COPPER RECOVERY FROM SPENT ETCHANT CUPRIC CHLORIDE SOLUTION BY ELECTROWINNING METHOD

Dr. Aprael S. Yaro and Zuhaira N. Hanna

Chemical Engineering Department – College of Engineering - University of Baghdad

ABSTRACT

Recovery of copper from actual spent etchant cupric chloride solution used in manufacturing of printed circuit board (PCB) containing 124 g/l Cu^{+2} ions concentration and 60 g/l hydrochloric acid was investigated in a batch mode jacketed tank. This tank was constructed with inner dimensions of 19×10×15 cm^3. Cylindrical rode-shape titanium was used as cathode, while two rectangular shaped graphite were used as anodes. The parameters studied were: current density (0.16-0.30 A/cm^2), copper concentration in etchant solution (30-124 g/l) and the temperature (25-45^o C). The highest current efficiency obtained was about 92% and the lowest power consumption achieved was about 2.7 W.h/g within the temperature range 25-35^o C.

الخلاصة

يهدف البحث الى استعادة النحاس بطريقة الترسيب الالكتروليتي من محلول كلوريد النحاس الفائض (المتخلف) من انتاج البطاقات الالكترونية، يحتوي المحلول على ايونات النحاس بتركيز 124 غم\لتر و حامض الهيدروكلوريك بتركيز 60 غم\اتر. تم البحث باستخدام نظام الوجبات في خزان ذو جاكيت لغرض التبريد و بابعاد داخلية 19×10×15 سم^3. استخدم قطب كاثود اسطواني الشكل من التيتانيوم و قطبي الانود مستطيلي الشكل من مادة الكرافيت. درست الظروف التشغيلية التالية: كثافة تيار (0.16-0.30 امبير\سم^2) و تركيز ايونات النحاس بالمحلول (31-124 غم\لتر) و درجة الحرارة (25-45 ^{5} م). اعلى كفاءة تيار تم الحصول عليها كانت حوالي 92 % و اقل طاقة مستهلكة لترسيب النحاس على سطح الكاثود بالساعة كانت حوالي 2.7 واطزساعة\غم ضمن درجة الحرارة 25-35 ^{5} م.

KEY WORD

Electro winning, copper recovery, spent etchant, cupric chloride.

INTRODUCTION

Metals contaminations in waste streams are serious problem for several industries. .these streams containing a metal concentration higher than the acceptable limit set by law. Therefore, the treatment of contaminated streams is required in order to reduce the amount of metal to an acceptable level. The prospect of recovery has attracted interest among industries for environmental and economic reasons.

Many previous studies have attempted to find reasonable ways to recover heavy metals. Electrochemical technology offers an efficient means of controlling pollution as it provides removing of heavy metals via redox reactions (Tenterio, 1978, Sioda, 1980 and Simonson, 1984).

The aim of the present study was to establish an electrolytic deposition method for the recovery of copper (II) from spent etchant cupric chloride solution taken as waste stream from Electronic Industries Company by electrowinning.

Operating conditions are very important to specify the typical deposition of the metal on the cathode surface (Parikh, 1974).

Any condition that increases the rate of formation of nuclei tends to increase the number of crystals and the deposit will be fine grain spongy or as powder (Mantel, 1960).

The following factors have been found to significantly affect the character of the metal (copper) deposits on the cathode: quantity and concentration of copper ion, current density, temperature, shape of the electrodes, and ratio of anode to cathode surface area (Parikh, 1974).

Materials and Experimental Method

This study illustrates the laboratory design of electrowinning system as well as the experimental work to investigate the best conditions of copper recovery from spent etchant cupric chloride solution which was brought from Electronic Industries Company (EIC) / printed circuit boards' production factory.

The test solution contains 124.5 g/l (124,500 ppm) copper ions and 60 g/l (60,000 ppm) hydrochloric acid (*HCl*).

Experiments were studied in a batch mode using D.C. power supply (HP 6269B) operated at a constant current mode.

