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Electrorefining of Copper at Inclined Electrodes

SAID M. SOLIMAN[1] and ABDEL-MONEM M. AHMED[2,*]

[1]Department of Chemistry, Rabigh College of Science and Art, King Abdulaziz University, Rabigh 21911, Saudi Arabia
[2]Department of Chemistry, Faculty of Science, Alexandria University, Alexandria, Egypt

*Corresponding author: Email: profabdelmonem@gmail.com

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The rate of electrowinning of copper from acidified $CuSO_4$ was studied under natural convection condition. The factors studied were $CuSO_4$ concentration, the height of cathode, the angle of rotation. It is found that the rate of electrowinning increases by increase concentration of $CuSO_4$, increase of angle of rotation and increase electrode height.

Keywords: Electrowinning, Copper, Inclined electrodes.

INTRODUCTION

In electrowinning of metals usually an insoluble anode is used where oxygen evolution take place. Anodic oxygen evolution could adversely affect the performance of the cell by increasing the ohmic[1-3] and disturbing the uniformity of current distribution[4-7]. On the other hand, anodic oxygen bubbles were found to enhance the rate of mass transfer[8-11] at the cathode to a modest degree in vertical parallel electrode cells. In electrorefining a soluble copper anode is used where the anodic reaction is copper dissolution instead of O_2 evolution.

Electrorefining and electrowinning of copper are diffusion-controlled processes whose rate depends on the physical properties of solution as well as its dynamics. Ahmed *et al.*[12-17] were studied the effect of SAS on electrorefining and electrowinning of metal[12-14]. They also studied the effect of different organic substances as phthalazine hydrazone derivatives[12], 1-aroyl-2-D-glyconylhdrazones[19], diarylsulphide and sulphone[18] and aromatic ketones and diketones[14,15] on the rate of electrodeposition of copper.

In industry, electrorefining of copper is usually carried out in unstirred cells to avoid contamination of the cathodic deposit with the anode slimes. In unstirred cells, mass transport is mainly by natural convection and unnecessarily slows. However, by modifying electrode orientation, which says by inclining the cathode, to make it facing up, it is possible to increase the effectiveness of natural convection.

In a previous study[24,25] the effect of acute angle of cathode inclination on the limiting current of copper deposition using a bench scale electrode was studied by Ahmed *et al.*[20,21].

The object of the present work is to study the effect of electrode inclination at an obtuse angle on the limiting current of copper deposition using a bench scale cell with electrode height, varying from 4-10 cm.

EXPERIMENTAL

The apparatus consisted essentially of an electrolytic cell of copper deposition and auxiliary equipment for measurement of total current and cathode potential relative to the bulk solution in the cell (Fig. 1). The anode and the cathode were vertical copper plates, 5 cm wide, fitting exactly into the rectangular plexi-glass electrolytic cell. The cathode-anode distance was 5 cm; the anode height was 10 cm and covered one side of the cell completely. The cathode heights were 4, 6, 8 and 10 cm. The cathode reached the bottom of the cell where the free liquid was about 10 cm above the upper end of the cathode.

Waxed bases giving an inclination of 105, 120, 135 and 150° to the cells were used. The concentration of $CuSO_4$, were 0.01, 0.05, 0.10, 0.15 and 0.25 mole/L in 1.5 M H_2SO_4. The electrical circuit was the same as described in previous pater[20].

The back part of cathode was insulated with polystyrene lacquer and the active surface of cathode was polished with fine emery paper, degreased with trichloroethylene, washed with alcohol and finally rinsed in distilled water. The cell is set up.

Polarization curves were plotted by increasing the applied current stepwise and measuring the corresponding steady state potential; one min. was allowed to reach the steady state potential. Limiting currents were determined from the polarization curves.

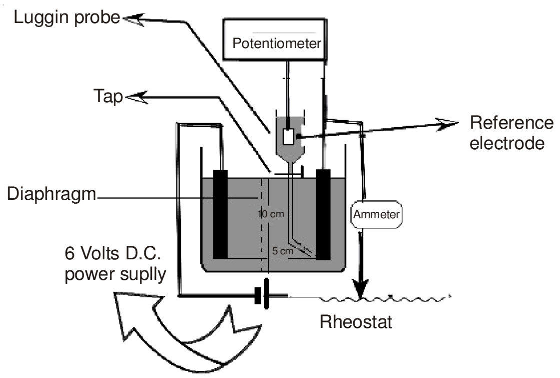

Fig. 1. Electrolytic cell and the electrical circuit

RESULTS AND DISCUSSION

Fig. 2 shows a typical current-potential curve in presence and in absence of different inclined at 25 °C. It is seen that the limiting current increases with the increase of inclination.

