

3.6 CORROSION-CONTROL METHODS

Corrosion is very harmful for metals or alloys. Since metals and alloys disintegrate or waste every year, corrosion costs a huge amount of money, effort and time and it is necessary to protect the metals or alloys against corrosion by some methods.

Some of the corrosion control methods are given below.

(a) Corrosion Control by Modifying the Metal

- By selection of the metal
- By using pure metals
- By proper alloying
- By proper design

(b) Cathodic Protection Method

- Sacrificial anodic protection
- Impressed current cathodic protection

(c) By using Inhibitors

- Anodic inhibitors
- Cathodic inhibitors
- Vapour-phase inhibitor

(d) Changing the environment

- De-aeration
- De-activation

- Dehumidification
- Alkaline neutralization

(e) By using Protective Coating

3.6.1 Cathodic Protection Method

The anode is the electrode at which a net oxidation reaction occurs, whereas cathodes are electrodes at which net reduction reactions occur. All cathodic protection systems require an anode, a cathode, an electric circuit between the anode and cathode, and an electrolyte. Thus, cathodic protection will not work on structures exposed to air environments. The air is a poor electrolyte, and it prevents current flowing from the anode to the cathode. **The principle involved in cathodic protection is to force the metal to behave like a cathode.**

Cathodic protection can be accomplished by two widely used methods:

(a) Sacrificial Anodic Protection

Coupling a given structure (say Fe) with a more active metal such as zinc or magnesium, produces a galvanic cell in which the active metal works as an anode and provides a flux of electrons to the structure, which then becomes the cathode. The cathode is protected and the anode progressively gets destroyed, and is hence, called a **sacrificial anode**.

(b) Impressed-current Cathodic Protection

The second method involves impressing a direct current between an inert anode and the structure to be protected. Since electrons flow to the structure, it is protected from becoming the source of electrons (anode). In impressed current systems, the anode is buried and a low-voltage dc current is impressed between the anode and the cathode.

(a) Sacrificial Anodic Protection Method

A sacrificial anode, or sacrificial rod, is a metallic anode used in cathodic protection where it is intended to be dissolved to protect other metallic components. The more active metal is more easily oxidized than the protected metal and corrodes first (hence the term 'sacrificial'); it generally must oxidize nearly completely before the less active metal will corrode, thus acting as a barrier against corrosion for the protected metal. In this method, the metallic structure to be protected is made the cathode by connecting it with the more active metal (anode metal). Because of this, all the corrosion will concentrate only on the active metal. The artificially made anode thus gradually corrodes protecting the original metallic structure. Hence, this process is otherwise known as **sacrificial anodic protection**.

Typical materials for sacrificial anodes are magnesium (for soil) and aluminium/zinc/galvalum/indium alloys (for sea water or seabed).

Example 1 This method is used for the protection of ships and boats. Sheets of Mg or Zn are hung around the hull of the ship (Fig. 3.11).

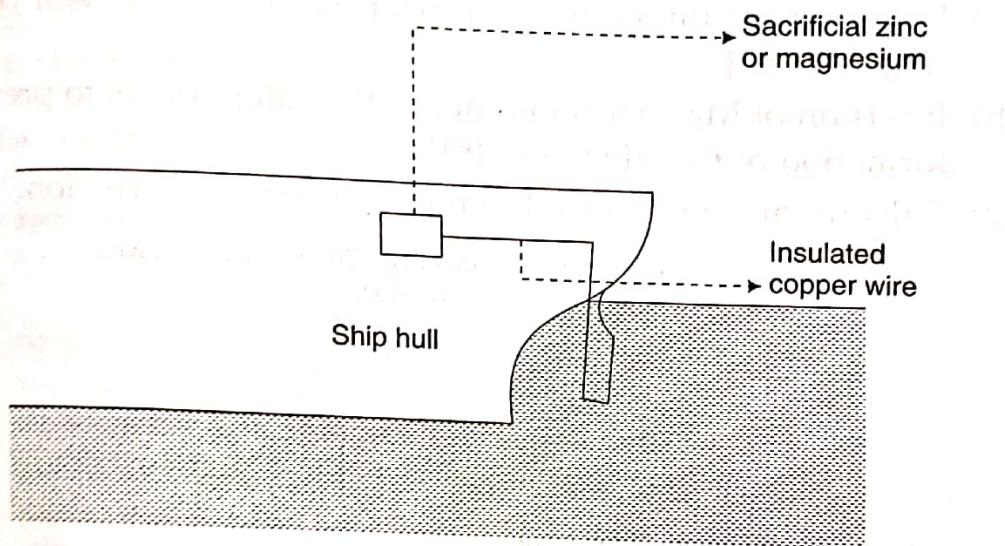


Fig. 3.11 Sacrificial anodic protection of ship

Zn or Mg act as anodes compared to iron (ship or boat is made of iron), so corrosion concentrates on Zn or Mg. Since they are sacrificed in the process of saving iron, they are called **sacrificial anodes**.

Sacrificial anodes are used on water-based vessels, such as yachts and powerboats, to minimize the corrosion of vital metal parts such as hulls and propellers. Conventionally made of zinc, aluminum and magnesium, boat anodes are designed for use in particular water types and with specific boat models. The number and size of anodes is determined by the type of material and the surface area being protected.