A cylindrical rode-shaped cathode of titanium and two rectangular-shaped of graphite anodes were used. The ratio of anode to cathode surface area was 4.6. Cathodic and anodic potential recorded versus a saturated calomel electrode (SCE).

One litter of solution was electrochemically treated for 30 minutes with mixer speed of 120 rpm in a jacketed tank with inner dimensions of 19×10×15 cm^3 and outer dimensions of 21×12×17.5 cm^3. Chiller was used to supply water to electrolytic cell through the tank's jacket to maintain the electrolyte at a desired temperature. Figure 1 shows the schematic layout of the experimental apparatus.

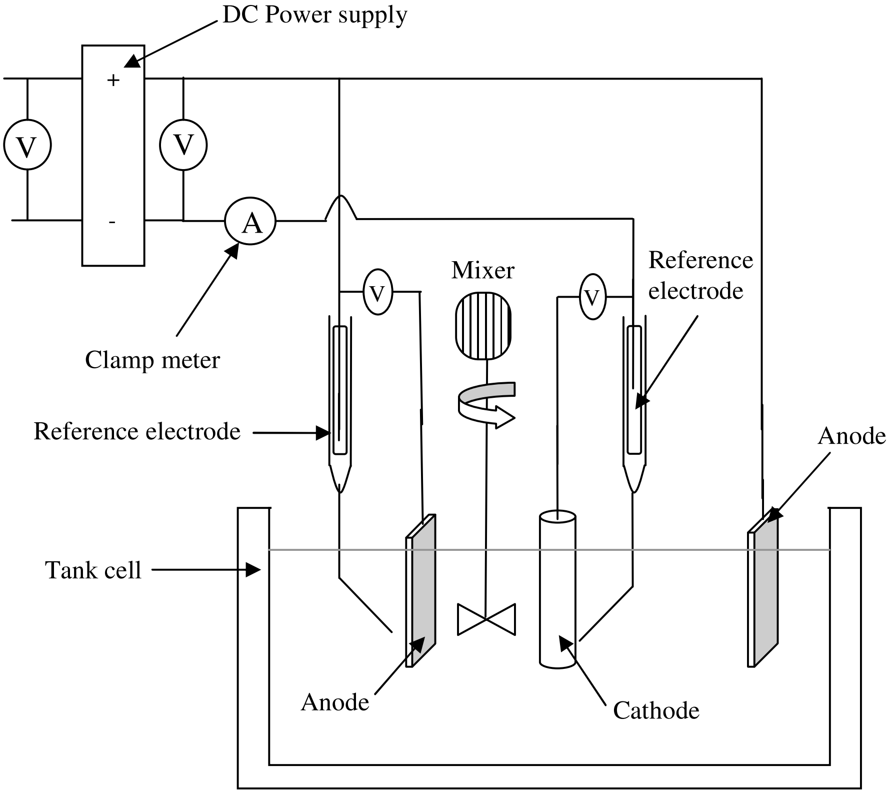

Fig. (1). Schematic layout of the electrical circuit

Results and Discussion

This study concerned with simple formulas based on Faraday's law of electrolysis and energy consumption for producing high purity copper metal from electrolytes through an aqueous electrolysis. The economics of electrowinning is not introduced since this is not the main subject in this study.

$$C.E.\% = 100 \times \frac{\text{Total weight deposited, g}}{\text{Theoretical weight deposited, g}} \qquad \ldots 1$$

Figure 2 represent the relationship between cathodic current efficiency and Cu^{+2} ion concentration for different temperatures.

It is clear that current efficiency decreases with increasing Cu+2 ion concentration when other conditions remained constant. Low ionic metal concentration is in general used for production of fine grained deposits (Mental, 1960).

