# METAL FINISHING

***(As per revised VTU syllabus: 2015-16)***

**Definition:** It is a process in which a specimen metal (article) is coated with another metal or a polymer in order to modify the surface properties of the specimen.

*Example:* [a] Electroplating of metals or alloys.
[b] Electroless plating of metals or alloys.

**Technological importance of metal finishing:**

[1] To get a decorative surface. *Example:* Gold plating on copper.
[2] To prevent corrosion. *Example:* Zinc coating on iron.
[3] To modify the surface properties such as thermal resistance, hardness, brightness, brittleness, etc. *Example:* Chromium or nickel coating on iron.

**Electroplating:** It is a process of coating a metal on the surface of another metal or a polymer or a ceramic article by electrolysis.

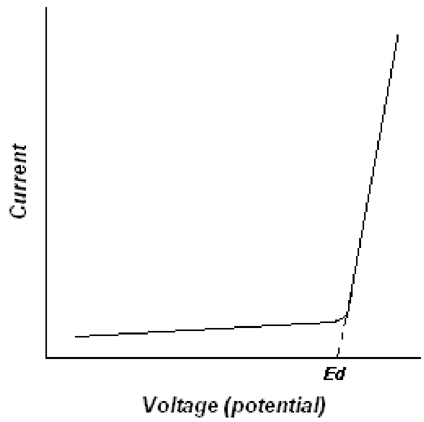
*Example:* [a] Electroplating of metals like zinc, chromium, nickel, tin, etc.,
[b] Electroplating of alloys such as Cu-Zn, Cu-Sn, Co-Ni, etc.,

**Principles governing metal finishing:**

**[1] Polarization:** It is an electrode phenomenon. Polarization of electrode occurs when there is variation of electrode potential due to inadequate supply of species from the bulk of the solution to the electrode. When a large current is passed through an electrolytic cell, the delay in establishing the equilibrium (between the reduction of metal ions to metal atoms and oxidation of metal atoms to metal ions; $Mn^{+} + ne \leftrightarrow M$) will lead to polarization of the electrode. Electrode polarization depends on several factors.

[a] Size and shape of the electrode.
[b] Electrolyte concentration and its conductivity.
[c] Temperature.
[d] Products formed at the electrodes.
[e] Rate of stirring of the electrolyte.

**[2] Decomposition Potential [Ed]:** It is defined as the minimum voltage which is required to bring about continuous electrolysis of an electrolyte. During electrolysis when the applied voltage is gradually increased, there will be a slight increase in the current and when the applied voltage reaches a certain value, the current suddenly increases with a slight increase in the voltage. Thus electrolysis is found to occur only when the applied voltage is above a certain value called the '*decomposition voltage*'. Below this value no electrolysis occurs, since the current flowing through the electrolytic cell will be very low. The decomposition voltage for an electrolytic cell may be obtained by extrapolation of the Current v/s Voltage - curve as shown in the figure.




**[3] Over voltage:** It is defined as the excess voltage that has to be applied above theoretical decomposition potential to start the electrolysis. It is denoted by ‘η’.

η = (Experimental decomposition potential) – (Theoretical decomposition potential)

Over voltage for a given electrolyte depends on the following factors.

[a] Nature of the metal used as an electrode.

[b] Nature of the substance deposited.

[c] Current density.

[d] Temperature.

[e] Rate of stirring of an electrolyte.

**Factors influencing the nature of electrodeposit:**

**[1] Current density:** It is defined as the current per unit area of the electrode surface. It is expressed in milli amperes per square centimeter ($mA/cm^2$). As the applied voltage is increased the current density rises till it reaches a limiting value. Low current densities favor a slow and well formed metal coating. A very high current density results in less ordered and bad metal coating due to mass transport. An optimum current density is required to obtain a well-defined metal coating.

**[2] Metal ion concentration:** The metal ion concentration is normally kept high between 1-3 $mol/dm^3$.

**[3] Concentration of electrolyte:** Electrolytes increase the conductivity of the plating bath. Therefore, the concentration of electrolytes should be high.

**[4] pH:** Optimum pH range for most of the plating processes is from 4-8. At low pH (highly acidic) evolution of hydrogen occurs resulting in burnt deposit. At higher pH (highly basic) the electrode surface gets coated with insoluble hydroxides.

**[5] Temperature:** Optimum temperature range for most of the plating processes is from 35-60 $^oC$. A good metal coating can be obtained at slightly elevated temperature because of the increase in the surface diffusion of ions. High temperature may also lead to corrosion of process equipment and decomposition of organic additives.

**[6] Throwing power:** It is the ability of the plating bath to give a uniform coating on the entire surface of the object. If the coating is uniform, irrespective of the object, throwing power of the plating bath is said to be good. Throwing power of plating path is determined by Haring-Blum cell.

**[7] Organic additives:** Some organic compounds are added to plating baths to obtain coating with unique structure and properties.

- *Brighteners:* Aromatic sulphones, thiourea etc., are used to obtain a bright coating.
- *Levellers:* Sodium ally sulphonate is used to obtain a level deposit.
- *Structure modifiers:* Electro-deposits are associated with internal stress, which may result in micro cracking of the deposit. Structure modifiers (stress relievers) are used to decrease internal stress.
- *Wetting agents*: During electroplating process, $H_2$ gas is liberated at cathode. Wetting agents are used to remove adsorbed $H_2$ from cathode surface. They also improve uniformity of the deposit and reduce brittleness.