Choosing the Correct Anode

Generally, boat owners should choose the anode most suitable for the type of water they berth in. Naturally, some boats will move between salt and freshwater, or be berthed in areas where water will change between brackish water or freshwater. In these cases boat owners must choose a cathodic protection system to minimize corrosion in all environments.

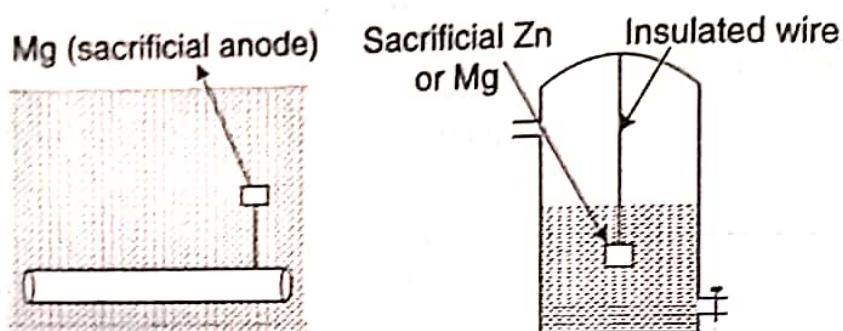
Not all anodes are suitable for use in every type of water. For example, if zinc or aluminum anodes are left in freshwater they will develop a layer of oxide which will stop the anode from working. On the other hand, aluminum anodes will operate effectively in brackish water whilst zinc anodes will become unreactive. If the wrong type of metal is chosen for the water type, the anode will become useless.

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Water	Metal Anode
Salt water	Zinc or aluminum anodes
Brackish water	Aluminum anodes
Freshwater	Magnesium anodes

Other applications of sacrificial anodic protection are

- (a) Protection of underground pipelines, cables from soil corrosion [Fig. 3.12 (a)]
- (b) Insertion of Mg sheets into domestic water boilers to prevent the formation of rust [Fig. 3.12 (b)]
- (c) Calcium metal employed to minimize engine corrosion.



(a) Underground pipeline

(b) Boiler

Fig. 3.12 *Sacrificial anodic protection*

3.6.2 Corrosion Inhibitors

This is a process of modifying the environment by adding certain chemicals to the corroding medium. These chemicals are known as corrosion inhibitors, as they arrest the anodic or cathodic reactions, i.e. a corrosion inhibitor is a substance which reduces the corrosion of a metal, when it is added in small quantities to the corrosive environment.

Types of Inhibitors

(i) Anodic Inhibitors

Anodic inhibitors retard the corrosion reaction, occurring at the anode, by forming an insoluble compound with a newly produced metal ions

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of anode. This precipitate will then be adsorbed on the metal (anode) surface, forming a protective film or barrier and thereby reducing the corrosion rate.

Anodic inhibitors should be used in enough amounts to cover the metal surface completely with the protective film, as otherwise corrosion will be concentrated on the remaining areas resulting in pitting corrosion.

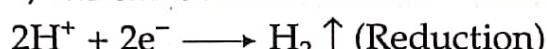
Examples: Chromates, molybdates, nitrates, phosphates, tungstates or other ions of transition elements with high oxygen content.

(ii) Cathodic Inhibitors

In an electrochemical corrosion, the cathodic reactions are of two types depending upon the environment.

1. In an Acidic Solution

In an acidic solution, the cathodic reaction is evolution of hydrogen



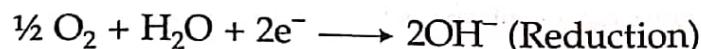
The functions of cathodic inhibitors in acidic environment are the following:

1. *To decrease the formation of hydrogen at the cathode:* This can be done by adding organic inhibitors like amines, pyridines, etc., which are adsorbed at the metal surfaces.
2. *To increase the overvoltage of hydrogen:* This can be done by adding antimony and arsenic oxides which deposit adherent film of metallic arsenic and antimony at the cathodic areas.

Examples: Organic inhibitors like anilines and its derivatives, mercaptans, heterocyclic nitrogen compounds, thioureas etc.

2. In a Neutral Solution

In a neutral solution, the cathodic reaction is absorption of oxygen or formation of hydroxyl ions.



Here, the formation of OH^- ion is only due to the presence of oxygen. So the corrosion can be controlled in two ways.

- (a) *By eliminating the oxygen from the corroding medium (neutral solution),* thereby formation of OH^- ions are inhibited. This can be done by either adding reducing agents like Na_2SO_3 , N_2H_4 or by deaeration.
- (b) *By retarding the diffusion of O_2 to the cathodic areas* eliminates the formation of OH^- ions from the neutral solution. This can be done by adding Mg , Zn or Ni salts. These react with OH^- ions form insoluble hydroxides, which are deposited on the cathode forming less impermeable self-barriers. Hence they retard the diffusion of O_2 to cathode.

Examples: Sodium sulphite (Na_2SO_3), hydrazine (N_2H_4).

(iii) Vapour-phase Inhibitors (VPI) or Volatile Corrosion Inhibitors (VCI)

This type of inhibitors are organic inhibitors, which readily vaporize (sublimes) and form a protective layer on the metal surface. VPI are used to avoid corrosion in closed spaces, storage containers, packing materials and sophisticated equipments, etc.

Examples: Dicyclohexylammonium nitrate (DCHAN), benzotriazole, Phenyl thiourea, etc.

