# AUTOMATED ELECTROPLATING PROCESS

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***Abstract*— People working in the electroplating industry may face risks from hazardous chemicals, metals, wet work, live electrical currents and heavy machinery. It primarily addresses the hazards involved with storage and handling of hazardous chemicals used in electroplating** [22].***Generally there is no accurate calculation related to desired thickness and electrical parameter control. That's why; general process is woks on trial and error method to get desired thickness with varying voltage and current "End-users need something so simple they don't have to become experts. "Experienced people (engineers or operators) react instinctively because they have experienced similar events. These operators or engineers do an excellent job of handling emergency situations or making decisions during a start - up. As a rule, the person that tends to respond based on methodical reasoning and calculations rarely can react fast enough to be of assistance in an emergency or if quick action is required in a start - up situation [23].***

***This paper presents new design and implementation of an automatic electroplating system using automation. Providing input events like desired thickness and area to be electroplated it automatically find the required time and current and complete the process automatically.***

***Keywords*— electrolyte, faradays laws, automation, automatic plating, copper plating, embedded in plating, plating thickness**

## 1. INTRODUCTION

Automation can be done either by using PLC or by using embedded system. Comparing the initial cost embedded system is preferred but it is not user friendly than the PLC. An automation system at the level of the process controller should have three things: First, it should be able to interpret sensor data and direct actuator behavior in real time. Second, it should have an HMI (Human Machine Interface) so that the operator can monitor and adjust the production process. And third, it should be able to network the local process control activity to a higher-domain system such as a DCS (Distributed Control System) or a SCADA (Supervisory Control and Data Acquisition) system. In general process workers clean the component in chemical by hand and put it in electroplating bath by hand, to reduce this risk to health of worker and environmental condition, automatic electroplating process is best solution.

Electroplating is an electrodepositing process for producing a dense, uniform, and adherent coating, usually of metal or alloys, upon a surface by the action of electric current. The coating produced is usually for decorative and/or protective purposes, or enhancing specific properties of the surface. The surface can be conductors, such as metal, or non-conductors, such as plastics. Electroplating products are widely used for many industries, such as automobile, ship, air space, machinery, electronics, jewellery, defence, and toy industries. The core part of the electroplating process is the electrolytic cell (electroplating unit). In the electrolytic cell (electroplating unit) a current is passed through a bath containing electrolyte, the anode, and the cathode. In industrial production, pre-treatment and post treatment steps are usually needed as well.

Electroplating involves the use of low voltage high current DC derived from rectifier units operating at primary voltages of 415 volts AC. Auxiliary equipment typically includes pumps, filters, blowers, centrifuges, heaters (fixed and transportable) as well as hand-held portable tools and instruments. Automated plants incorporate conveyors, and lifting and manipulating equipment operated by control systems which range from simple contractor systems to sophisticated microprocessor controls.

### *1.1 Working Principle Of Electrolysis*

**Faraday's laws of electrolysis:**

Michael Faraday, perhaps the greatest experimental scientist in history, enunciated his laws of electrolysis in 1833, and these laws have remained unchallenged ever since. They are basic to both the understanding and the practical use of electrolytic processes. They may be stated as follows:

1. The amount of chemical change produced by an electrical current is proportional to the quantity of electricity that passes.

2. The amounts of different substances liberated by a given quantity of electricity are inversely proportional to their chemical equivalent weights.

Equivalent weight is an older term, but still used widely in analytical and electrochemistry. In redox chemistry it is the molar mass divided by the number of electrons in the balanced redox half-equation.

That is, the total cathodic charge used in the deposition, Q(C), is the product of the number of gram moles of the metal deposited, m, the number of electrons taking part in the reduction, n, Avogadro's number, Na (the number of atoms in a mole), and the electrical charge per electron, Qe(C). Thus, the following equation gives the charge required to reduce m moles of metal:

$$Q = mnNaQe$$

The product of the last two terms in above equation is the Faraday's constant, F. Therefore, the number of moles of the metal reduced by charge Q can be obtained as:

$$m = \frac{Q}{nF}$$

These laws correctly predict that:

1) By measuring the quantity of electricity passed, one has a measure of the amount of chemical change that will thereby be produced;

2) Knowing the chemical equivalent weight of a substance, one can predict the amount of that substance that will be liberated by a given quantity of electricity.

No true exceptions to these laws have ever been confirmed. Apparent exceptions can always be explained by the failure to take into account all the chemical reactions involved, or, occasionally, by the partially non-electrolytic nature of the reaction.