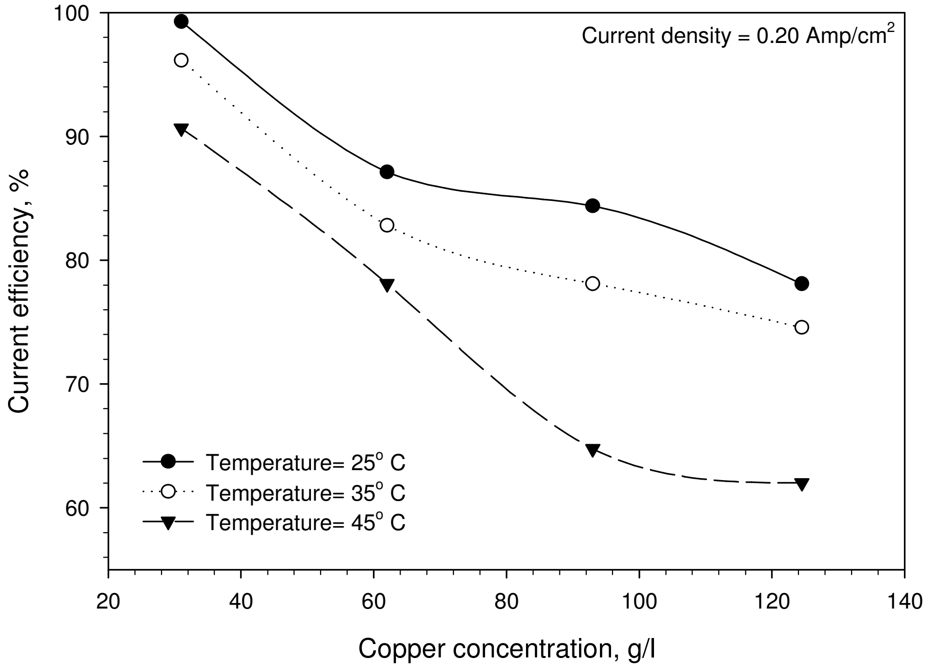

Fig.(2)., Current efficiency versus copper concentration at different temperatures and current density = 0.20 Amp/cm^2

Figure 3 shows the effect of increasing temperature on current efficiency at different current densities and copper ion concentration.

Current efficiency decreases as temperature increases. Decreasing the temperature decreasing the ionic migration, diffusion and convection, which promote the rate of formation of crystal nuclies.

Figure 4 shows that current efficiency decreases with increasing current density. Increasing the current density increases the capacity or output of product.

Because of high current densities are employed, so that the concentration of the discharging ion declines considerably in the cathodic layer, the temperature increase may be ascribed, in this case to an appreciable increase of ohmic resistance of the cathodic layer following ion discharge, so part of current converts to heat which causes decreasing of current efficiency (Calusaru, 1979).