3.7 PROTECTIVE COATINGS

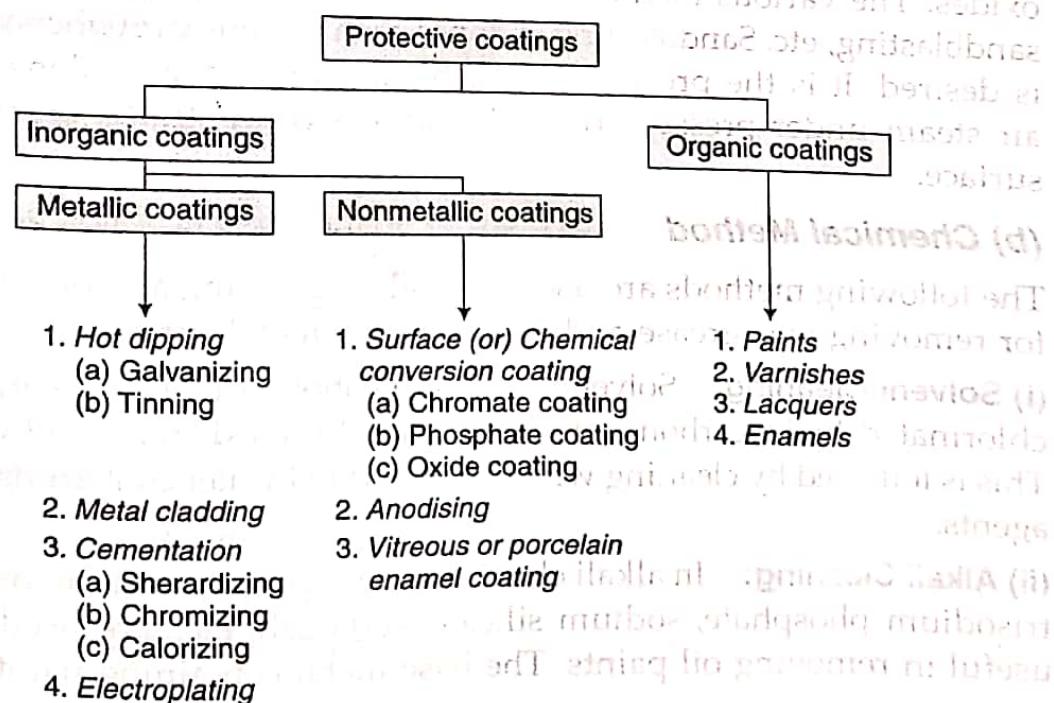
Protective coatings are used to protect the metals from corrosion. Protective coatings act as a physical barrier between the coated metal surface and the environment. However, they are also used for the decorative purpose. In addition to corrosion protection and decoration, they impart some special properties such as hardness, electrical properties, oxidation resistance and thermal insulating properties to the protected surface.

(a) Main Requirements

Protective coatings should be chemically inert to the environment at any temperature and pressure conditions.

(b) Classifications

Protective coatings are broadly of two types, i.e., inorganic and organic. They are further classified as shown below.



Coatings like paints, varnishes, lacquers and enamels are called organic coatings. They are applied on the metallic surfaces for both corrosion resistance and decoration.

3.8 PRE-TREATMENT OF METAL SURFACE OR PREPARATION OF MATERIAL FOR COATING

The base-metal surface is usually contaminated with rust, scale, oil, grease, etc. For proper adhesion of plating or coating, the metal surface (base metal) to be plated should be free from these impurities. If they are present at the time of coating, it will give porous and discontinuous coatings. So these impurities should be removed by proper pre-treatment methods. This is called **pre-treatment of metal surface**. This usually involves three steps.

- 1. Degreasing:** It is a process of removal of grease, oil and other surface contaminants.
- 2. Descaling:** It removes loose and hard oxide scale from the metal surface.
- 3. Etching:** It is a treatment to secure adhesion or a polishing to improve the appearance of applied coating.

The following methods are used to achieve the fresh metal surface for providing protective coating.

(a) Mechanical Method

This method is used for descaling purpose, i.e., to remove loose scale and oxides. The various methods are hammering, scraping, wire brushing sandblasting, etc. Sandblasting is done when a slightly roughened surface is desired. It is the process in which sand or abrasives along with an air steam under pressure of 25–100 atm is concentrated on the metal surface.

(b) Chemical Method

The following methods are used for both degreasing and descaling, i.e., for removing oils, grease and rust from the metal surface.

(i) Solvent Cleaning: Solvents such as alcohols, acetone, xylene, toluene, chlorinated hydrocarbons, etc., are generally used in solvent cleaning. This is followed by cleaning with steam and hot water containing wetting agents.

(ii) Alkali Cleaning: In alkali cleaning, chemicals like sodium hydroxide, trisodium phosphate, sodium silicate, soda ash, etc., are used. This is useful in removing oil paints. The base metal containing paint coating

is removed by keeping it in an alkali cleaning agent ($\text{NaOH} + \text{Na}_3\text{PO}_4 + \text{Na}_2\text{CO}_3$). This cleaning is always to be followed by a thorough rinsing with water.