The Faraday's constant represents the amount of electric charge carried by 1 mol, or the Avogadro's number of electrons. The Faraday's constant can be derived by dividing Avogadro's number, or the number of electrons per mole, by the number of electrons per coulomb. The former is approximately equal to $6.02 \times 10^{23}$ and the latter is approximately $6.24 \times 10^{18}$

Therefore,

$$F = \frac{6.02 \times 10^{23}}{6.24 \times 10^{18}}$$

$$F = 9.65 \times 10^{4} C/mol$$

Time required to desired thickness for copper plating from desired current density and plating thickness:

$$Time(s) = \frac{\text{desired thicknessm (m)} \times 140700\left(\frac{\text{mol cu}}{m^3}\right) \times 6.022 \times 10^{23}\left(\frac{\text{cu ion}}{\text{mol cu}}\right) \times 2\left(\frac{\text{electron}}{\text{cu ion}}\right)}{6.242 \times 10^{18}\left(\frac{\text{electron}}{c}\right) \times \text{current density}\left(\frac{mA}{mm^2}\right) \times 1000\left(\frac{mm}{m}\right)}$$

Setting the desired thickness value on numeric key board of controller it can calculate the desired time required completing the process; the required formula for copper electroplating.

*1.2 Electrolysis*

In chemistry, the production of chemical changes by passing an electric current through a solution or molten salt (the electrolyte), resulting in the migration of ions to the electrodes: positive ions to the negative electrode (cathode) and negative ions (anions) to the positive electrode(anode).During electrolysis, the ions react with the electrode, either receiving or giving up electrons. The resultant atoms may be liberated as a gas, or deposited as a solid on the electrode, in amounts that are proportional to the amount of current passed, as discovered by English chemist Michael Faraday.

For instance, when acidified water is electrolysed, hydrogen ions ($H^+$) at the cathode receive electrons to form hydrogen gas; hydroxide ions ($OH^-$) at the anode give up electrons to form oxygen gas. One application of electrolysis is electroplating, in which a solution of a salt, such as silver nitrate ($AgNO_3$), is used and the object to be plated acts as the negative electrode, thus attracting silver ions ($Ag^+$). Electrolysis is used in many industrial processes, such as coating metals for vehicles and ships, refining bauxite into aluminium, and the chlor-alkali industry, in which brine (sodium chloride solution) is electrolysed to produce chlorine, hydrogen, and sodium hydroxide (caustic soda); it also forms the basis of a number of electrochemical analytical techniques, such as polarography.

*Summary of electrolysis:*

1. All ionic compounds when molten can be decomposed when electricity is passed through using electrolysis.
2. The metal and hydrogen always forms at the cathode.
3. Non-metal always forms at the anode.
4. Cations travel to the cathode.
5. Anions travel to the anode.
6. The electrodes are made from inert material such as graphite, so that they do not involve themselves with the reaction.
7. The molten substance been electrolysed is called the electrolyte.

*1.3*

*1.3 Electrochemistry Fundamentals*

*Electrical parameter:*

Faraday's laws give theoretical prediction of electro deposition in an ideal situation. In a real application, many factors influence the coating quantity and quality.

- *Current efficiency:*

It is stated in Faraday's laws that the amount of chemical charge at an electrode is exactly proportional to the total quantity of electricity passing. However, if several reactions take place simultaneously at the electrode, side reactions may consume the product. Therefore, inefficiencies may arise from the side reactions other than the intended reaction taking place at the electrodes. Current efficiency is a fraction, usually expressed as a percentage, of the current passing through an electrolytic cell (or an electrode) that accomplishes the desired chemical reaction.

Note that the cathode efficiency is the current efficiency applied to the cathode reaction, and the anode efficiency is the current efficiency applied to the anode reaction.

- *Current density:*

Current density is defined as current in amperes per unit area of the electrode. It is a very important variable in electroplating operations. It affects the character of the deposit and its distribution.

- *Current distribution:*

The local current density on an electrode is a function of the position on the electrode surface. The current distribution over an electrode surface is complicated. Current will tend to concentrate at edges and points, and unless the resistance of the solution is very low, it will flow to the work pieces near the opposite electrode more readily than to the more distant work pieces. It is desired to operate processes with uniform current distribution. That is, the current density is the same at all points on the electrode surface.

*1,4Surface Preparation*

Metal finishing processes involve treatment of a metal work-piece in order to modify its surface properties, impart a particular attribute to the surface, or produce a decoration. Plating is a subset of such finishing operations that involves putting a coating of metal over a base metal substrate to give various desirable properties to the object. Metal coating is another subset of such finishing operations and involves the application of paint or powder coating to a metal work-piece. Products from metal finishing operations can range from structural steel to jewellery.

