

MODULE 4

Corrosion control methods:

Corrosion protection - cathodic protection – sacrificial anodic and impressed current protection methods; Advanced protective coatings: electroplating and electroless plating, PVD and CVD.

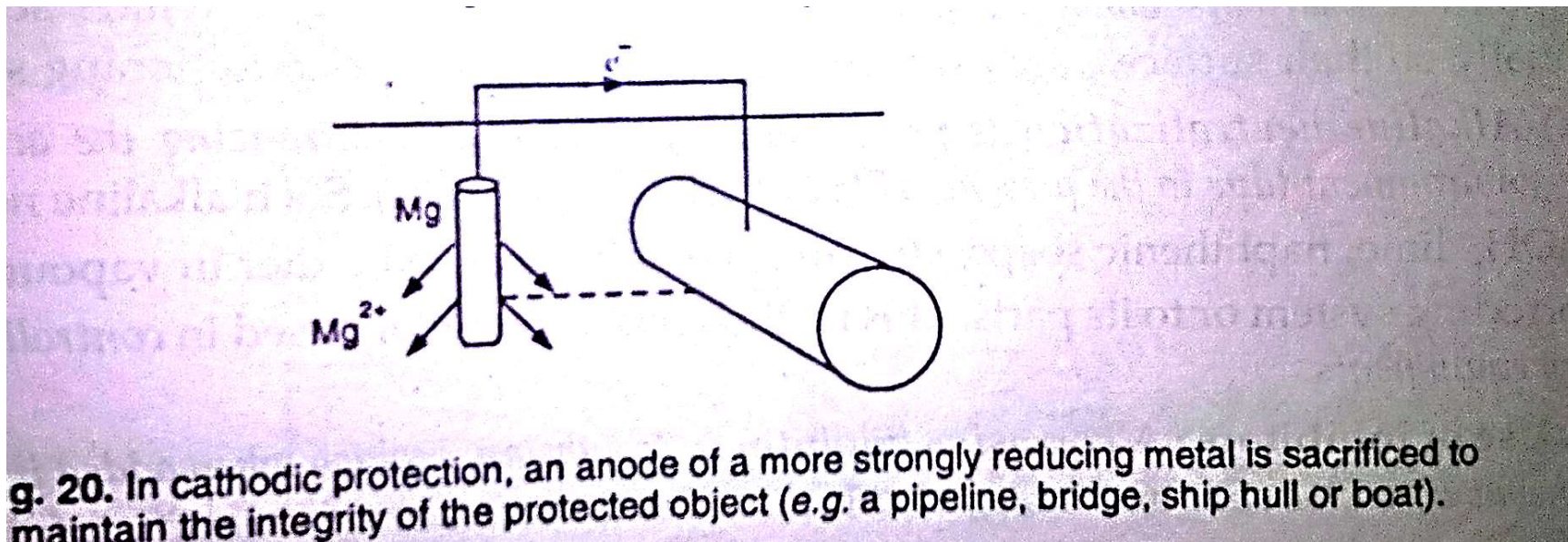
Alloying for corrosion protection – Basic concepts of Eutectic composition and Eutectic mixtures - Selected examples – Ferrous and non-ferrous alloys.

Cathodic protection

- Principle is to force the metal to be protected to behave as a cathode (only anode gets corroded!)
- Two types – sacrificial anodic protection and impressed current cathodic protection

Sacrificial anodic protection

- Metallic structure to be protected is connected by wire to a more anodic metal. This way, all the corrosion is concentrated at the anodic metal, which itself may get corroded slowly.
- The more active metal is the sacrificial anode
- The corroded metal can be periodically replaced
- Commonly used sacrificial anode metals are magnesium, Zinc, aluminium and its alloys
- Metal components that are protected this way include buried pipelines, underground cables, marine structures, ship hulls, water tanks, piers





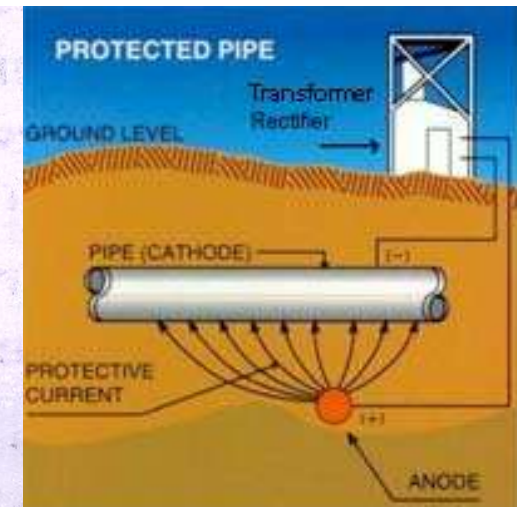
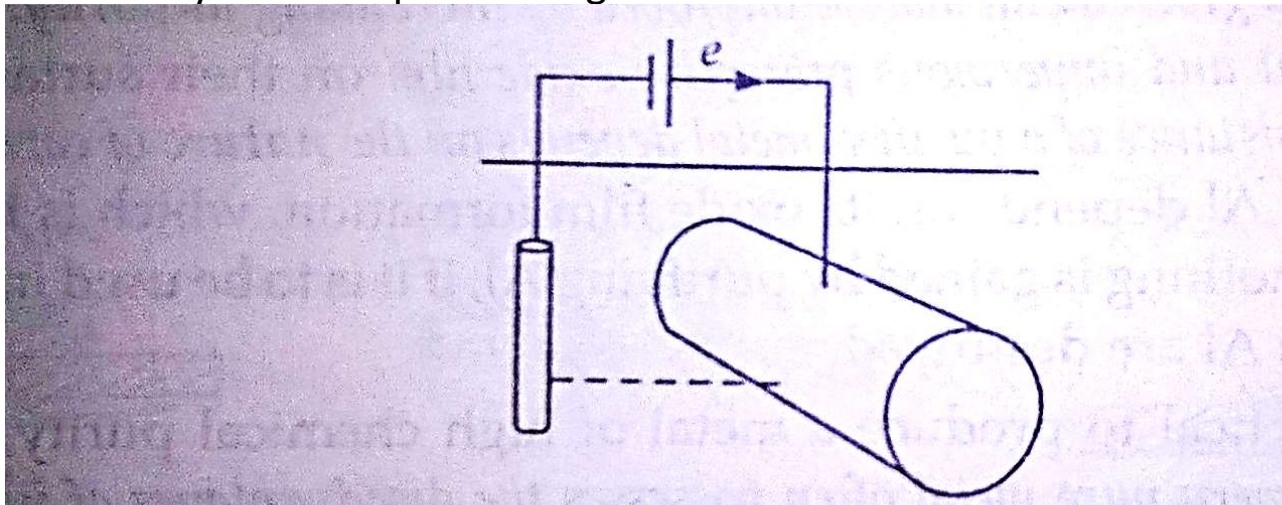
The white patches visible on the ship's hull are zinc block sacrificial anodes.

Sacrificial anodes



Impressed current cathodic protection

- An impressed current is applied opposite in direction to the corrosion current, thus converting the corroding metal from anode to cathode
- The current is drawn from a D.C source (battery or rectifier) with an insoluble anode like graphite, high silica iron, scrap iron, stainless steel or platinum.
- A sufficient current is applied to the insoluble anode, buried in soil and connected to the metallic structure to be protected.
- The anode is in a backfill composed of coke breeze or gypsum, to increase electrical contact with the surrounding soil
- This type of protection is applied to open water-box coolers, water tanks, buried water or oil pipes, condensers, transmission line towers, marine piers, laid-up ships
- Particularly useful to protect large structures



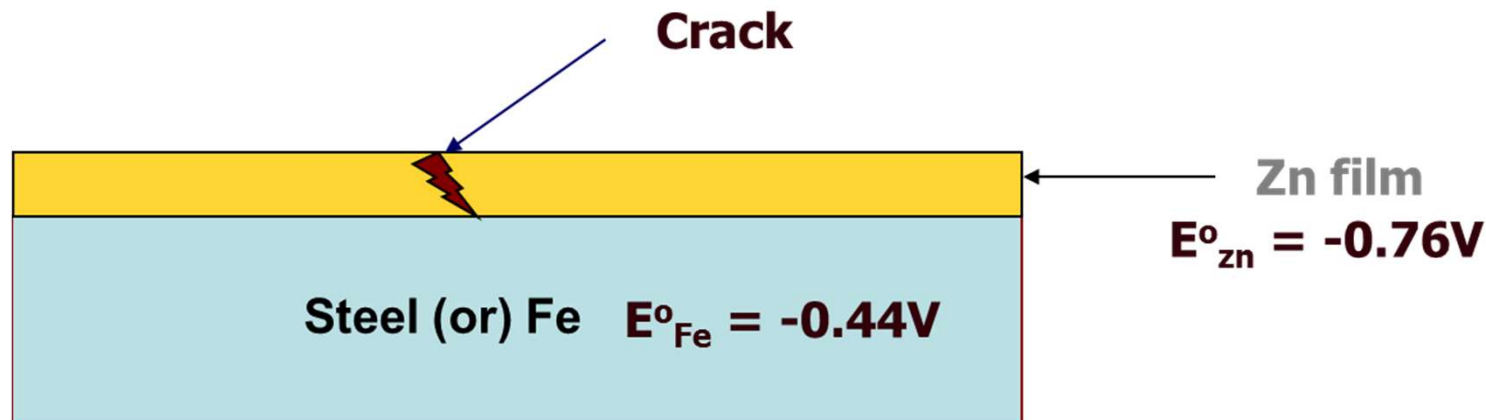
g. 21. In impressed-current cathodic protection, electrons are supplied from an external cell so that the object itself becomes cathodic and is not oxidized.