(iii) Acid Pickling: Basic natures of rusty scales are removed by pickling. It is a process of dipping the object in hot dilute acids such as H_2SO_4 , HCl , HF , H_3PO_4 and HNO_3 . Brass and bronze are pickled by a mixture of H_2SO_4 , HCl and a small amount of HNO_3 . Iron and steel surfaces are pickled in H_3PO_4 or in H_2SO_4 followed by H_3PO_4 .

(c) Electrochemical Method

This method is used where the oxide scales cannot be removed by the other methods. The metal whose surface has to be cleaned is made either anode (cathode pickling) or cathode (anode pickling). The electrolyte is usually in acid solution or an alkali solution and on passing a direct current, the dissolution of the oxide scales at anode or cathode takes place.

3.9 ELECTROPLATING OR ELECTRODEPOSITION

3.9.1 Principle

Electroplating is the process in which the coating metal is deposited on the base metal by passing a direct current through an electrolytic solution containing the soluble salt of the coating metal.

Base Metal (cathode): The metal which is coated upon is known as the base metal.

Coat Metal (anode): The metal applied as coating is referred to as coat metal. The coat metal should be chemically inert and resistant to corrosion and should preferably have low melting point.

The base metal to be plated is made the cathode of an electrolytic cell, whereas the anode is either made of the coating metal itself or an inert material of good electrical conductivity.

Example: Graphite.

3.9.2 Objectives

(a) On Metals

1. To increase the resistance to corrosion of the coated metal
2. To improve the hardness and physical appearance of the article
3. To increase the decorative and commercial values of the article

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4. To increase resistance to chemical attack
5. To improve the properties of the surface of the article

(b) On Nonmetals

1. To increase strength
2. To preserve and decorate the surfaces of nonmetals like plastics, wood, glass, etc.
3. For making the surface conductivity by utilization of light weight, nonmetallic materials

3.9.3 Process

Electroplating is carried out in an electrolytic cell. Before electroplating, the article to be plated is first treated with dil. HCl (or) dil. H_2SO_4 to clean the surface. The cleaned article is then made the cathode of an electrolytic cell. The anode is either the coating metal itself or an inert material of good electrical conductivity (like graphite).

The electrolyte is a solution of a soluble salt of a metal (to be deposited). The anode and cathode are dipped in an electrolytic solution kept in an electroplating tank. The tank is made of glass, enameled iron, and stoneware.

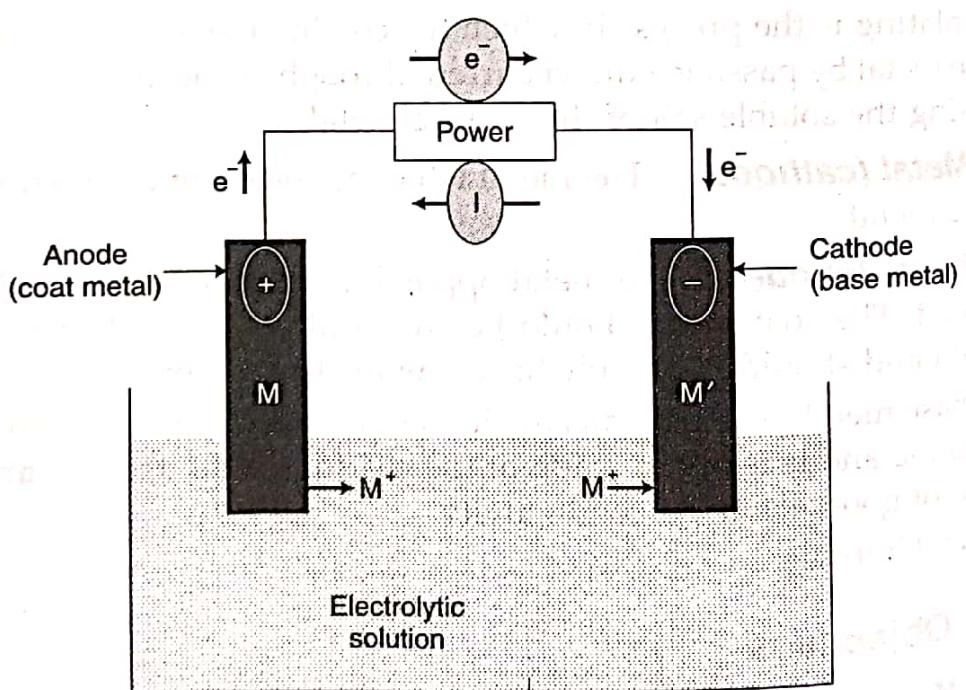
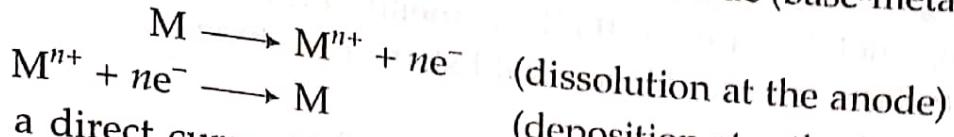


Fig. 3.14 Electroplating

The electrodes are dipped in this electrolytic solution and a direct current of electricity is passed. On electrolysis, the anode (coat metal) dissolves into the electrolytic bath and the metal ions from a bath solution

are migrated and deposited as metal over the cathode (base-metal article to be plated).



When a direct current is passed from a battery, coating metal ions migrate to the cathode and get deposited there. Thus, a thin layer of coating metal is obtained on the article (at cathode).