The reasons for carrying out metal finishing can include:

• Decoration,

• Protection against corrosion,

• Providing resistance to oxidation, high temperatures, or UV radiation,

• Imparting mechanical properties, such as resistance to fatigue, improvement of ductile strength.

• Resistance to the use of abrasives, and,

• Imparting electrical & thermal properties such as semi-conduction, thermal resistance, fire resistance, etc.

Metal plating and finishing occurs in industries from small indigenous metal working installations to large multinational companies such as the electronics industry. Some of the larger facilities fall under the Integrated Pollution Prevention and Control (IPPC) licensing system. However, this guide is aimed at the smaller metal finishers and mainly focuses on environmental best practices that are relatively simple and straight forward to implement in an existing facility. Therefore some of the more expensive best practice options (for example electro dialysis to concentrate drag-out; ultra filtration for process, bath maintenance, etc.) have been omitted from this guide.

## 2. WHY NEED OF AUTOMATION?

In existing process numbers of problems are induced related to accuracy and hazards to human health. Automation is used to increase efficiency of plant and workers safety with reducing time and cost

1] Chemical health hazards: workers at electroplating workplaces may be exposed to hazardous chemicals in the form of fumes, vapours, mists, metal dusts, electrolytic solutions, solvents, heavy metals and toxic wastes.

Exposure to chemical hazards may cause short and/or long term health problems including skin and eye irritation, burns, asthma/breathing problems, nerve disorders, and in some cases, cancer. Adverse health effects due to exposure to hazardous chemicals are dependent on the type and amount of contact, the duration of exposure and the route of entry into the body.

2] Electrical hazards: electroplating involves a combination of conductive solutions and live electrical currents. Common hazards in electroplating workplaces include exposed live conductors, damaged insulation, broken sockets, corrosion of system parts, and heaters not earthed.

3] Accuracy: there is no accurate calculation related to desired thickness and electrical parameter control. That's why; general process works on trial and error method to get desired thickness with varying voltage and current.

Reduce the hazards risk to human as well as environmental.

4) Reduction in required worker.

5) No highly skilled labour required.

6) Highly accurate method.

7) Easy to control.

8) Cost effective method.

9) Less labour is required to operate the machine.

10) No further operation required on component to get clearance.

11) Reduce in rejection and rework.

12) Increase the plant efficiency.

*2.1 Automation in Electroplating Process*

*Electronic system:*

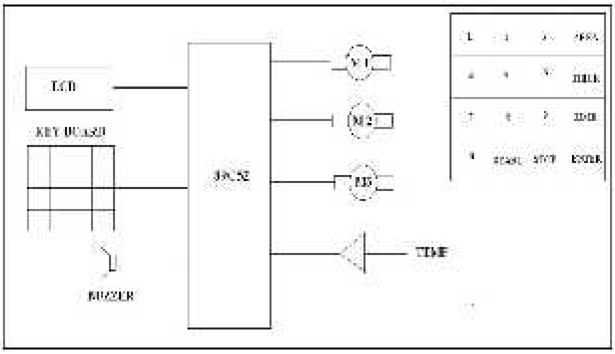



Fig1: Embedded setup

*Description:*

The AT89C52 is a low-power, high-performance CMOS 8-bit microcomputer with 8K bytes of Flash programmable and erasable read only memory (PEROM). The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry-standard 80C51 and 80C52 instruction set and pin out. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C52 is a powerful microcomputer which provides a highly-flexible and cost-effective solution to many embedded control applications.

*2.2 Working of System and flow chart:*

Cleaning: including solvent cleaning (either cold soaking or vapour phase), aqueous cleaning, abrasive cleaning, and other types of cleaning such as ultrasonic cleaning, chemical polishing and electro polishing. Cleaning is usually carried out before the main metal finishing operation and sometimes between operations.

Chemical and electrochemical conversion coatings: including chromating, phosphating, anodising, and colouring, "Conversion" refers to the fact that these processes involve changing or converting the surface layer to impart various properties to the surface. These processes are usually applied before painting to improve coating adhesion and provide corrosion protection.

Plating: electroplating of various types of metals on to metal surfaces. Other metallic coating: including hot dipping (such as galvanising) and mechanical plating (such as the penning process used for Dublin's 'spire').

Organic and other non-metallic coating: covers organic and other non-metallic coating and includes powder and liquid paints, resins and enamels. The coatings that have been applied are subsequently dried. This can be by leaving to dry in ambient air or assisted drying using an oven.