Protective coatings

- Age old method to protect metal from getting corroded
- **The protective coating applied**
 - Must be chemically inert to the environment which attacks the metal
 - **Must prevent the penetration of the environment to the metal that they protect**

Anodic coatings

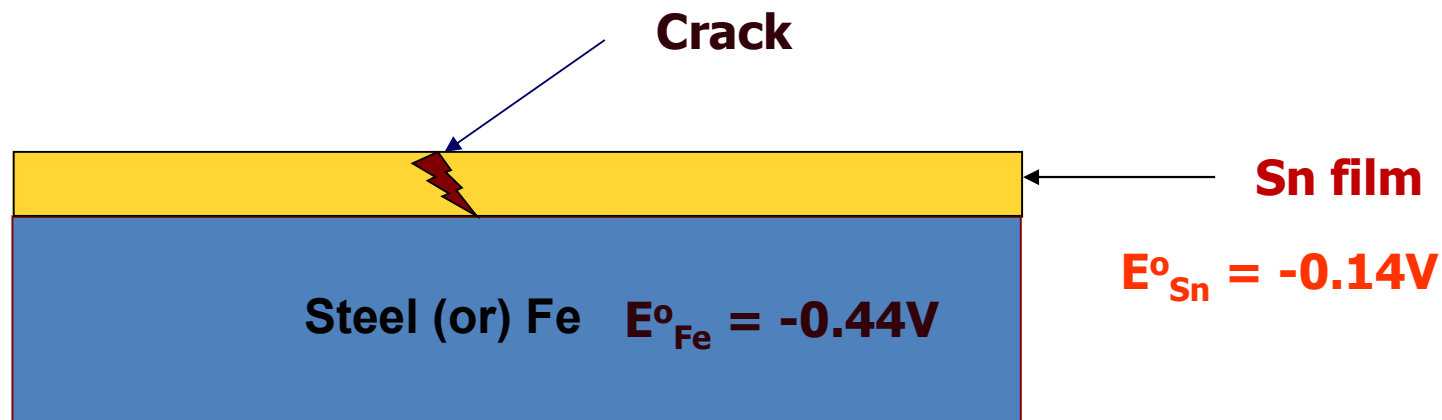
- The metal coating chosen, should be anodic to the base metal to be protected
- E.g to protect steel, Zn, Al or Cd are chosen as the coating metals based on the e-chem series
- If any discontinuity or pores in the coating develops, a galvanic corrosion cell develops with the coating metal anodic and the protected metal as cathodic area
- Thus the coating undergoes corrosion and sacrificially (anodically) protects the cathodic metal



Graphic courtesy: Dr. Arockiasamy

Cathodic coatings

- Coating of a noble metal (higher electrode potential) with higher corrosion resistance than the base metal
- **Base metal is protected only if the coating is continuous without any pores or discontinuities**
- Punctures or pores in the coating can accelerate the corrosion of the base metal
- **E.g tin coating of iron sheet is protective only as long as the coating is perfect**
- Small pores can lead to corrosion of exposed iron (small anodic area) and severe local corrosion can occur leading to pitting and perforation of the base metal

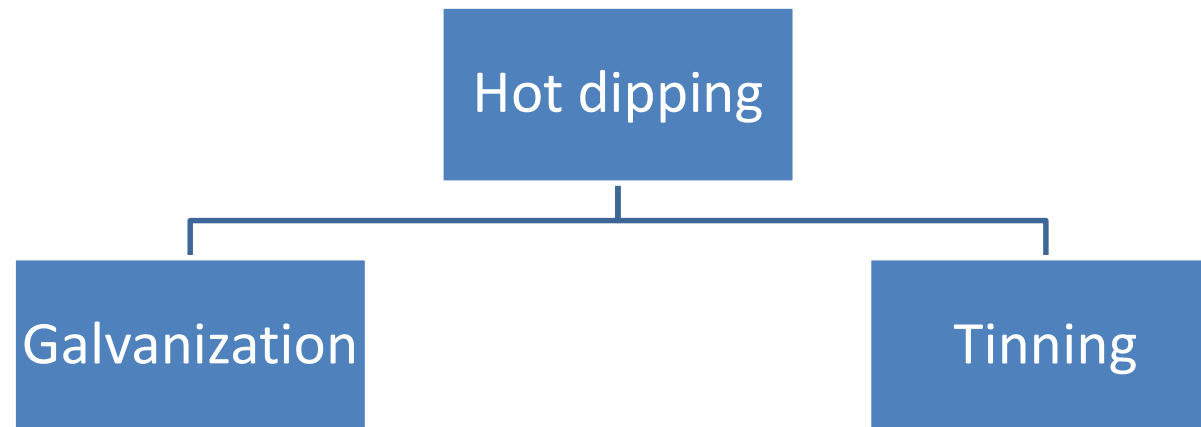


Anodic coating	Cathodic coating
Protects the underlying base metal “sacrificially”	Protects the base metal due to its noble character and higher corrosion resistance
Electrode potential of coating metal is lower than that of base metal	Electrode potential of coating metal is higher than the base metal
If pores or discontinuity breaks out, the base metal is not corroded, until all the coating metal is consumed	If pores break out, the corrosion of base metal is accelerated greatly
Coating of Zn on iron is an example	Coating of tin on iron is an example

Metal Coating methods

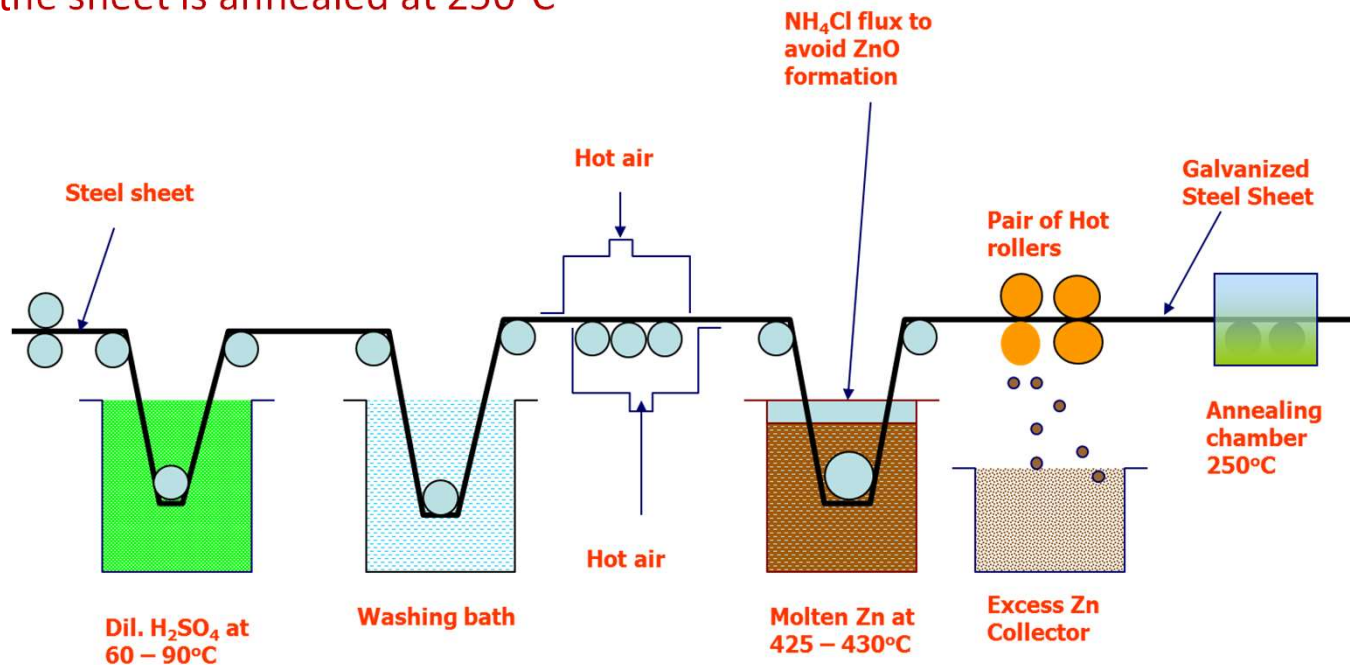
Hot dipping

- Used for coating low-melting metals like Zn, Sn, Pb, Al etc on iron, steel and copper which have very high melting points
- Metal to be coated is first covered by a molten flux (zinc chloride) layer, which cleans the base metal surface and prevents the oxidation of the molten coating metal.
- Then the base metal is dipped in a bath of molten coating-metal
- For good adhesion, the base metal surface has to be very clean. Else it cannot be wetted properly