In order to get a strong, adherent and smooth deposit, certain additives (glue, gelatin, etc.) are added to the electrolytic bath. In order to improve the brightness of the deposit, brightening agents are added in the electrolytic bath. The favorable conditions for a good electrodeposit are optimum temperature, optimum current density and low metal-ion concentrations.

Advantages of Electroplating

A very thin coating (useful for deposition of costly metals like Au, Ag) can be obtained by adjusting suitably the factors responsible for controlling the thickness of coating.

3.9.4 Factors Affecting Electroplating

1. Surface Treatment: Cleaning of the article is essential for a strong adherent electroplating. Oily substances present in the base metal should be removed by solvent cleaning.

2. Concentration of Coating Metal Ion: Low concentration of the metal ions in the electrolyte will produce a uniform coherent metal deposition.

3. Thickness: Thickness of the deposit should be minimized in order to get a strong adherent coating.

4. Current Density: Current density used for electroplating should be optimum, because high current density produces loose and powdery deposit and low current density decreases the rate of electrodeposition.

5. Additives: Additives like gelatin and glue are added to electrolytic bath in order to get a strong, adherent and mirror-smooth coating.

6. Electrolyte: The electrolyte selected should have a good conductivity of current.

7. pH: The pH of the electrolytic bath must be properly maintained to get the deposition effectively. Usually, acidic pH 5–6 is preferred for high conductivity.

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8. Stirring: should not be fast, since it will hinder the good adherence of coating metal atoms on the base metal and so a porous and rough deposit will be formed. Hence, mild stirring is done.

Table 3.5 *Electroplating of some metals and conditions*

Metal Deposited	Anode	Cathode	Electrolyte	Operating Temperature	Current Density	Additives
Copper	Pure copper plates	Metal article	CuSO_4	40–50°C	35–40 mA cm ⁻²	—
Nickel	Pure Ni pellets or pieces in Ti mesh basket	Metal article	Solution of $\text{NiSO}_4 + \text{NiCl}_2 +$ Boric acid	40–70°C	20–30 mA cm ⁻²	Saccharin
Gold	Pure gold	Metal article	Gold + KCN	60°C	5–10 mA cm ⁻²	—
Chromium	Pb-Sn (or) Pb-Sb alloy coated with PbO_2 (or) stainless steel	Metal article	Chromic acid + H_2SO_4 in 100: 1 ratio	40–50°C	100–200 mA cm ⁻²	SO_4^{2-}

3.10 ELECTROLESS PLATING

Non-electrical plating of metals and plastics are used to achieve uniform coatings by a process of controlled autocatalytic (self-continuing) reduction. Discovered in 1944 by A Brenner and G E Riddell, electroless plating involves the deposition of such metals as copper, nickel, silver, gold, palladium on the surface of a variety of materials by means of a reducing chemical bath. It is also used in mirroring, in which a clean surface of glass is dipped into an ammoniacal silver solution mixed with Rochelle salt or with a nitric acid–cane-sugar alcohol solution.

Nonmetallic surfaces, such as plastics, must be chemically treated prior to electroless plating. The major expansion of electroless plating has come in the area of plastics, as in the plating of printed electronic circuits. A large number of consumer goods are coated by this method to create durable and attractive surfaces.

Definition It is a process of deposition of a metal from its salt solution on a catalytically active surface by a suitable reducing agent without using electricity.

Process First, M-ions are formed from its salt solution and then the reduction is accomplished by the presence of a reducing agent. Metallic

ions are reduced to the metal with the help of reducing agents. Once a metal is formed, it gets plated over a catalytically activated surface.

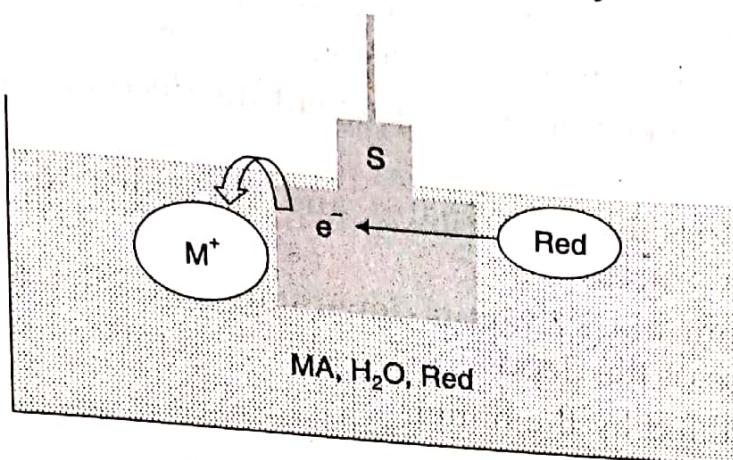
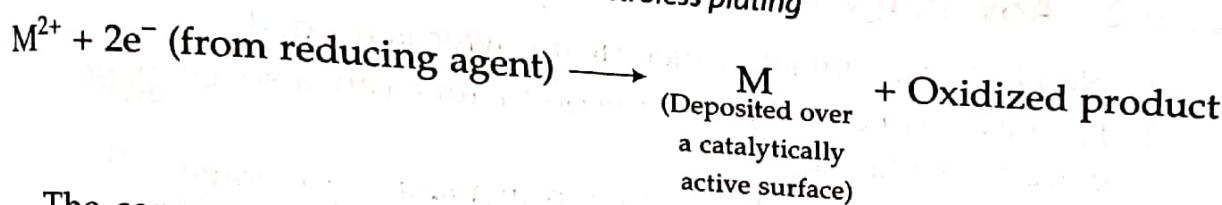


Fig. 3.15 Electroless plating



The common reducing agents are formaldehyde, Hypophosphorous acid, alkali borohydrides and alkali diboranes.