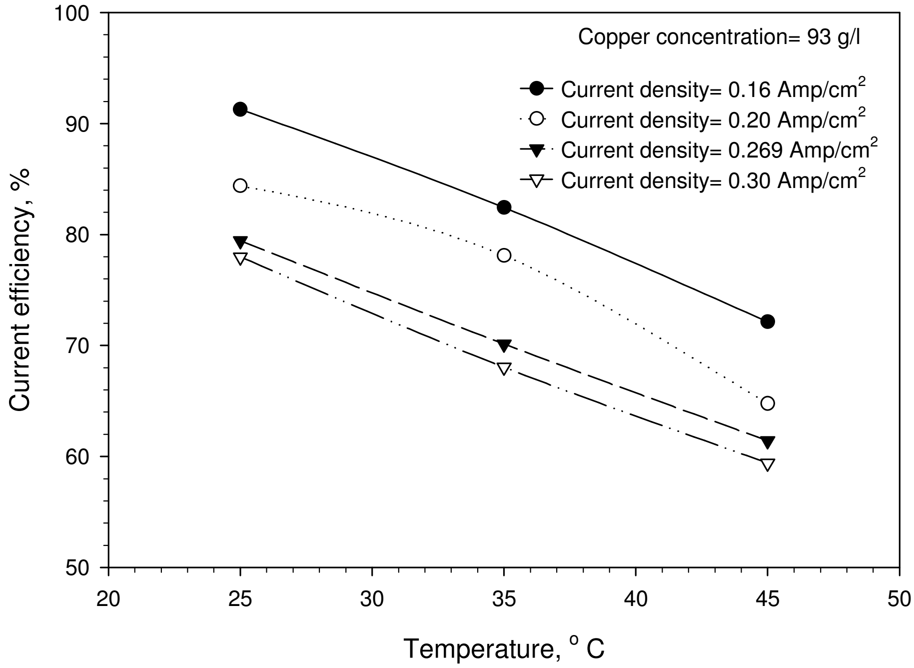

Fig. (3)., Current efficiency versus temperature at different current densities and copper concentration= 93 g/l

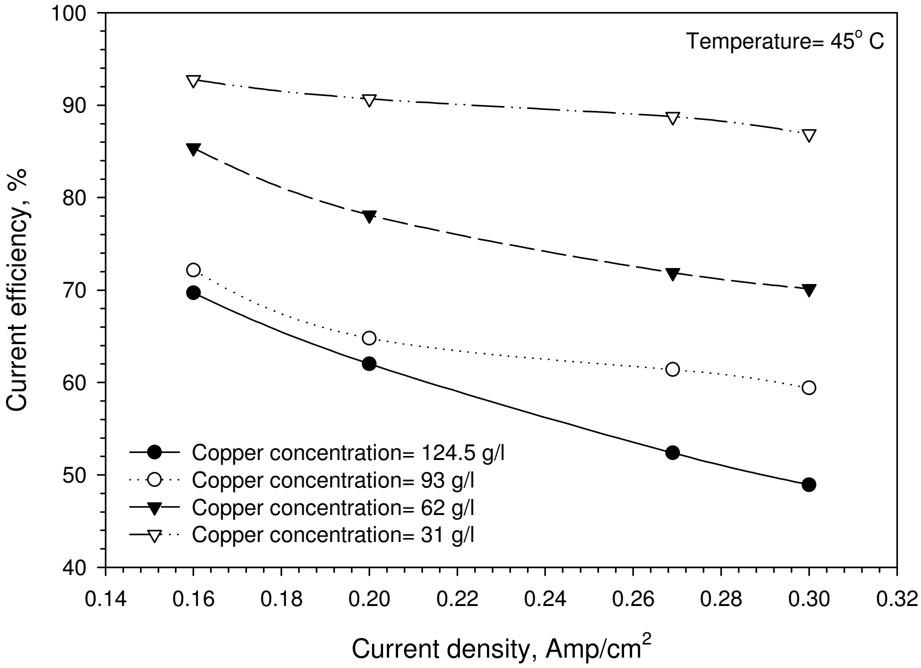

Fig.(4)., Current efficiency versus current density at different copper concentrations and at 45° C

Power consumption is a vital to the economic justification of the method; it depends on current applied, cell voltage, time and weight of copper recovered.

$$\text{Power consumption} = \frac{\text{I V h}}{\text{g}} \qquad \ldots 2$$

Power consumption is electrical power required to deposit one gram of metallic ions as metal on the electrode in one hour Mantel, 1960).

The cell potential is the sum of a number of components.

$$V_{cell} = V_c + V_a + V_s \qquad \ldots 3$$

Potential drop across the solution (*Vs*) depends upon the conductivity of solution. As the conductivity of solution decreases, *Vs* increases due to the increasing in the resistance of solution and leads to increase in power consumption (Canning, 1970), which means increasing the cost of copper recovery.

Figure 5 shows at minimum Cu^{+2} ion concentration, higher power consumption is recorded because the solution of low conductivity causes an increase in the resistance of solution, accordingly the voltage of the cell increases leading to increase in power consumption. As Cu^{+2} ion increase above 80 g/l, power consumption raises because at high Cu^{+2} ion concentration current efficiency decreases leading to decrease the weight of copper recovered.