Galvanization

- It is the process of coating iron/steel sheets with a thin coating of Zinc to prevent rusting
- The process involves:
 - The iron/steel article (sheet, pipe, wire etc) is cleaned by *pickling* with dil. H_2SO_4 for 15 – 20 minutes at 60 -90°C to remove any scale, oxides or other impurities
 - After washing and drying, the article is dipped in a bath of molten zinc (425 - 435°C)
 - The surface of the bath is kept covered with a flux (ammonium chloride) to prevent oxidation
 - The coated sheet is passed through hot rollers to remove excess zinc
 - Finally the sheet is annealed at 250°C



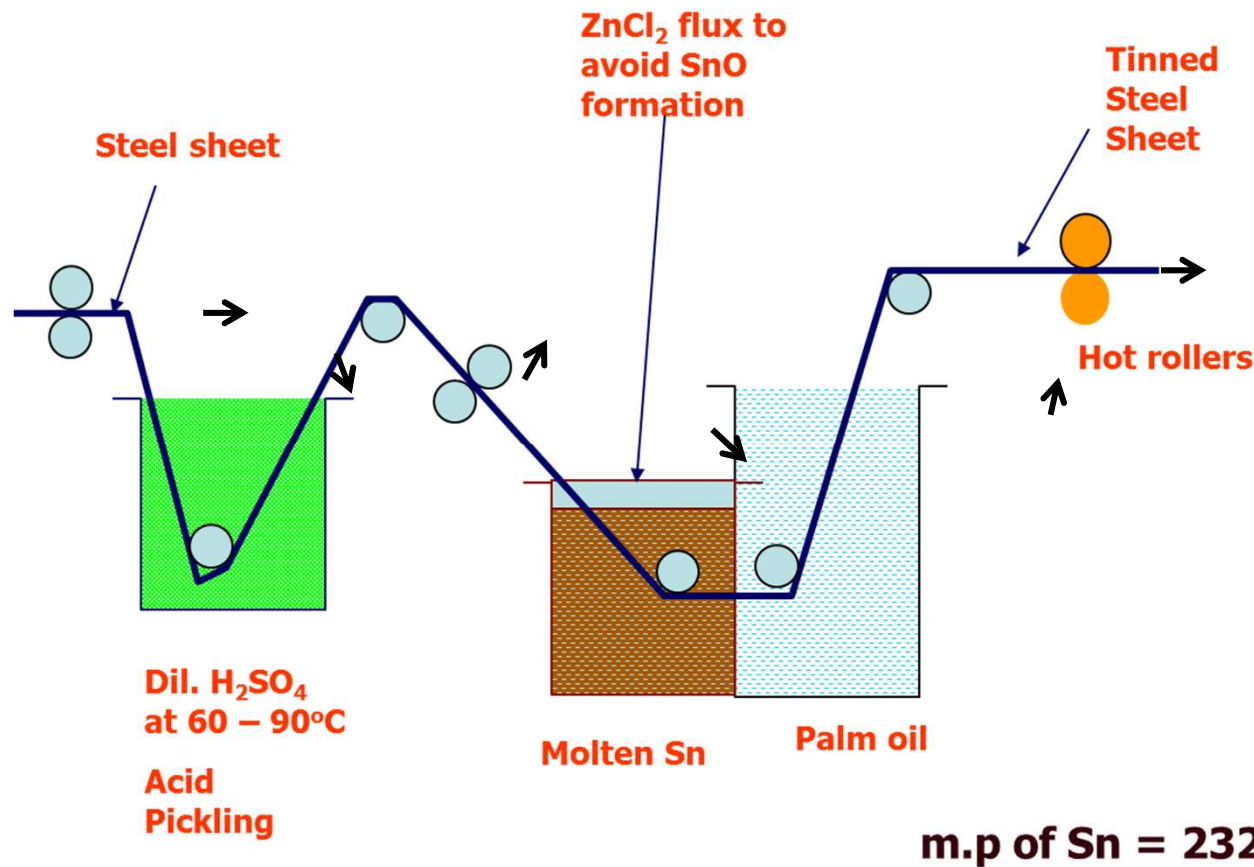
m.p of Zn = 419°C

- Iron used in roofing sheets, wires, nails, bolts, screws, buckets, tubes etc are protected from corrosion by the process of galvanization
- The Zn coating may get dissolved on contact with dilute acids, forming toxic compounds. For this reason, galvanised utensils are not suitable for preparing and storing foodstuff, especially the acidic ones



Tinning

- The process involves:
 - The iron/steel sheet is cleaned by *pickling* with dil. H_2SO_4 to remove any oxide films
 - Then dipped in a bath of molten zinc chloride flux, to aid in better adhesion of tin
 - The sheet then passes through molten tin and then through palm oil which protects the freshly coated hot tin from getting oxidised
 - the sheet is passed through rollers to attain uniform thickness



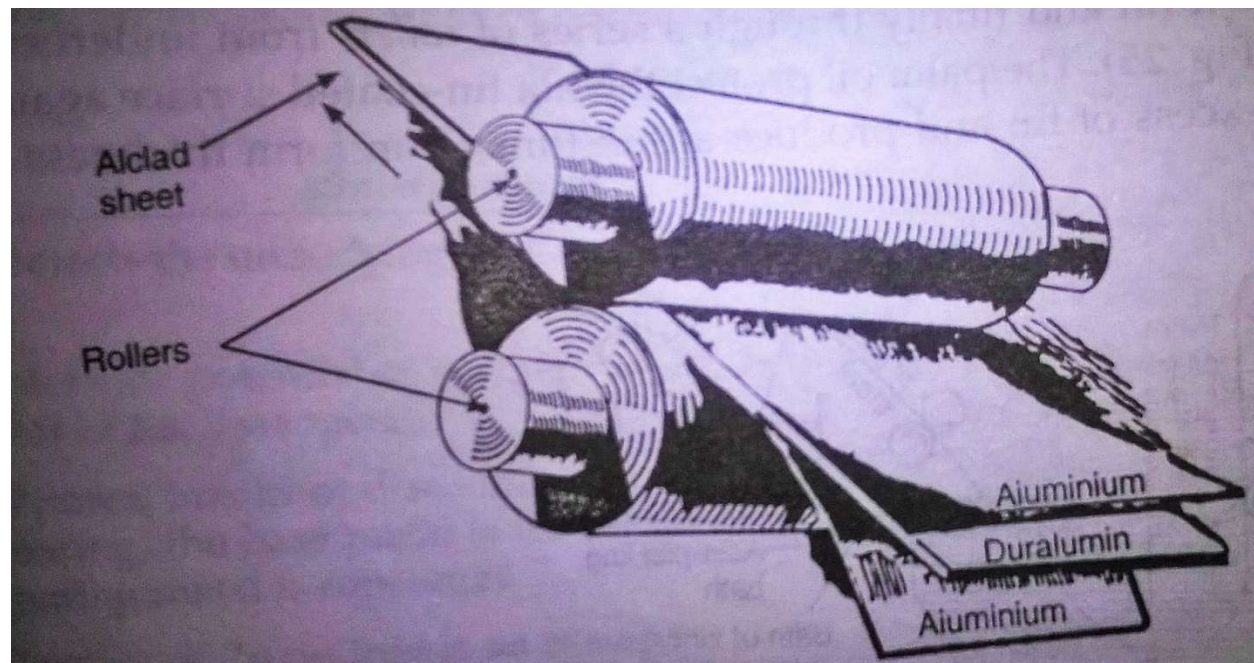
Graphic courtesy: Dr. Arockiasamy

- Tin has considerable resistance against atmospheric corrosion
- It is also non-toxic and so widely used in coating steel, copper and brass sheets that are used in making containers for foodstuff
- Tinned copper sheets are used for making utensils and refrigeration equipment