Stripping: used to remove previous metallic coatings from parts or to remove coatings from articles that have to be reworked.

A series of process tanks and rinse tanks through which the work-pieces are passed, either contained in barrels in the case of bulk small items, or hung from racks or jigs in the case of bigger items. The majority of metallic coating operations and conversion coatings take place in such a set-up.

Spray equipment. This is mainly used in painting and other non-metallic coating operations. The majority of spray equipment would be manually operated. Automated spray equipment is sometimes used in larger facilities. There are some applications involving flow or curtain coating, dip coating, or brush application.

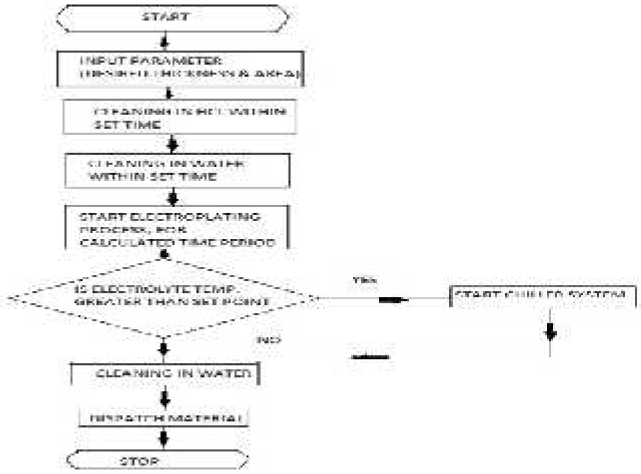



Fig2: Flow chart

## 3. MECHANICAL SYSTEM DESIGN

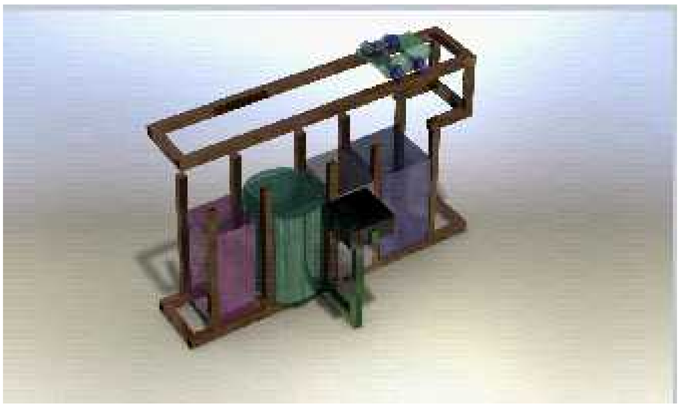


Fig4: Overall setup of plating Machine in Solid works [1]

Fig.3: Actual system setup

**Tanks:**

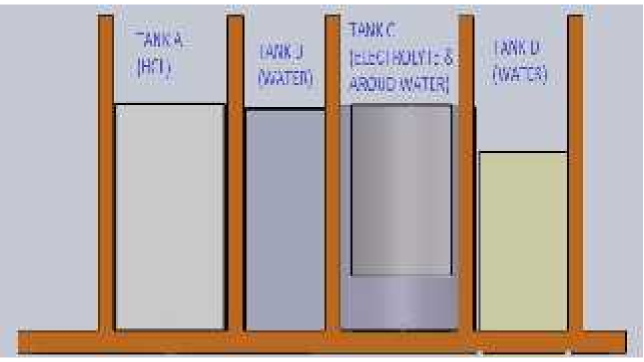


Fig4: Arranging tanks in sequence

Fig.5: Actual tank arrangement

Tanks are arranged in sequentially manner to reduce the flow of work piece or handling of work piece. The operation sequence depends on the plating and there preparation of surface method. First tanks contains HCl acid to clean the component, second tank contains water to remove acid from component. If acid goes in the electrolyte it reduces current flowing capacity of electrolyte. Third tank provides main electroplating process and last tank contains water to remove electrolyte and give clean product.

[2] The structure is made up of square steel tube of 1inch and all tanks are of plastic material; to eliminate the chemical reaction and current risk.

*Cooling Tank and Cooling Tower:*

It has one or more fans located at the tower bottom to push air into the tower. During operation, the fan forces air at a low velocity horizontally through the packing and then vertically against the downward flow of the water that occurs on either side of the fan. The drift eliminators located at the top of the tower remove water entrained in the air. Vibration and noise are minimal since the rotating equipment is built on a solid foundation. The fans handle mostly dry air, greatly reducing erosion and water condensation problems.