These polarization curves are served to determine the limiting current from which the mass transfer coefficient was calculated according to the equation:

$$K = I/ZFC \quad (1)$$

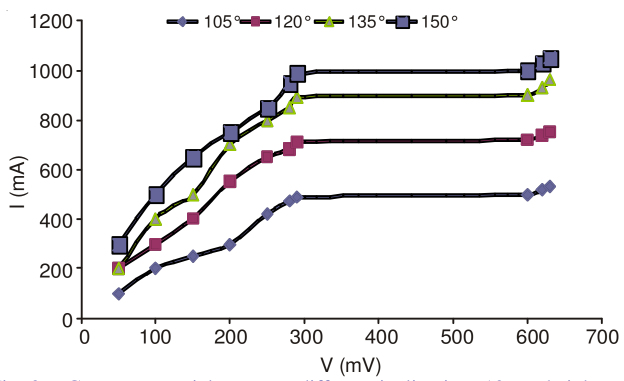

Fig. 2. Current-potential curve at different inclination, 10 cm height and 0.01 M $CuSO_4$

Polarization curves obtained in experiments with different inclinations are similar in shape but the limiting currents are found to depend on the inclination. At a given inclination, the current is linearly dependant on copper sulphate concentration.

The results of cathodic limiting current measurements for the inclination 105, 120, 135 and 150 are summarized in Table-l. The limiting current density inclination of 150 as a function of hulk concentration of $CuSO_4$, satisfies the relation $I \propto (C_o)^{1.333}$.

This result agrees-with the data reported earlier[20,22-25].

In cases of acute angles, the relation was found to be:

$$I \propto (C_o)^{1.333} \quad (2)$$

Effect of concentration on the rate of copper deposition is higher in case of obtuse angles[21]. For a given electrolyte, concentration and a given angle of inclination, but different immersion heights (H), log I *vs.* log H is found to be linear. It is seen that the limiting current density decreases with increasing electrode height. The data at inclination of 120° can be represented by equation:

$$I \propto (H)^{-0.5} \quad (3)$$

This agrees with equation obtained in cases of acute angles[21]

$$I \propto (H)^{-0.5} \quad (4)$$

The limiting current density increases with increasing inclination in the range of 105° to 150°. The data can be represented by:

$$I \propto (\theta)^{1.04} \quad (5)$$

In case of acute angles the corresponding relation[21]

$$I \propto (\theta)^{0.333} \quad (6)$$

That means limiting current dependence on angle is larger at obtuse angle, Table-1, shows that the limiting current can be related to θ, C and H by equation:

$$I = 2.5\ [(C_o)^{1.333}\ (\theta)^{1.04}\ (H)^{-0.5}]^{1.15} \quad (7)$$

which differs from equation in case of acute angle

$$I = 32\ [(C_o)^{0.8334}\ (\theta)^{0.333}\ (H)^{-0.5714}] \quad (8)$$

TABLE-1
LIMITING CURRENT AT DIFFERENT CONDITIONS

C (mole/L)	(θ°)	I, mA (cm²) at			
		(H = 10 cm)	(8 cm)	(6 cm)	(4 cm)
0.01	105	0.50	0.80	1.10	1.20
	120	0.72	0.90	1.30	1.30
	135	0.90	1.10	1.40	1.70
	150	1.00	1.30	1.50	1.80
0.05	105	2.80	4.40	6.67	8.75
	120	3.00	4.80	6.07	6.80
	135	3.62	5.00	6.40	9.73
	150	3.80	5.25	6.73	10.50
0.096	105	6.00	6.75	9.00	12.50
	120	6.20	7.25	9.17	14.00
	135	6.60	7.25	9.50	14.50
	150	6.80	6.80	10.00	16.00
0.141	105	9.50	11.75	15.50	19.00
	120	12.20	13.25	16.00	21.20
	135	13.80	14.70	17.00	23.25
	150	15.00	15.50	17.00	20.75
0.25	105	17.60	20.00	24.00	34.50
	120	18.40	22.50	25.00	36.25
	135	20.80	26.25	26.50	41.25
	150	22.00	29.00	29.00	42.20

The scale of operations also has an effect on limiting current. A comparison is shown between the equations obtained using small scale and large-scale electrodes[20], under the same condition in Table-2.

TABLE-2
A COMPARISON BETWEEN EQUATIONS, WHICH WERE OBTAINED IN CASE OF SMALL AND LARGE-SCALE ELECTRODES

Small scale electrode	Large scale electrode
$I \alpha (C_o)^{1.333}$	$I \alpha (C_o)^{1.333}$
$I \alpha (\theta)^{1.04}$	$I \alpha (\theta)^{0.833}$
$I \alpha (H)^{-0.5}$	$I \alpha (H)^{-0.2}$

The dependence of limiting current on C, θ, H on the scale of the cell may be attributed to the fact that natural convection flow in large scale cells tends to be turbulent while in small scale cell, it tends to be laminar or less turbulent.

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