Galvanization	Tinning
Coating of iron /steel with a thin coat of zinc to protect it from rusting	Coating iron/steel with a coat of tin to prevent rusting
Zn protects iron sacrificially, since it has lower electrode potential than iron	Tin protects iron due to its noble character and its high corrosion resistance
In galvanised articles, zinc continues to protect the iron sacrificial galvanic cell action even when the coating is broken in places	Tin protects iron inly as long as the coating is perfect without any discontinuities by pores or punctures
Galvanised iron cannot be used for making food storage containers because zinc may react with food acids forming highly toxic compounds	Tin coated containers can be used for storing foodstuff due to non-toxic nature of tin

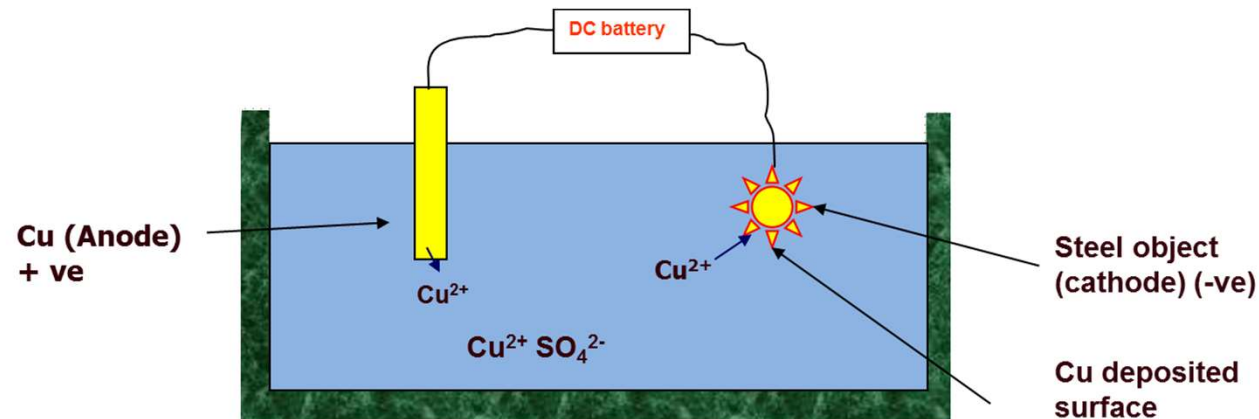
Metal Cladding

- Process by which a dense, homogenous layer of coating metal is bonded firmly to the base metal
- Any corrosion-resistant metals (Ni, Cu, Pb, Ag, Pt etc) and alloys (stainless steel, alloys of Ni, Pb, Cu) can be used as cladding materials
- Usual base metals are mild steel, Al, Cu, Ni and their alloys
- Base metal is sandwiched between two layers of coating metal and are pressed by rollers under heat and pressure, bonding them all together
- **Alclad**, used in aircraft industry, is obtained by cladding a plate of duralumin between two layers of 99.5% pure aluminium

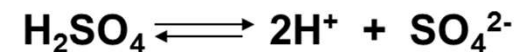


Electroplating

- Also known as electrodeposition
- Process by which 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
- Films obtained by electroplating are uniform, with very few pin-holes per unit area
- Number of pin holes decrease as the thickness of coating increases
- The base metal to be plated is usually made the cathode of the electrolytic cell,
- The anode is made of the coating metal itself or an inert material that conducts well (graphite)



Ionization reaction of electrolyte:



On passing current: $\text{Cu}^{2+} + 2\text{e}^- \longrightarrow \text{Cu}$ (at cathode)



Characteristics and factors affecting electroplating

- **Thickness** - thin deposit for decorative purpose and thick plating for corrosion resistance
- **Adherence** – Weakly adhering electrodeposit leads to peeling off of the coating
- **Hardness** – to protect against abrasion. Hardness is measured in Brinells. Lead coatings have 5 Brinells hardness and chromium coatings have 1000 Brinells
- **Protective value** - depends on porosity and the thickness of the electrodeposit
- **Throwing power** - Ability of an electrolytic cell to give a deposit of uniform thickness over the entire cathode area
 - Maximum throwing power when the cathode has regular shape
 - When cathode has irregular shape, throwing power can be improved by separating the distance between the electrodes and agitating the solution to minimise electrolytic resistance
- **Temperature** - close to room temperature is preferred
 - Warmer baths are also used to improve solubility of the electrolytes which gives better current density
 - But at higher temperatures, H_2 evolution may take place along with decomposition of organic additives

- At moderate temperatures, surface diffusion is higher than H_2 evolution. Hence plating temperature is maintained at 35 – 60 °C
- **Cleaning of article to be plated** – coating adhesion is maximised only when the base metal surface is clean from grease and dirt and corrosion products.
 - Metal surface is cleaned and pre-treated before electroplating
 - Porosity and smoothness of the metal surface greatly affect the adhesion of the protective coating



Composition of the electrolytic bath

a) Plating metal ion solution - moderate concentration (1 -3 M) is employed for adherent coating

- Higher concentrations will decrease the mass transfer and badly affect the quality of the deposit
- To increase conductivity of the bath non-participating electrolytes are added and inert electrodes maybe used

b) Complexing agents – they are used when,

- The cathode metal and plating metal ions may react. E.g when Cu is plated over Fe, Cu^{2+} is complexed with CN^- to avoid the oxidation of Fe by Cu^{2+}



- To make the potential of the plating metal ions more negative to carry out the plating at a lower applied potential
- To avoid passivation of the anodes and make them dissolve more easily
- To enhance throwing power of plating bath, complexing agents like cyanide, sulphamate, hydroxide are used
 - Smooth and adherent coatings of Cu, Ag, Au, Cd, Zn are obtained in presence of cyanide

Composition of the electrolytic bath

c) **Organic additives** - good electrodeposits are obtained when certain additives are added

1. **Brighteners** produce microscopic fine deposits which reflect light off the surface, because the grain size smaller than the wavelength of incident light

- Aromatic suphonates and compounds containing -CN, C=O or -N=C=S groups (coumarin, thiourea) are some common brighteners

2. **Levellers** – plating in regions of dislocations is rapid due to faster diffusion of ions and produce uneven thick deposits

- Levellers get adsorbed in such regions and decrease the electron transfer rates
- In Ni plating, sodium allyl sulphate is used as a leveller

3. **Structure modifiers or stress relievers** – used to alter the structure of electrodeposits for better properties. E.g saccahrin

- Electrodeposits are internally stressed and any impact may peel the deposit off the surface. Microcracking may also occur

4. **Wetting agents** – (e.g. sodium lauryl sulphate) are added to release H₂ bubbles form the surface of cathode and helps in levelling as well. In absence of wetting agents, these bubbles maybe entrapped within the plated metal making it brittle.

Current density

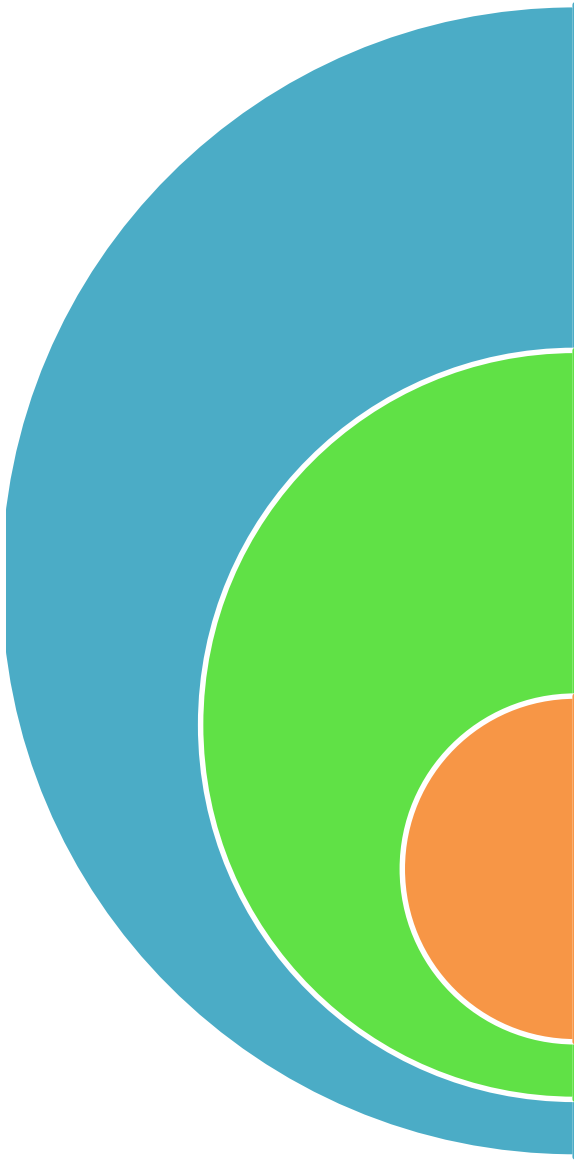
- It is the current per unit surface area of the cathode (A/m^2)
- On increasing applied voltage, current density increases till a limiting value is reached
 - A. **At low current density** – surface diffusion is faster than electron transfer resulting in uniform deposits
 - B. **On increasing current density**, surface diffusion slows down compared to electron transfer .
 - Less ordered deposits may results because the the ions are not in a position to reach the most favourable points of deposit and also due to higher voltage (to produce higher current density) may increase the number of nuclei (of the plating)
 - C. **At very high current density below limiting values**, mass transport in solution by diffusion of ions to electrode surface predominates and result in poorly adherent, rough and powdery textured deposits
 - D. **At very high current density above limiting values**, the evolution of H_2 on the surface of electrode predominates leading to formation of dispersed deposits of metal oxides and hydroxides