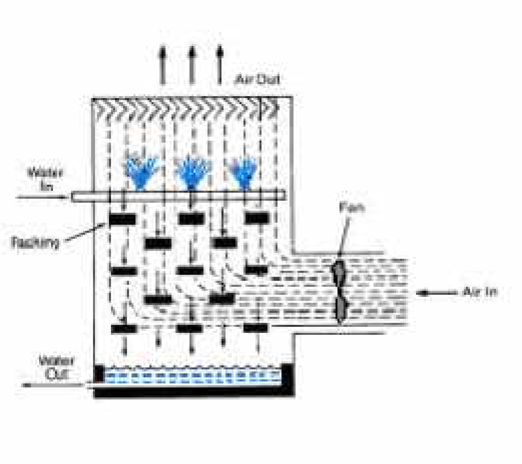



Fig.6: Forced draft cooling tower

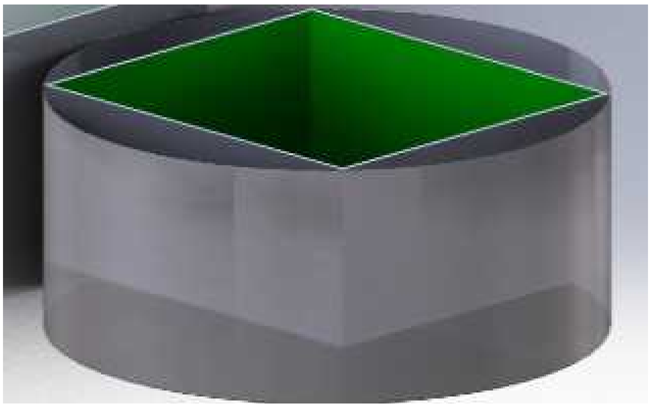


Fig.7: Cooling tank

Cooling towers are heat removal devices used to transfer process waste heat to the atmosphere. Cooling towers make use of evaporation whereby some of the water is evaporated into a moving air stream and subsequently discharged into the atmosphere. As a result, the remainder of the water is cooled down significantly.

*Overhead Tran*

Equipment used for lifting and moving, such as cranes, hoists, and forklifts, have made it safer and easier to move large, heavy loads. Many ranger stations and work centres have commercially produced cranes and hoists or use equipment designed by local personnel.

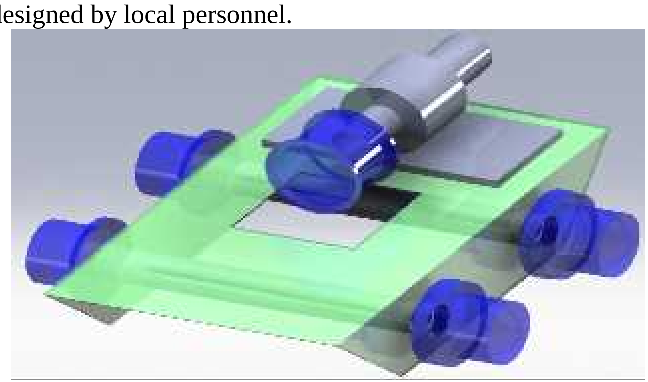


Fig.8: Overhead crane

Safe practices must be followed to operate cranes and hoists. Operators may place themselves and others at risk if they use equipment that cannot safely handle heavy loads, or use the equipment improperly.

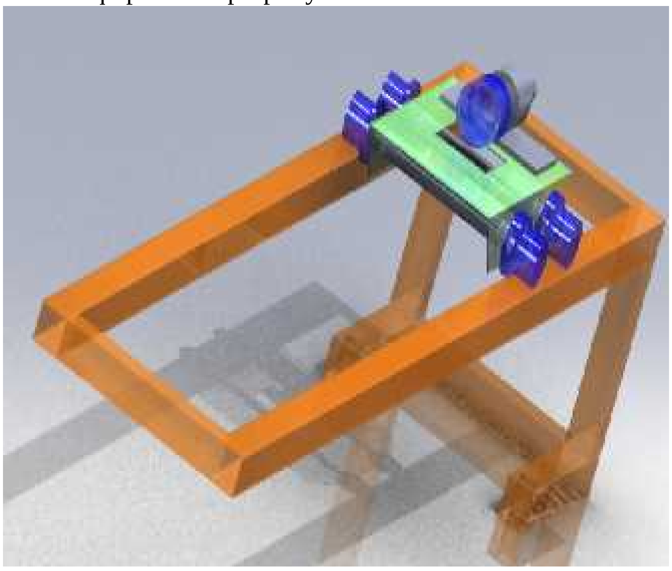


Fig.9: Track of overhead crane

## 4. RESULTS

*4.1 Effect on thickness by varying time:*

Time is major parameter used in electroplating process. Thickness is directly proportional to the time. By varying time then quantity of metal deposition also changes. After the choice of a deposit to satisfy a particular manufacturing requirement, the single most important parameter to the metal finisher is the thickness of that deposit.

