</sub>	Joint Efficiency	-
E <sub>prot</sub>	Protection Potential	Volt
g	Mass	Gram
G	Gravity	Meter per square second
g/kg	Amount of metal in sample	Gram of substance per Kilo-gram of sample
g/L	Concentration of metal in sample solution	Gram of substance per Liter of leaching solution

g/mL	Concentration of metal in sample solution	Gram of substance per Milli-Liter of leaching solution
g/t	Amount of metal in sample	Gram of metal per tonne of sample
Hz	Amplitude	Hertz
K	Temperature	Kelvin
kg	Mass	Kilo-gram
kg per capita	Production mass of metal	Kilo-gram per capita
kV	Voltage	Kilo-Volt
L	Volume of solution	Liter
M	Concentration	Molarity
mA/cm <sup>2</sup>	Current Density	Milli-Ampere per Square Centi-Meter
mg	Mass	Milli-gram
mg/kg	Mass concentration of metal	Milli-gram of metal per Kilo-gram of sample
mg/L	Concentration of metal in solution	Milli-gram of metal per Liter of sample solution
mins	Time duration	Minutes
mL	Volume of solution	Milli-Liter
mm	Length	Milli-meter
mM	Concentration	Milli-Molarity
mole/L	Concentration	Mole per Liter
mV	Voltage	Milli-Volt
mV/s	Scan rate	Milli-Volt per Second
Ø <sub>A</sub>	Anodic peak in cyclic voltammetry	-
Ø <sub>C</sub>	Cathodic peak in cyclic voltammetry	-

P	Operating Pressure of reactor	kilo-Pascal (kPa)
pH	Power of hydrogen ion	-
$P_{\max}$	Maximum Allowable Pressure	kilo-Pascal (kPa)
ppm	Concentration of metal in solution	Parts per Million
$P_s$	Static Pressure caused by the solution	kilo-Pascal (kPa)
$P_T$	Total Pressure	kilo-Pascal (kPa)
R	Correlation Coefficient	-
$r_i$	Reactor Internal Radius	m, cm, mm
rpm	Stirring speed	Revolution per minute
s	Time duration	Seconds
S	Maximum Allowable Working Stress	kilo-Pascal (kPa)
$t_w$	Reactor Wall Thickness	m, cm, mm
V	Applied potential or potential	Volt
$V_{(pH=2)}$	Potential at pH = 2	Volt
$V_S$	Volume of Solution	L
$V_{SCE}$	Potential based on Saturated Calomel Electrode as reference electrode	Volt
$V_T$	Volume of Reactor	mL, L
w/v	Pulp Density	Weight of sample per Volume of leaching solution
wt. %	Weight percentage	-
$x_s$	Mesh size	mm, $\mu\text{m}$
$\rho$	Density	Mass per Volume
$\Phi$	Dimension	-
$(\text{SCN}_2\text{H}_3)_2$	Formamidine disulphide	-

$[\text{Au}(\text{CN})_2]^-$	Gold-cyanide complex ion	-
$[\text{Au}(\text{S}_2\text{O}_3)_2]^{3-}$	Gold-thiosulphate complex ion	-
$[\text{FeSO}_4 \cdot \text{SC}(\text{NH}_2)_2]^+$	Ferric sulphate-thiourea complex ion	-
Ag	Silver	-
Ag/AgCl	Silver/silver chloride reference electrode	-
Al	Aluminum	-
As	Arsenic	-
Au	Gold	-
$\text{Au}[\text{SC}(\text{NH}_2)_2]^{2+} / \text{Au}(\text{TU})^{2+}$	Gold(I)-thiourea complex ion	-
$\text{Au}^\circ$	Elemental gold	-
Ba	Barium	-
$\text{Br}_2$	Bromine gas	-
C	Carbon	-
Ca	Calcium	-
Cd	Cadmium	-
$\text{Cl}_2$	Chlorine gas	-
$\text{CO}_2$	Carbon dioxide	-
Cr	Chromium	-
$\text{Cr}^{6+}$	Hexavalent chromium (Chromium (VI))	-
Cu	Copper	-
$\text{Cu}(\text{TU})_n^+$	Copper-thiourea complex ion	-
$\text{Cu}^{2+}$	Cupric ion	-
Fe	Iron	-
$\text{Fe}^{2+}$	Ferrous ion	-

$\text{Fe}_2\text{O}_{12}\text{S}_3$	Ferric sulphate	-
$\text{Fe}_2\text{O}_{12}\text{S}_3 \cdot x\text{H}_2\text{O}$	Ferric sulphate hydrate	-
$\text{Fe}^{3+}$	Ferric ion	-
$\text{H}^+$	Hydrogen ion	-
$\text{H}_2$	Hydrogen gas	-
$\text{H}_2\text{O}$	Water	-
$\text{H}_2\text{O}_2$	Hydrogen peroxide	-
$\text{H}_2\text{SO}_4$	Sulphuric acid	-
$\text{HCl}$	Hydrochloric acid	-
$\text{HClO}_4$	Perchloric acid	-
$\text{Hg}$	Mercury	-
$\text{Hg}_2\text{Cl}_2$	Mercury(I) chloride (Calomel)	-
$\text{HNO}_3$	Nitric acid	-
$\text{Mg}$	Magnesium	-
$\text{Mn}$	Manganese	-
$\text{Na}$	Sodium	-
$\text{Na}_2\text{SO}_3$	Sodium sulphite	-
$\text{NaOH}$	Sodium hydroxide	-
$\text{NH}_2\text{CN}$	Cyanamide	-
$\text{Ni}$	Nickel	-
$\text{O}$	Oxygen	-
$\text{O}_2$	Oxygen gas	-
$\text{Pb}$	Lead	-
$\text{Pd}$	Palladium	-
$\text{Pt}$	Platinum	-
$\text{S}$	Sulphur	-
$\text{S}^{2-}$	Sulphide ion	-

SC(NH <sub>2</sub> ) <sub>2</sub>	Thiourea	-
Si	Silicon	-
Sn	Tin	-
SO <sub>4</sub> <sup>2-</sup>	Sulphate ion	-
Ti	Titanium	-
Zn	Zinc	-

## LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrometry
ACS	American Chemical Society
AHP	Analytic Hierarchy Process
CE	Counter Electrode
CV	Cyclic Voltammetry
D	Diameter
DC	Direct Current
DOE	Malaysia Department of Environment
ED	Electrodeposition
EDX	Energy Dispersive X-ray
EEE	Electrical and Electronic Equipment
EIS	Electrochemical Impedance Spectroscopy
E-waste	Electronic Waste
FDS	Formamidine Disulphide
$F_{\text{scan}}$	CV Forward Scan
H	Height
HF	Hydrofluoric acid
IC	Integrated Circuit
ICP-MS	Inductive Coupled Plasma – Mass Spectrometry
ICP-OES	Inductively Coupled Plasma – Optical Emission Spectroscopy
ICT	Information and Communication Technology
LSV	Linear Sweep Voltammetry
MYR/g	Malaysia Ringgit per gram
OCP	Open Circuit Potential