Choice of electrolyte

The electrolyte should be

- A good conductor
- Highly soluble
- Not undergo hydrolysis, oxidation, reduction and other chemical changes
- Possess sufficient covering power
- Usually a mixture of two or more electrolytes are used
- E.g in copper plating, copper sulphate is used along with dilute sulphuric acid

pH of electrolytic bath



Good pH range for most electroplatings is between pH 4 (moderately acidic) to pH8 (slightly alkaline). Required pH is maintained by using buffers

pH lower than optimum value results in strong H_2 evolution at cathode

pH higher than the optimum value results in the precipitation of the hydroxides of the metal on the electrode surface

Methods of cleaning the surface

1. Solvent cleaning – used to remove oils, greases, buffing compounds and fatty substances
 - Naphtha, carbon tetrachloride, toluene, xylene, acetone are used
2. Alkali cleaning – trisodium phosphate along with soaps and wetting agents like caustic soda are used
 - Thorough rinsing followed by immersion in 0.1% chromic acid (slightly acidic)
3. Mechanical cleaning – generally done by hand cleaning with bristle brush, abrasive and detergent or with tools like knife scraper, grinding wheels etc
 - Rust and dirt are dislodged from the surface
4. Flame cleaning – treatment with hot flame to remove moisture and loosely adhering scales
5. Sand blasting – for removing oxide scale and for slightly roughening the surface
 - Sand is introduced into an air stream (25 to 100 atm pressure) and the blast is impacted on the metal to be cleaned
 - Care should be taken by workers to avoid silicosis

6. Pickling and etching – convenient method of scale removal than mechanical or sand blasting

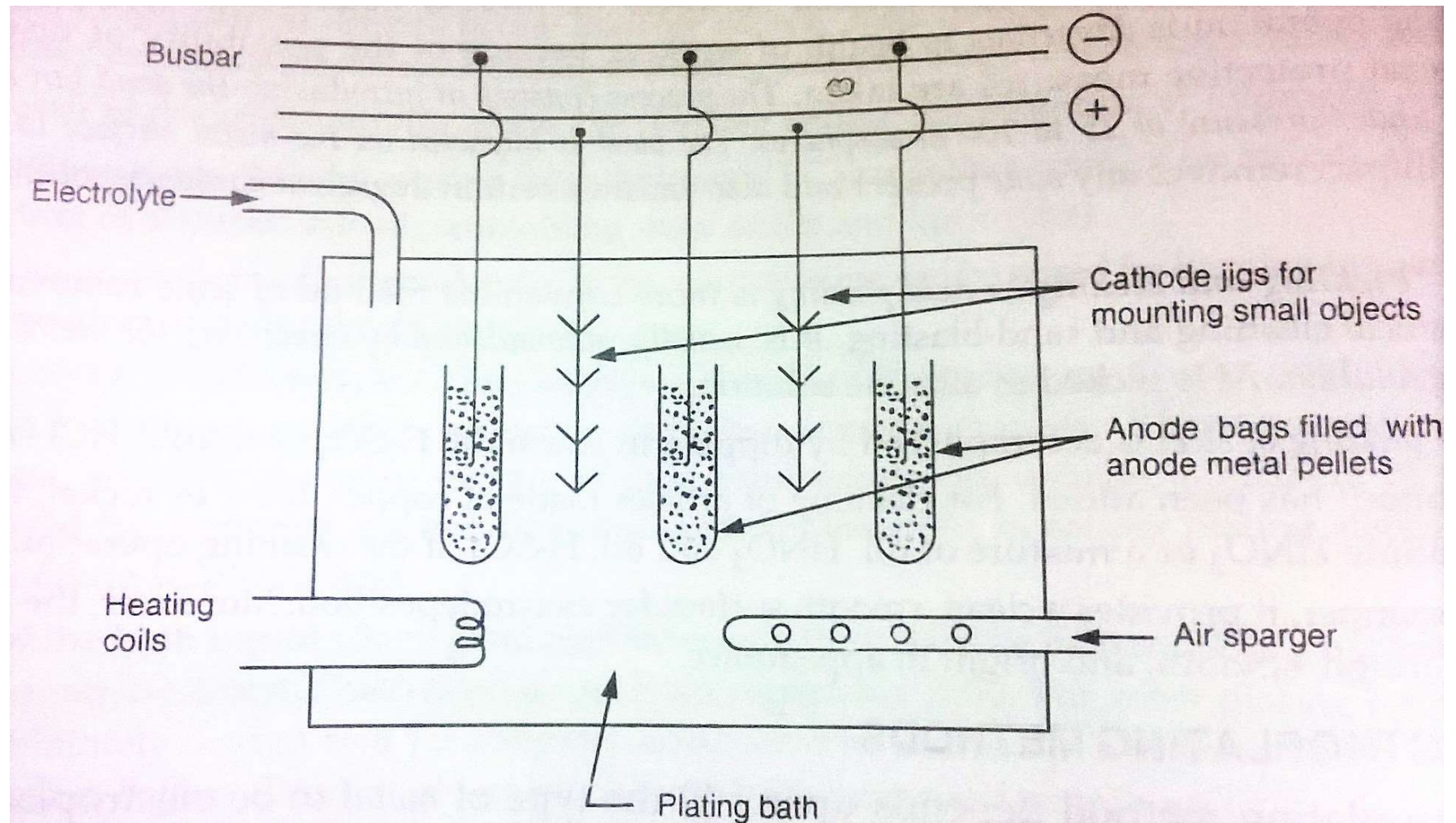
- Usually metal (except Al) is immersed in acid. Al is treated by alkali



Electroplating process

- Plating tank is a vat (25 to 2,000L) made of wood or steel with ceramic or polymer lining inside
- Plating bath solution is highly conductive
- Heating arrangements by means of heating coils are made available
- Convection current in the bath is maintained by use of air sparger or N₂ sparger
- DC voltage arrangement by means of DC motor generators and rectifiers
 - Initial application of a high overvoltage for nucleation and thereafter a voltage of around 8 - 12 V at current densities of 1 – 200 mA/cm² is required
- Plating process- after the articles to be coated are cleaned they are suspended into the bath along with the anodes.
 - Appropriate voltage and current density are maintained to get a smooth deposit
 - The thickness range from 0.01 to 100 microns
 - The required time range from a few seconds to 30 minutes

An electroplating cell



(1) Electroplating of copper :		+
	<i>Sulphate bath</i>	<i>Cyanide bath</i>
Plating bath composition (per L)	200–250 g CuSO_4 + 50– 75 g H_2SO_4 . Rest water.	40–50 g CuCN + 20 – 30 g KCN + 10 g K_2CO_3 . Rest water.
Additives	Gelatin or dextrin, sulphur-containing brightener, sulphonic acid.	Sod. thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$).
Temperature ($^{\circ}\text{C}$)	20 – 40	40 – 70
Current density (mA cm^{-2})	20 – 50	10 – 40
Anode	P contained rolled Cu	Oxygen-free high conducting Cu
Current efficiency (%)	95 – 98	60 – 90
Throwing power	Low	Good
Applications	In printed circuit boards (<i>not suitable</i> for iron and its alloys plating).	As an undercoat for Cr plating and printed circuit boards (<i>suitable</i> for iron and its alloys plating).