A number of metals like nickel, cobalt, copper and some precious metals can be deposited by electroless plating. The most popular metal deposited electrolessly is nickel.

3.10.1 Various Steps involved in Electroless Plating

The various steps involved are as follows:

(a) Surface Preparation for Electroless Plating

This is achieved by using any one of the following methods:

- (i) **Etching:** Impurities are removed from the surface by acid treatment.
- (ii) **Electroplating:** A thin layer of the metal or any other suitable metal is electroplated on the surface.
- (iii) **Treatment of Surface with Stannous Chloride and Palladium Chloride Alternatively:** Nonconducting surfaces such as plastics or printed circuit boards are treated with Stannous Chloride and Palladium Chloride.

(b) Preparation of Plating Bath

The main constituents of the electroless solution are

- (i) Metal salts to provide metal ions for deposition (coat metal)

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- (ii) Reducing agents like formaldehyde and hypophosphite for the reduction of metal ions to metal atoms
- (iii) Complexing agents like EDTA and trisodium citrate to complex metal ions to prevent bulk decomposition
- (iv) A stabilizer like thiourea to prevent the decomposition of plating bath solution
- (v) Accelerators like succinates and fluorides to accelerate the reduction process
- (vi) Brighteners like cadmium ions and lead ions to improve the brightness of the deposit
- (vii) PH controlled by the buffer

3.10.2 Advantages of Electroless Plating

1. No electrical contact or electrical power is needed.
2. Plastics, insulators and semiconductors can also be plated by electroless plating.
3. It is readily adoptable for three-dimensional coverage.
4. This method enhances deposit uniformity.
5. Resulting deposits have unique chemical, mechanical and magnetic properties.

Table 3.6 Differences between electroplating and electroless plating

Sl. No	Electroplating	Electroless Plating
1.	It is carried out by passing electrical energy.	Here, there is no need of electrical energy.
2.	Here, a separate anode is used.	Anodic reaction takes place on the surface of the substrate.
3.	Plating on semiconductors and insulators are difficult.	Plating on semiconductors and insulators are easy.

3.12 ANODIZED COATING

Anodized coatings are made by anodic oxidation process. This leads to the formation of protective, corrosion resistant, electrically insulating oxide film on the surface of nonferrous metals like Al, Zn, Mg and their alloys. **Anodized coating** is an electrochemical process in which the base metal is the anode. Anodizing involves the electrolytic oxidation of a surface to produce a tightly adherent oxide scale, which is thicker than the naturally occurring film.

It is carried out by passing moderate direct current through a bath in which the metal or alloy is suspended from anode at **35°C to 40°C**. The bath usually contains sulphuric acid, chromic acid, oxalic acid, phosphoric acid or boric acid.

3.12.1 Aluminum Anodizing

Aluminum anodizing is an electrochemical process in which an oxide (anodic) layer is chemically built on the surface of the metal. This oxide layer acts as an insulator and can be dyed in a wide variety of colours. Anodizing provides surface-corrosion protection along with an excellent substrate for decorative finishes.

Anode:	Aluminium (base metal)
Cathode:	Any inert material of good electrical conductivity (lead/stainless steel)
Electrolyte:	Sulphuric acid, chromic acid, oxalic acid or phosphoric acid
Temperature:	35°C to 40°C
Current density:	Moderate current density

On electrolysis, the oxygen liberated at the anode combines with aluminium to form oxide. An oxide film, initially very thin, grows on the metal surface and increases in thickness. The outer part of the oxide film formed is very porous and easily prone to corrosion. Hence, the anodized surface containing pores can be sealed by treatment with hot water/

steam for more than a few minutes. This treatment converts aluminium oxide into its monohydrate ($\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$) which occupies more volume, thereby sealing the pores. An other solution used for sealing is dilute sodium dichromate. These anodized coatings may be coloured with organic dyes and inorganic pigments to give surface coloration for decorative effects.

Anodized coatings on Zn can be obtained by making Zn as the anode in an electrolytic bath containing chromic acid or chromates.

Applications Aircraft parts, refrigerators, pistons, reflectors, machine parts, etc., are anodized by this method.

Some of the common anodizing processes used in the industries are

- Hard-coat anodizing
- Bulk anodizing
- Sulphuric acid anodizing

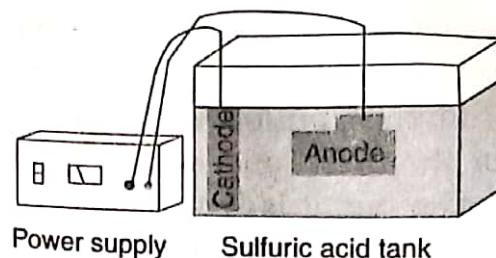


Fig. 3.16 Aluminium anodizing

3.13 HOT DIPPING

It is a process of producing a coating of low-melting point metal such as Zn, Sn, Pb, Al, etc., over the surface of Fe, steel and copper which have high melting points.