The thickness is defined by several traditional specification protocols. Unfortunately the understanding of these protocols is neither uniform nor consistent within industry. In addition electrolytic or electroless deposits produce a non-uniform thickness layer thus exacerbating the problem.

**Trial 1:-**

Given data:-

Area (a) $=2000\ mm^2$

Time (T) =300 sec

Thickness (t) =?

Formula:-

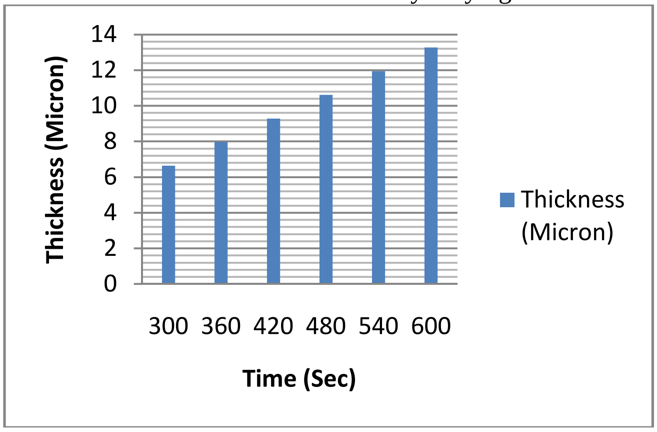
$T= 0.0226\times t\times a$

$300 = 0.0226\times t\times 2000$

$t = 6.637\ \mu m$

| Sr. No. | Time (sec) | Thickness (µm) |
|---|---|---|
| 1. | 300 | 6.637 |
| 2. | 360 | 7.965 |
| 3. | 420 | 9.292 |
| 4. | 480 | 10.619 |
| 5. | 540 | 11.947 |
| 6. | 600 | 13.274 |

Table : Effect on thickness by varying time

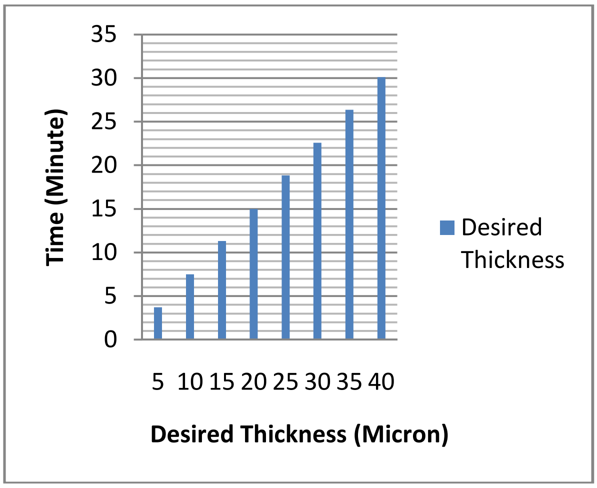



Graph1: Thickness Vs time

*4. 2 Effect of variation in time on desired thickness:*

| Sr. No. | Desired Thickness (Micron) (±2 Micron) | Area($mm^2$) | Time (Minute) |
|---|---|---|---|
| 1 | 5 | 2000 | 3.7 |
| 2 | 10 | 2000 | 7.5 |
| 3 | 15 | 2000 | 11.3 |
| 4 | 20 | 2000 | 15 |
| 5 | 25 | 2000 | 18.83 |
| 6 | 30 | 2000 | 22.6 |
| 7 | 35 | 2000 | 26.36 |
| 8 | 40 | 2000 | 30.13 |

Table 2: Effect of variation in time on desired thickness




Graph2: Time Vs desired thickness

*4.3 Effect on thickness by varying current*:

Current is second major parameter used in electroplating process. Thickness is directly proportional to the current. By varying current then quantity of metal deposition also changes.

**TRIAL NO:-1**

GIVEN DATA:-

Area (a) =2000 $mm^2$

Time (T) =300 sec

Current (I) =200 mA

Thickness (t) =?