Figure 6 shows that the higher the temperature the higher the power consumption because increasing the temperature decreases the weight of copper recovered due to a decrease in current efficiency compared with cell voltage.

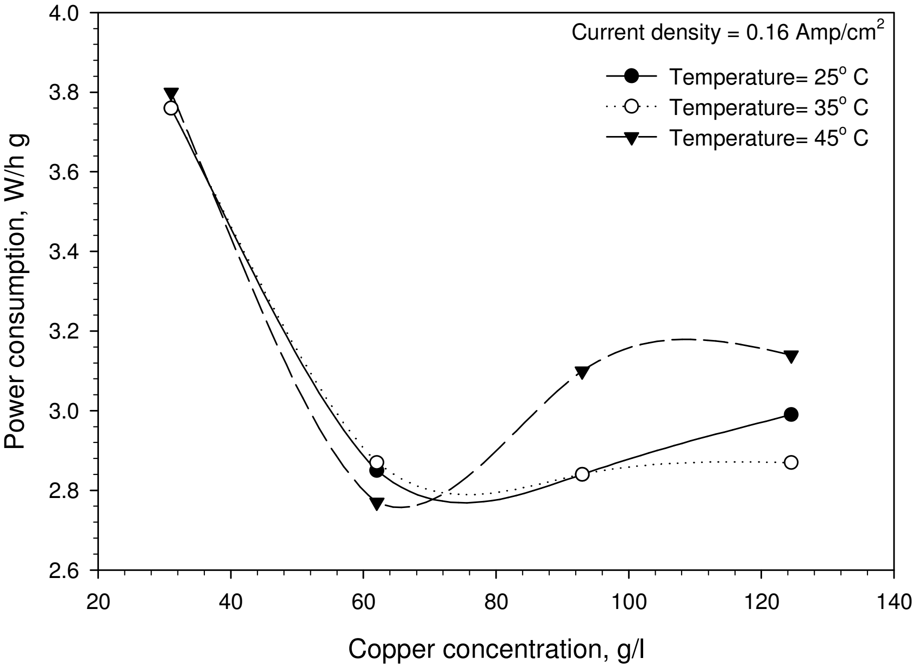

Fig. (5)., Power consumption versus copper concentration at different temperatures and current density = 0.16 Amp/cm^2

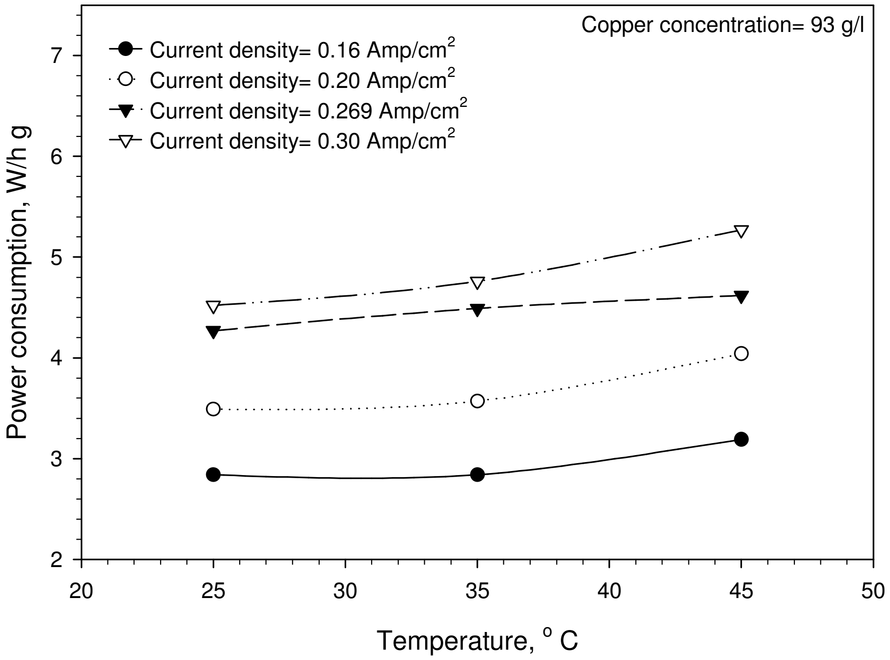

Fig. (6)., Power consumption versus temperature at different current densities and copper concentration= 93 g/l

Figure 7 shows that power consumption increases as current density increases. Current density has the greatest effect because as current applied increases, cell voltage increases and also current efficiency decreases which leads to decrease in the weight of copper recovery, accordingly power consumption increases.