Base metal: High-melting-point metal (Fe, steel and copper)

Coat metal: Low-melting-point metal (Zn, Sn, Pb, Al etc)

The two most widely used hot-dipping methods are

1. Galvanizing
2. Tinning

3.13.1 Galvanizing

Galvanizing is the process of coating of zinc on iron or stainless-steel sheets.

(a) Process

The iron or stainless-steel article (e.g. sheet, pipe, wire) surface is first cleaned by acid pickling with dilute H_2SO_4 solution for 15–20 minutes at 60–90°C. This treatment removes any scale, rust (oxide layer) and impurities on the metal surface. The article is then washed well with

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water and dried. It is then dipped in the bath containing molten zinc, maintained at 425–430°C. The surface of the bath is kept covered with a flux, i.e. ammonium chloride, which is used for cleaning the surface of the metal and also to prevent oxide formation. When the article is taken out, it is found to have been coated with a thin layer of zinc. In order to get uniform thickness, it is passed through a pair of hot rollers, which removes any superfluous (excess) of zinc. Then, it is annealed at a temperature of 650°C and finally, cooled slowly.

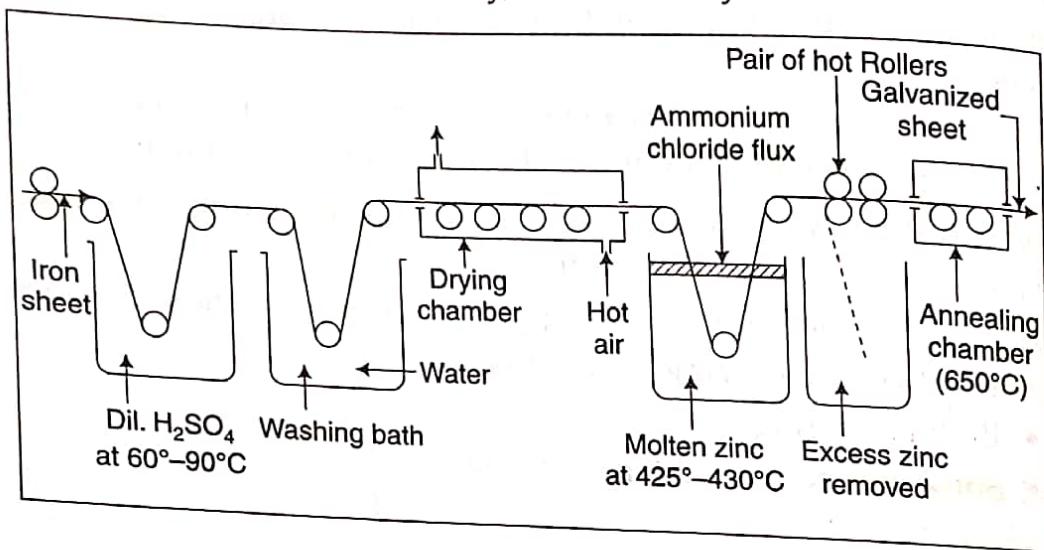


Fig. 3.17 Galvanizing process

(b) Uses

It is most widely used for protection of iron from atmospheric corrosion in the form of roofing sheets, wires, pipes, bolts, screws, buckets, tubes, etc. It may be pointed here that zinc gets dissolved in dilute acids to form highly toxic (or poisonous) compounds. Hence, galvanized utensils cannot be used for preparing and storing foodstuffs, especially acidic ones.

3.13.2 Tinning

Tinning is the process of coating of tin on iron or stainless-steel sheets.

(a) Process

In this process, iron or stainless-steel sheets are first treated with dilute sulphuric acid to remove the oxide scale on the surface. After this, it is passed through a bath containing zinc chloride flux. It helps the molten metal to adhere to the metal sheet. And then it is passed through the tank of molten tin which is kept at $230\text{--}235^\circ\text{C}$. In this process, palm oil

helps to protect the hot tin-coated surface against oxidation. In order to get uniform thickness, it is passed through a pair of hot rollers, which removes any superfluous (excess) of tin. Then, it is annealed and finally, cooled slowly.