(2) Electroplating of nickel :		+
	Sulphate bath	Sulphamate bath
Plating bath composition (per L)	250 g NiSO_4 + 45 g NiCl_2 + 30 g boric acid. Rest water.	600 g Ni sulphamate + 5 g NiCl_2 + 40 g boric acid. Rest water.
pH of bath	4.5	4
Additives	Coumarin, saccharin, benzene sulphonamide	naphthalene 1, 3, 6- trisulphonic acid
Temperature ($^{\circ}\text{C}$)	40 – 70	50 – 60
Current density (mA cm^{-2})	20 – 50	50 – 400
Anode	Ni pallets or pieces in titanium mesh basket.	Ni pallets or pieces in titanium mesh basket.
Current efficiency (%)	95	98
Throwing power	Medium	Good
Applications	Undercoat for Cr plating	Decorative purposes and mirror finish at high current density (400 mA cm^{-2}).

Electroless plating

- Electroless plating (also known as autocatalytic plating) is a plating process which involves deposition without any current applied. This process is a chemical reaction and is autocatalytic
- It is defined as the deposition of a metal from its salt solution on a catalytically active substrate surface using a chemical reducing agent without the use of electrical energy

Metal ions + chemical reducing agent → metal deposit + oxidised product

- The decrease in free energy involved in the redox reaction is responsible for plating.
- The surface of the substrate must be prepared to be catalytically active

The surface of the substrate must be prepared to be catalytically active by etching the surface by acid treatment

Activation can also be done by electroplating the surface with a thin layer of the same metal or another suitable metal followed by heat treatment

Non conducting surfaces like plastics, ceramics are activated by treating them alternatively with SnCl_2 and PdCl_2

Advantages of Electroless plating

- Electrical power and electrical contacts are not required
- Insulators and semi conductors can be plated
- No elaborate arrangements needed
- The deposits are more compact and highly adherent

Electroless plating of copper

The electrolyte bath consists of:

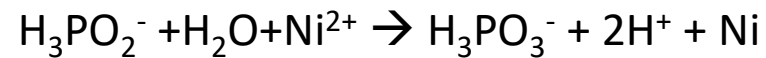
1. Salt : $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
2. Reducing agent: formaldehyde
3. Buffer: NaOH + Rochelle salt, $\text{pH} = 11$
4. Complexing agent: EDTA
5. Temperature: 298K



Electroless plating of Nickel

The electrolyte bath consists of:

1. Salt : NiCl_2
2. Reducing agent: Sodium hypophosphite NaH_2PO_2
3. Buffer: acetate buffer, pH = 4 -5
4. Complexing agent: sodium succinate
5. Temperature: 346K

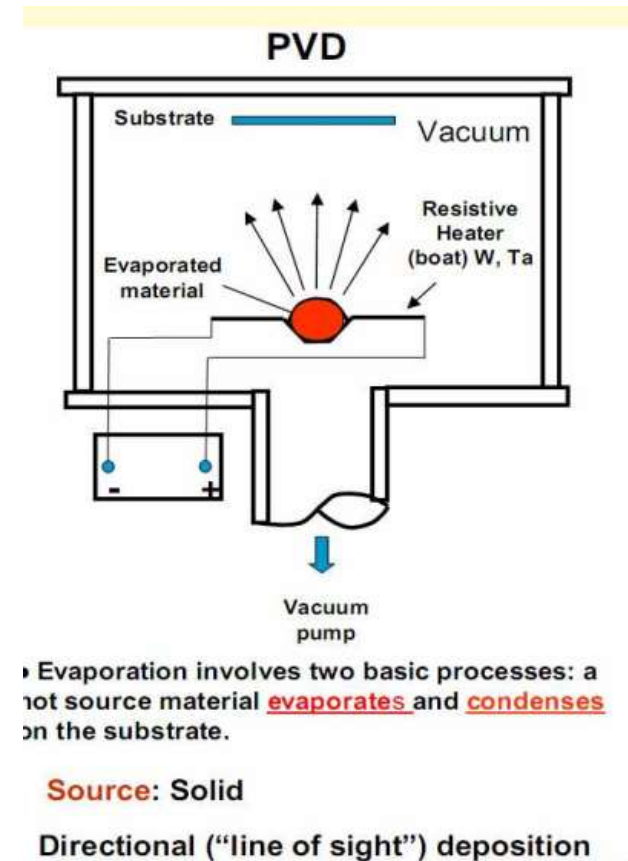


Vapour deposition techniques

- **Physical vapor deposition (PVD)**
- **Chemical vapour deposition (CVD)**

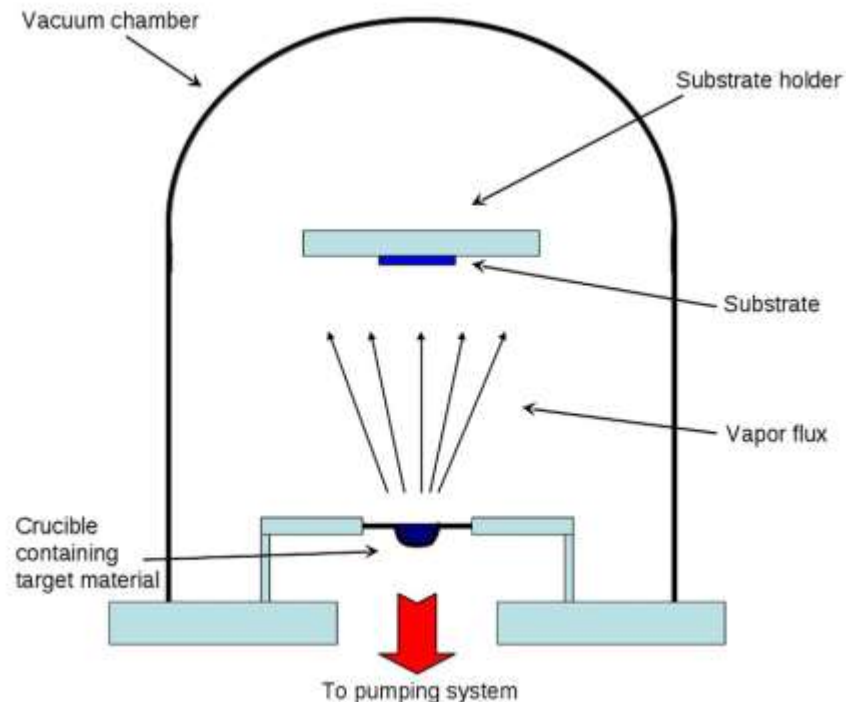
Physical vapour deposition (PVD)

- The processes of depositing materials directly from the vapour phase
- *Physical vapour deposition* (PVD) involves the generation of a vapour flux and its subsequent condensation in the form of a thin film on a substrate in a vacuum chamber
- Many methods such as *thermal and electron-beam evaporation, sputtering, and laser ablation* to generate the vapour flux from a target made of a specific material
- PVD techniques are used to fabricate a wide variety of thin films ranging from decorative optical coatings to high-temperature superconducting films
- The thickness of the deposits can vary from a few angstroms to several millimeters
- A very large number of inorganic materials (metals, alloys, compounds, and mixtures) as well as some organic materials can be deposited using PVD techniques



Thermal evaporation method

- During this process, atoms and clusters of atoms or molecules are removed in the form of a vapour flux from a metal crucible, containing some bulk material (target) by heater the crucible, either by passing a current through it or by a heater filament.
- Alternatively, during electron-beam (e-beam) evaporation, a beam of electrons bombards the bulk material in the crucible to generate the vapour flux
- The crucible and its contents are placed in a vacuum chamber, with pressure typically below 10^{-4} Torr. The vapour flux condenses on a substrate.