**Electroplating of nickel (Watt's bath):**

| | |
|---|---|
| **Plating bath** | ***Watt's bath***<br>Nickel sulfate (25 g) + Nickel chloride (4.5 g) + Boric acid (2 g) |
| **Temperature** | 40-50 $^oC$ |
| **Current density** | 20-50 $mA/cm^2$ |
| **Anode** | Nickel pellets |
| **Cathode** | Object (article) |
| **pH** | 4.5 |
| **Additives** | Saccharin |
| **Applications** | [1] Used as an under coat for gold, chromium, platinum.<br>[2] To make black nickel-plated name boards. |

**Reactions:**

At anode: $Ni \rightarrow Ni^{2+} + 2e^-$

At cathode: $Ni^{2+} + 2e^- \rightarrow Ni$

**Electroplating of chromium (decorative and hard):**

| | |
|---|---|
| **Plating bath** | ***Chromic acid bath:*** Chromic acid + Sulfuric acid (100:1) |
| **Temperature** | 45-60 $^oC$ |
| **Current density** | 100-200 $mA/cm^2$ |
| **Anode** | Pb-Sn alloy or stainless steel |
| **Cathode** | Object (article) |
| **pH** | 2-4 |
| **Applications** | To obtain decorative and corrosion resistant coating on automobile and surgical instruments. |

**Reactions:**

$CrO_3 + H_2O \rightarrow H_2CrO_4 \rightarrow CrO_4^{2-} + 2H^+$

$2H_2CrO_4 \rightarrow H_2Cr_2O_7 + H_2O \rightarrow$ \`$Cr_2O_7^{2-} + 2H^+ + H_2O$

$Cr_2O_7^{2-} + 14H^+ + 6e \rightarrow 2Cr^{3+} + 7\,H_2O$

$Cr^{3+} + 3e \rightarrow Cr$

*Note:* Chromium anodes are not used in chromium plating for the following reasons:

[a] Chromium metal passivates strongly in acid sulphate medium.

[b] Chromium anode gives Cr(III) ions on dissolution. In presence of Cr(III) ions in large concentration, a black Cr deposit is obtained.

**Electroless plating:** Deposition of a metal from its salt solution on a catalytically active surface by a suitable reducing agent without using electrical energy is known as 'electroless plating'.

Metal ion + Reducing agent → Metal + Oxidized product

**Distinctions between electroplating and electroless plating:**

| Electroplating | Electroless plating |
|---|---|
| Electricity is required. | Electricity is not required. |
| Insulators cannot be electroplated. | Conductors, semiconductors and insulators can be electroless plated. |
| Electroplating bath will not have reasonable throwing power to plate irregular parts of an article. | Electroless baths have reasonably high throwing power; hence any shaped article can be effectively plated. |
| A separate anode is required during electroplating of an article. | Catalytically active surface of the article itself acts as anode. |
| Electroplated coatings are less hard. | Electroless plated coatings are harder. |

**Electroless plating of copper on PCB (Printed Circuit Board):**

**[1] Preparation of the surface:** The surface of plastic is cleaned by treating with organic solvents, then treated with dilute acid and finally washed with distilled water. The cleaned surface is treated with $SnCl_2$ and $PdCl_2$ alternatively to obtain catalytically active surface.

**[2] Composition of electroless bath:**

- $CuSO_4$ solution
- HCHO (Reducing agent)
- NaOH + Rochell's salt (Buffer)
- EDTA (Complexing agent)
- pH = 11
- Temperature = 25 $^oC$

*Note:* Rochelle's salt is 'Potassium sodium tartrate - $KNaC_4H_4O_6 \cdot 4H_2O$'.

**[3] Reactions:**

*Anode:* $2HCHO + 4OH^- \rightarrow 2HCOO^- + 2H_2O + H_2 + 2e$

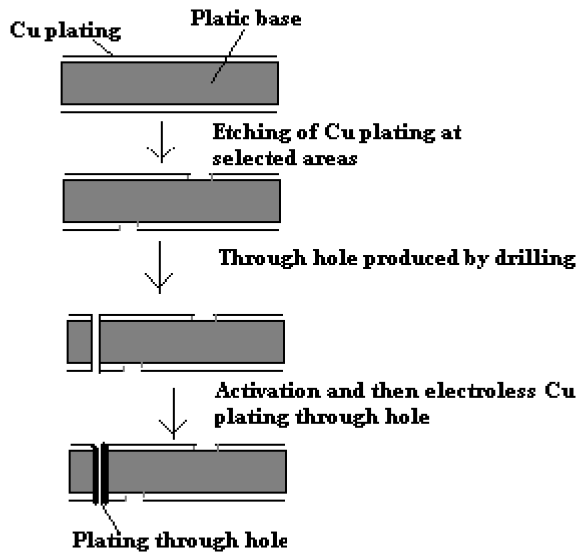
*Cathode:* $Cu^{2+} + 2e \rightarrow Cu$

*Net reaction:* $2HCHO + 4OH^- + Cu^{2+} \rightarrow Cu + 2HCOO^- + 2H_2O + H_2$

***Applications:***

Electroless copper plating is used in making PCBs particularly double sided PCBs in which plating through holes is required.

**Schematic representation of Electroless plating of Cu through holes on PCB *(Subtractive method):*** This method is used to connect two sides of a PCB by electroless Cu plating through holes.




-------------------------------