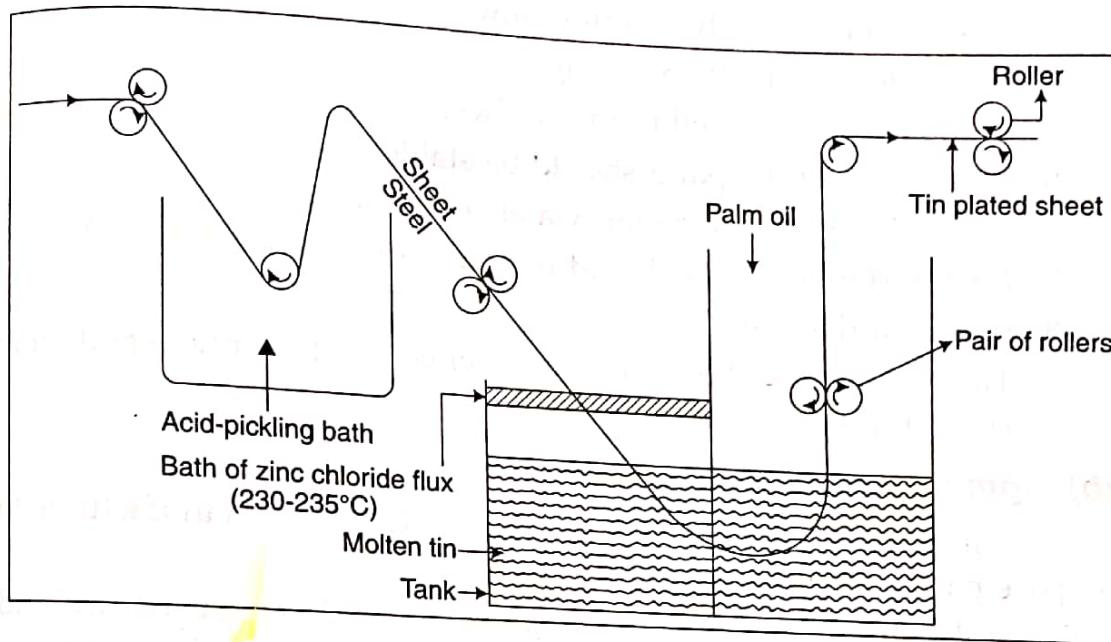


Fig. 3.18 Tinning process

(b) Uses

Tin-plated iron is used in food containers because of its nontoxic nature.

Table 3.7 Differences between galvanizing and tinning

Sl. No	Galvanizing	Tinning
1.	It is a process of coating of Zn on iron/steel.	It is a process of coating of Sn on iron/steel.
2.	It cannot be used for making food containers, because Zn reacts with food acids forming highly toxic zinc compounds.	It can be used for making containers for storing and packing food products.

3.14 PAINTS

Paint is a mechanical dispersion of one or more finely divided pigments in a medium (thinner + vehicle). When paint is applied to a metal surface, the thinner evaporates, while the vehicle undergoes slow oxidation forming a pigmented film.

(a) Requisites (or) Characteristics of a Good Paint

A good paint should satisfy the following requirements:

1. It should spread easily on the metal surface.
2. It should have high covering power.
3. It should not crack on drying.
4. It should adhere well to the surface.
5. The colour of the paint should be stable.
6. It should be corrosion-and water resistant.
7. It should give a smooth and pleasing appearance.
8. It should dry quickly.
9. The colour should be stable to the effect of atmosphere and other agencies.

(b) Pigment Volume Concentration (PVC)

It is an important criterion or a guide for the paint manufacturer to prepare paints with desired properties.

Generally, the characteristics of paints depend on the nature and quantities of pigments, extenders and vehicles present in the paint. The following equation is used to calculate the PVC.

$$\text{PVC} = \frac{\text{Volume of the pigment in the paint}}{\text{Volume of the pigment in the paint} + \text{Volume of nonvolatile vehicle in the paint}}$$

If the volume of PVC increases, the durability, adhesion and consistency of the paint decreases. The pigment volume concentration of a paint should be kept within the limit.

3.14.1 Constituents of Paints

The important constituents of paints are as follows:

1. Pigments
2. Thinner (or) solvent
3. Vehicle (or) drying oil
4. Drier
5. Antiskinning agent
6. Plasticizers
7. Fillers (or) extenders.

Table 3.8 Constituents of paints and their functions

Sl. No	Constituents	Function	Example
1.	Pigments It is a solid substance which imparts colour to the paint.	(i) To give the desired colour (ii) To cover the manufacturing defects (iii) To protect from UV light. (iv) To provide strength to the paint (v) To increase weather resistance of the film	White: Pb,TiO ₂ , ZnO Blue: Indigo, Prussian Blue Red: Red lead, chrome red Green: Chromium oxide, Cr-green Yellow: Cr-yellow, Cd-yellow Black: Graphite, carbon black
2.	<i>Thinner or solvent</i> This is a volatile portion of the medium. It easily evaporates after application of the paint.	(i) Used to dilute the paints in order to make it easy to apply on the surface (ii) Reduces the viscosity of the paint (iii) It dissolves vehicles, oil, pigment, etc., and produces a homogeneous mixture. (iv) It increases the penetrating power of the vehicle.	Turpentine oil, kerosene, alcohol
3.	<i>Vehicle or drying oil</i> It is a nonvolatile portion of a medium and film-forming material.	(i) It is used to dissolve the pigment and holds the pigment on the metal surface. (ii) It imparts water repellency, durability, and toughness to the film.	Coconut oil, linseed oil, castor oil, soyabean oil.
4.	<i>Driers</i> Substances used to accelerate the process of drying	They act as catalysts or oxygen carriers and increase the rate of drying process.	Litharge, borates, resinates and tungstates of heavy metals of Pb,Zn,Mn and Co.
5.	<i>Antiskinning agent</i>	To prevent skinning of the paint	Polyhydroxy phenol
6.	<i>Plasticizers</i>	They increase the elasticity of the film and to minimize its cracking.	Triphenyl phosphate, tributyl phosphate, try cresyl phosphate, tertiary amyl alcohol.
7.	<i>Fillers or extenders</i> Inert materials which improve the properties of the paint	(i) They increase the volume of the paint and reduce the cost. (ii) They fill the voids in the film. (iii) It increases the durability of the paint. (iv) It prevents shrinkage and cracking.	Gypsum, asbestos, China clay, talc, BaSO ₄