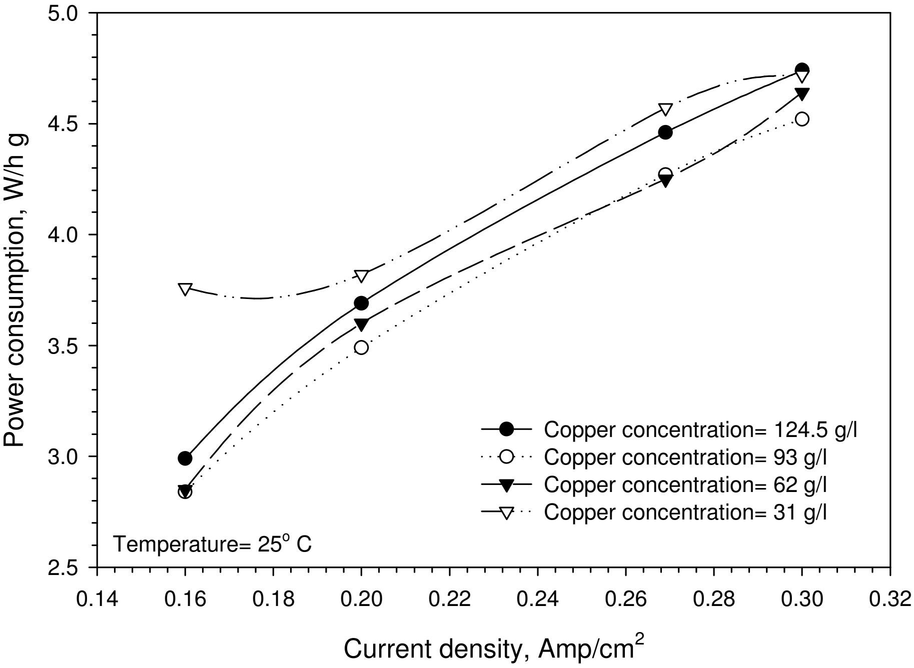

Fig. (7)., Power consumption versus current density at different copper concentrations and at 25° C

CONCLUSIONS

1. Current efficiency increases with decreasing Cu^{+2} ion concentration for all current densities and temperatures. The highest current efficiency between 75 to 92 % and lowest power consumption is about 2.7 to 3.7 Watt. h/g, within 60-124 g/l Cu^{+2} ion concentration, were achieved under the conditions of 0.16 to 0.2 Amp./cm^2 current density and 25-35° C temperature.
2. Although the highest current efficiency had been achieved at minimum Cu^{+2} ion concentration of 31 g/l, the operation was not economic, because of high power consumption.

REFERENCES

- Calusaru, A., 1979, "*Electrodeposition of metal powder*", Elsevier Scientific Company, New York.
- Canning, W., 1970, "*Canning handbook on electroplating*", Birmingham, England.
- Mantell, C. L., 1960, "*Electrochemical engineering*", McGraw-Hill Book Company, New York.
- Parikh, G. D. and Wittard, W. C., 1974, US patent 3,784,455.

- Simonsom, D., 1984, J. Appl. Electrochemistry, **14**, p. 595.
- Sioda, R. E. and Piotroska, H., 1980, Electrrochemical Acta, **25**, p. 331.
- Tenterio, A. and Casolo-Ginelli, U., 1978, J. Appl. Electrochemistry, **8**, p. 195.