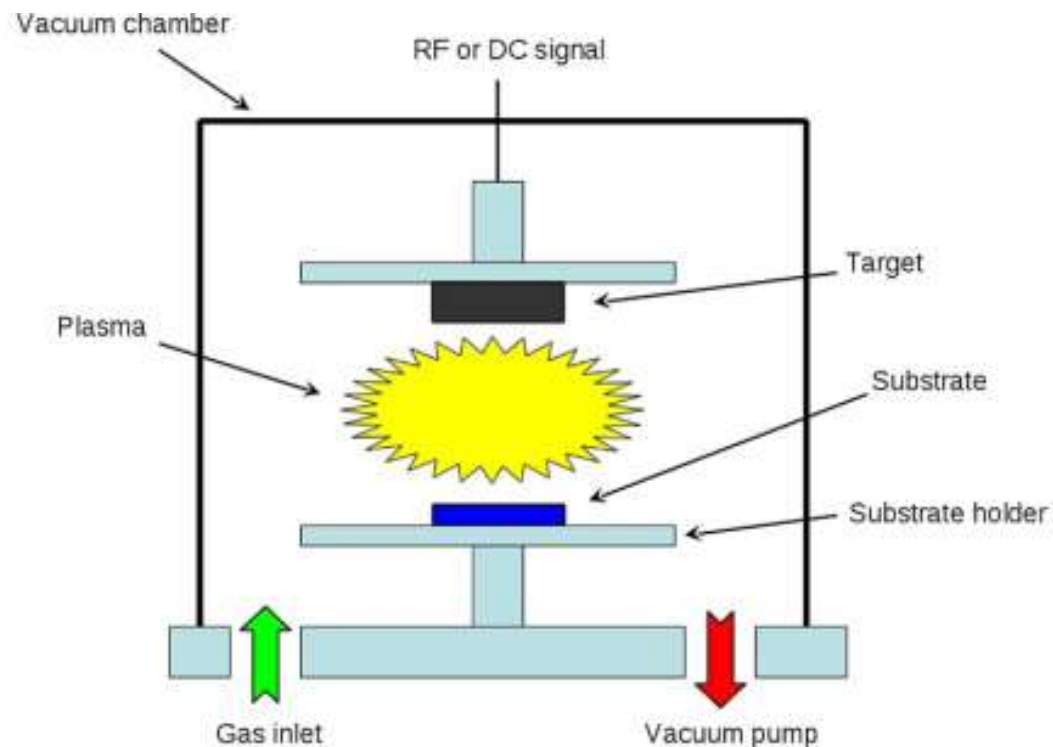
- For most materials that vaporize below a temperature around 1,500°C, evaporation can be achieved simply by putting the source material in contact with a hot surface that is resistively heated by passing a current through it

aluminized PET film for food packaging



Sputtering method

- A cathode made of the target material is bombarded by energetic ions generated in a glow-discharge plasma situated in front of the target
- The bombardment process causes the removal, i.e., sputtering, of target atoms by momentum transfer from the bombarding energetic gas ions (such as argon ions) accelerated in an electric field.
- The sputtered atoms form a vapour flux, which may then condense on a substrate as a thin film
- In **DC mode**, a cathode (target), an anode (on which the substrate is placed), and a DC power source are placed in a vacuum chamber. Argon is widely used to establish a discharge.
- The **RF configuration** is generally used for the deposition of electrically insulating materials such as oxides and polymers.



Schematic of a typical sputtering system in either the DC or the RF configuration.

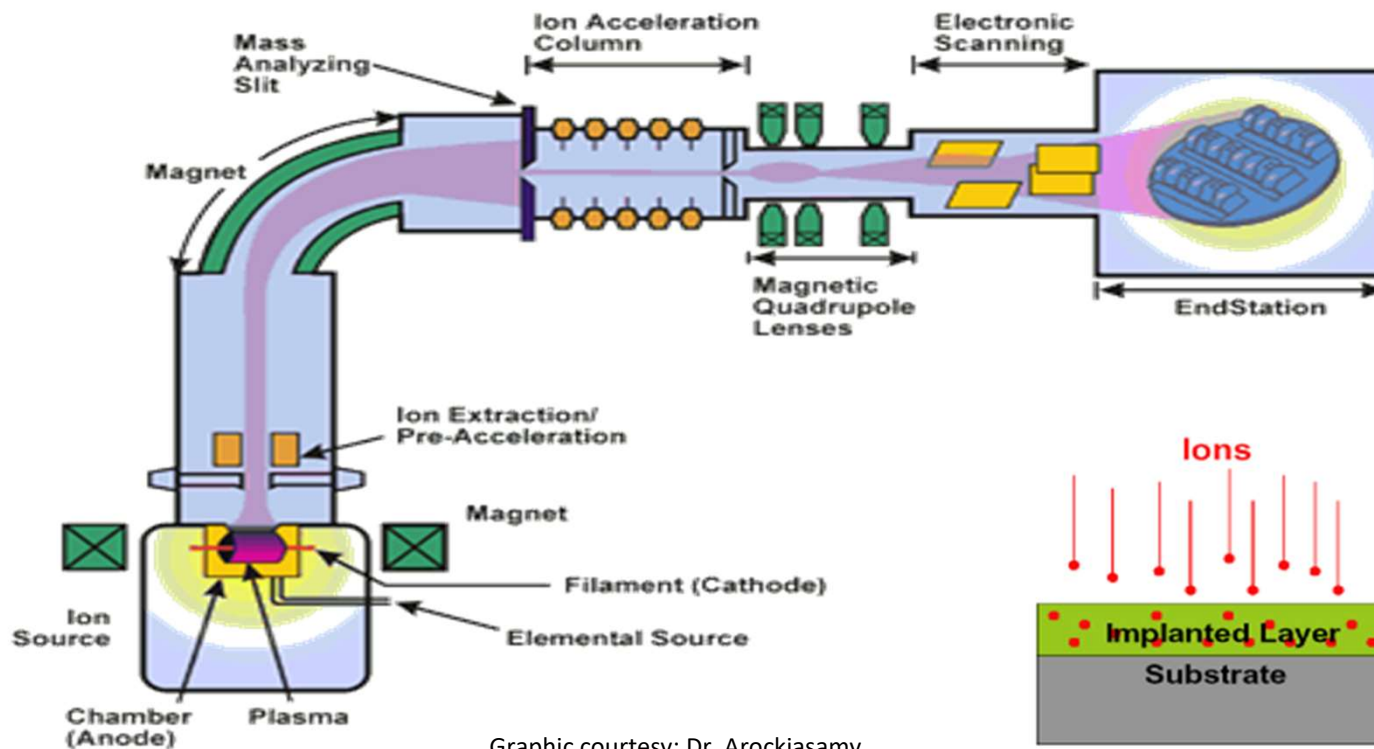
- In the **magnetron-assisted** configuration, a magnetic field is imposed to increase the plasma density as well as the current density at the cathode (target), thereby effectively increasing the sputtering rate.
- The magnetic field is tangential to the cathode surface.
- This configuration enables sputtering at low pressure with a high deposition rate

Ion implantation method

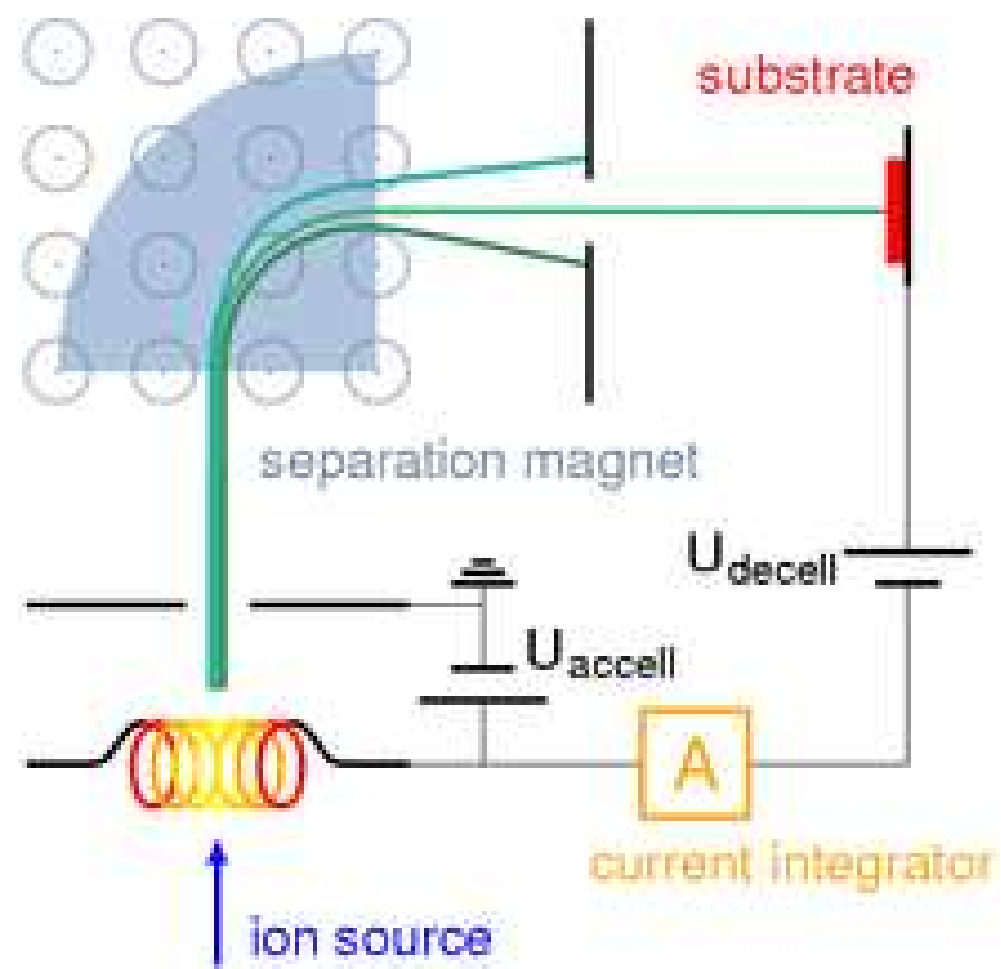
- A process by which ions of a material can be implanted into another solid (substrate), thereby changing the physical properties of the solid (substrate).