Formula:-

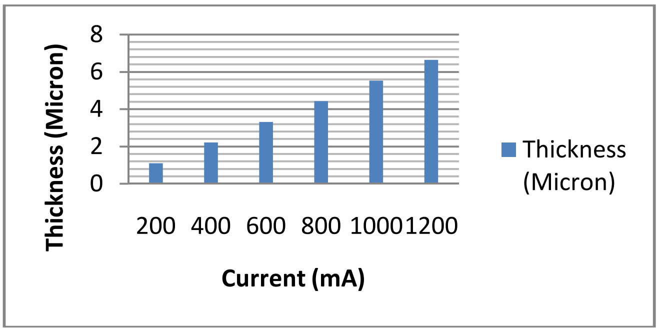
$t = 5.531\times10^{-3}\times I$

$= 5.531\times10^{-3}\times200$

$=1.1062\ \mu m$

| Trial no. | Current (mA) | Thickness(µm) |
|---|---|---|
| 1. | 200 | 1.1062 |
| 2. | 400 | 2.2124 |
| 3. | 600 | 3.3186 |
| 4. | 800 | 4.4248 |
| 5. | 1000 | 5.531 |
| 6. | 1200 | 6.637 |

Table 3: Effect on thickness by varying current




Graph3: Effect on thickness by varying current

*4.4 Effect of current on desired thickness:*

[3] Photograph 7: Work piece before plating

[4] Photograph 8: Work piece after plating

This test is conducted on microscope by observing grain structure on plated metal.

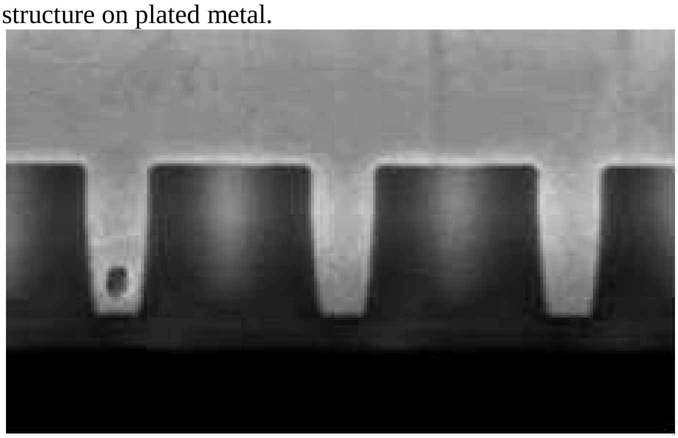


Fig13: Too low current (0.32 Micron)

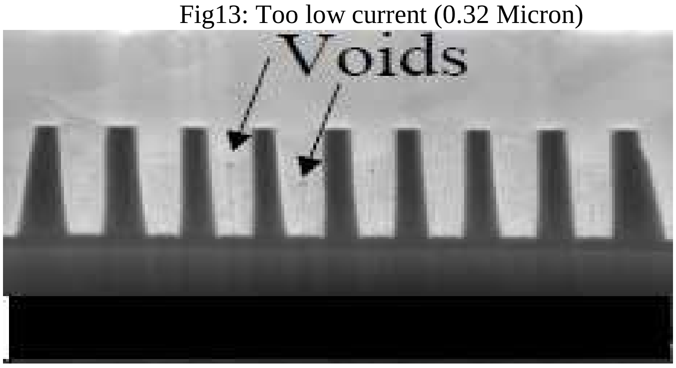



Fig14: Too high current (0.18 Micron)

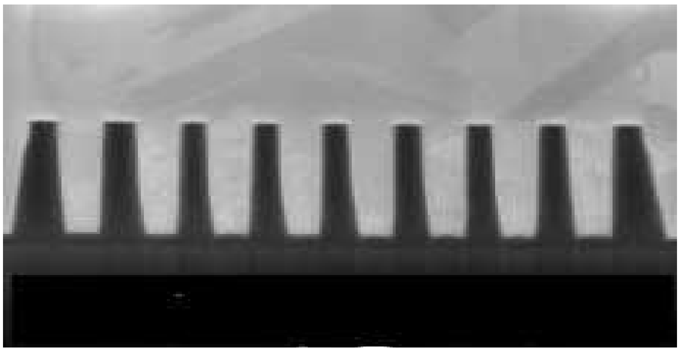


Fig15: Optimum current (0.18 Micron)

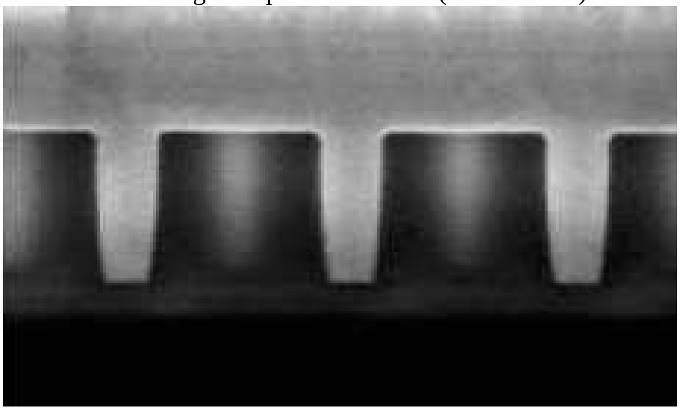
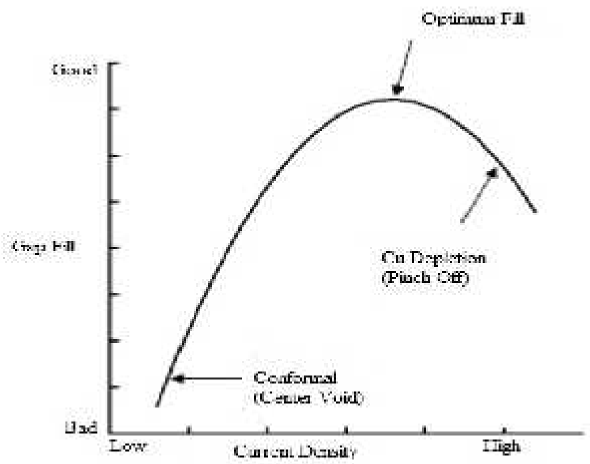


Fig16: Optimum current (0.35 Micron)



Graph4: Current Vs gap fills

**Effect of temperature on electrolyte (copper salt):**

As per chemical supplying company or supplier there is no major change by the varying temperature on electrolyte, but it is checked periodically to remove the impurities and levelling the plating tank by electrolyte.

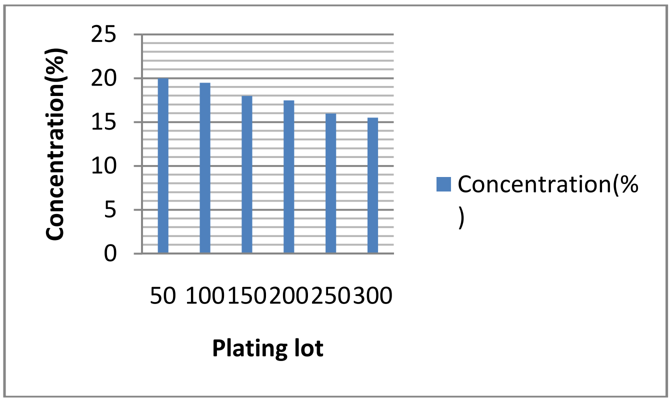
Cooling is essential to plating solution to maintain the heat transfer rate to plant environment and there supporting structure.

Effect on chemical concentration by continues use:

Molar mass of copper salt=63.546 g/mol.

| Sr. No. | Plating lot | Concentration (%) |
|---|---|---|
| 1 | 50 | 20 |
| 2 | 100 | 19.5 |
| 3 | 150 | 18 |
| 4 | 200 | 17.5 |
| 5 | 250 | 16 |
| 6 | 300 | 15.5 |

Table 4: Effect on chemical concentration by continuous use



Graph5: Concentration Vs plating lot

## 5. CONCLUSION AND FUTURE EXPANSION

As mentioned above we have introduced a electroplating process with all required parameters. As we compare traditional electroplating process with our proposed method, it has many advantages. We can successfully design system of high accuracy with fast response, this proposed system as designed currently can consider a good alternative for traditional electroplating process, though further work is being carried out to archive better results and ease in implementation.

Time is major parameter used in electroplating process. Thickness is directly proportional to the time. By varying time then quantity of metal deposition also changes.

Current is second major parameter used in electroplating process. Thickness is directly proportional to the current. By varying current then quantity of metal deposition also changes

Chemical concentration is directly depends on the number of parts to be plated.

*Future Expansion*

- Replace the over head crane (Robo) in to continuously rotating chain conveyor.

- Insert the chemical sensor in to the chemical to detect the concentration and adjust the plating time.
- Providing the plating tank supply internally of the circuit to adjust the current and voltage with respect to plating thickness and time required.
- Use changeable micro controller to change the plating type. By using this method on a single machine numbers of plating types are done with accuracy.
- Insert the chemical temperature sensor to get the accurate temperature of electrolyte.
- Insert drying of fan system under the crane to dry the component after plating is done.
- Provide the rotating system to component when electroplating is done to get accurate or uniform thickness on component.
- Provide the guide way to component when it goes to chemical tank it may be deflect by inertia effect.

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