Ion implantation equipment typically consists of

- **An ion source**, where ions of the desired element are produced
- **An accelerator**, where the ions are electrostatically accelerated to a high energy
- **And a target chamber**, where the ions impinge on a target, which is the material to be implanted.



Graphic courtesy: Dr. Arockiasamy

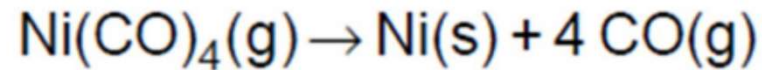
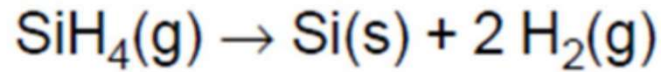


Chemical vapour deposition (CVD)

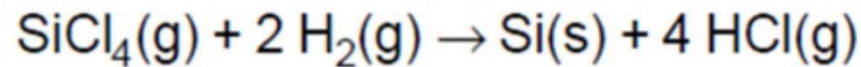
- *Chemical vapour deposition* (CVD) involves either the dissociation of a gaseous chemical and/or chemical reactions between gaseous reactants when heated, irradiated by photons, or subjected to a plasma.
- Depending on the activation sources for the chemical reactions, the deposition process can be categorized into thermally activated, laser assisted, or plasma-assisted CVD
- As a product, a thin film is deposited on a surface.
- This technique is used to produce very pure high-performance solid materials.
- Depending on the activation sources for the chemical reactions, the deposition process can be categorized into **thermally activated**, **laser assisted**, or **plasma-assisted CVD**
- The CVD process occurs in a vacuum chamber, with pressures ranging from the atmospheric pressure (atmospheric-pressure CVD) to below 10^{-8} Torr (ultrahigh-vacuum CVD)
- The main steps are
 1. transport of reacting gaseous species to the surface of a substrate
 2. adsorption of the species on that surface
 3. heterogeneous surface reaction catalysed by the surface of the substrate
 4. surface diffusion of the species to growth sites
 5. nucleation and growth of the film on the substrate
 6. desorption of gaseous reaction products and transport of reaction products away from the surface
- The chemical reactions include pyrolysis, oxidation, reduction, hydrolysis, or a combination of these and may be catalysed by the substrate

Some important reactions for CVD process

pyrolysis



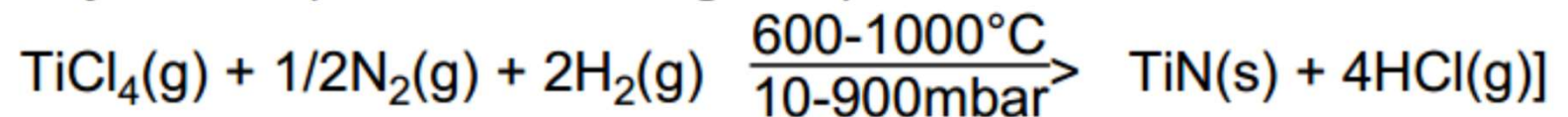
Reduction

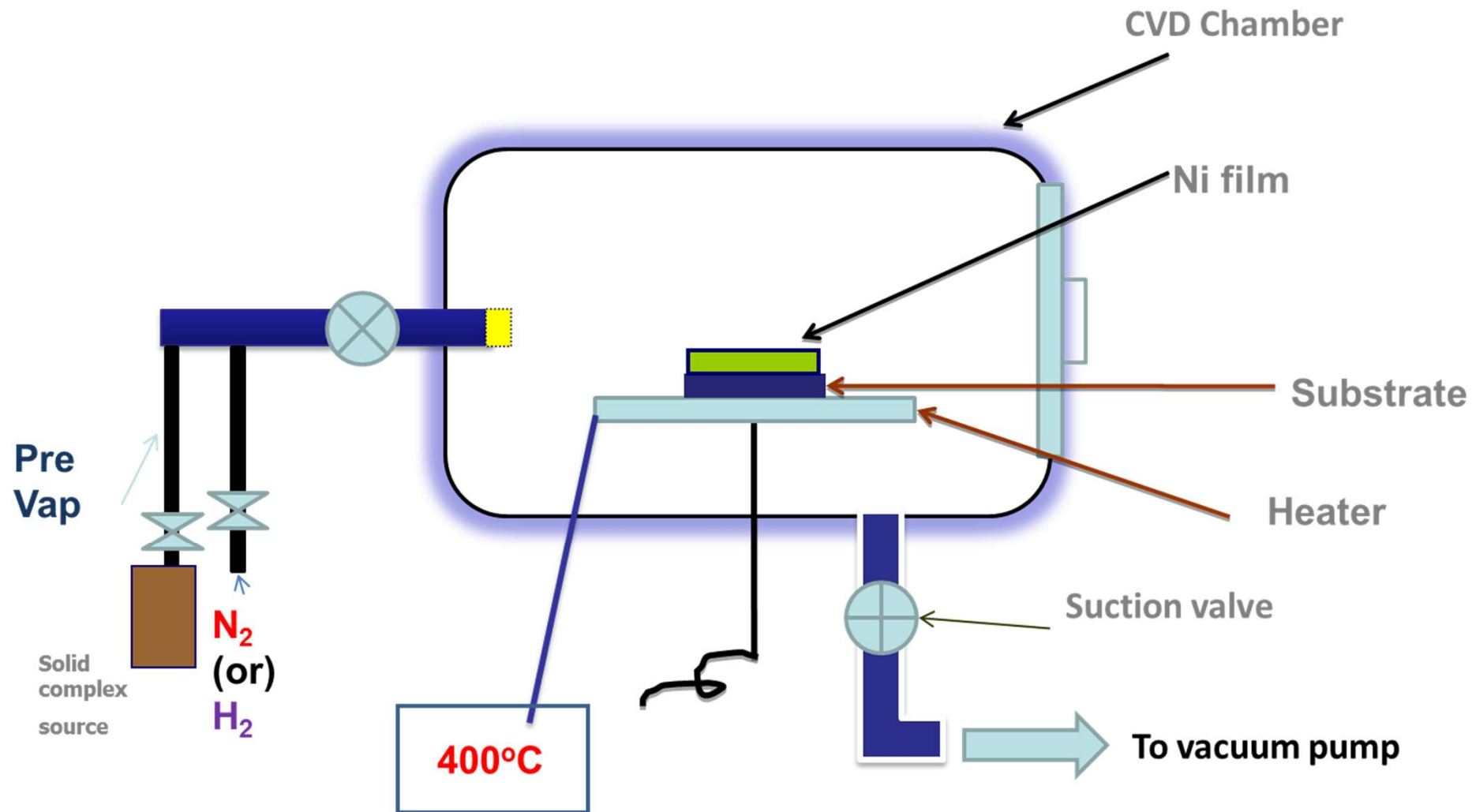


Oxidation



Nitridation





	CVD	PVD
Deposition	<ul style="list-style-type: none"> • $T = 800 - 1000\text{ }^{\circ}\text{C}$ 	<ul style="list-style-type: none"> • $T = 70 - 500\text{ }^{\circ}\text{C}$
Cycle Time	<ul style="list-style-type: none"> • 8 – 24 hours 	<ul style="list-style-type: none"> • 3-4 hours for cutting tools
Properties	<ul style="list-style-type: none"> • excellent adherence • coating thickness up to $20\text{ }\mu\text{m}$ 	<ul style="list-style-type: none"> • excellent adherence • uniform coating thickness • typical coating thickness $3\text{-}5\text{ }\mu\text{m}$
Applications	<ul style="list-style-type: none"> • cutting tools, forming tools 	<ul style="list-style-type: none"> • cutting tools, forming tools, components, medical devices, decorative

Alloying for corrosion protection

- A metal alloy is a mixture of two or more metals.
- Alloys are usually less malleable and ductile than pure metals and tend to have lower melting points.
- An alloy is made by melting the different metals in the alloy together. The amounts of each metal are usually quite important.

Ferrous Alloys

- Ferrous alloys are the type of steels in which the elements like Al, B, Cr, Co, Cu and Mn are present in sufficient quantities in addition to carbon and iron
- Alloying imparts corrosion resistance to steels

Nichrome • Contains 60% Ni, 12% Cr, 26% Fe and 2% Mn

Stainless steels or corrosion resistant steels

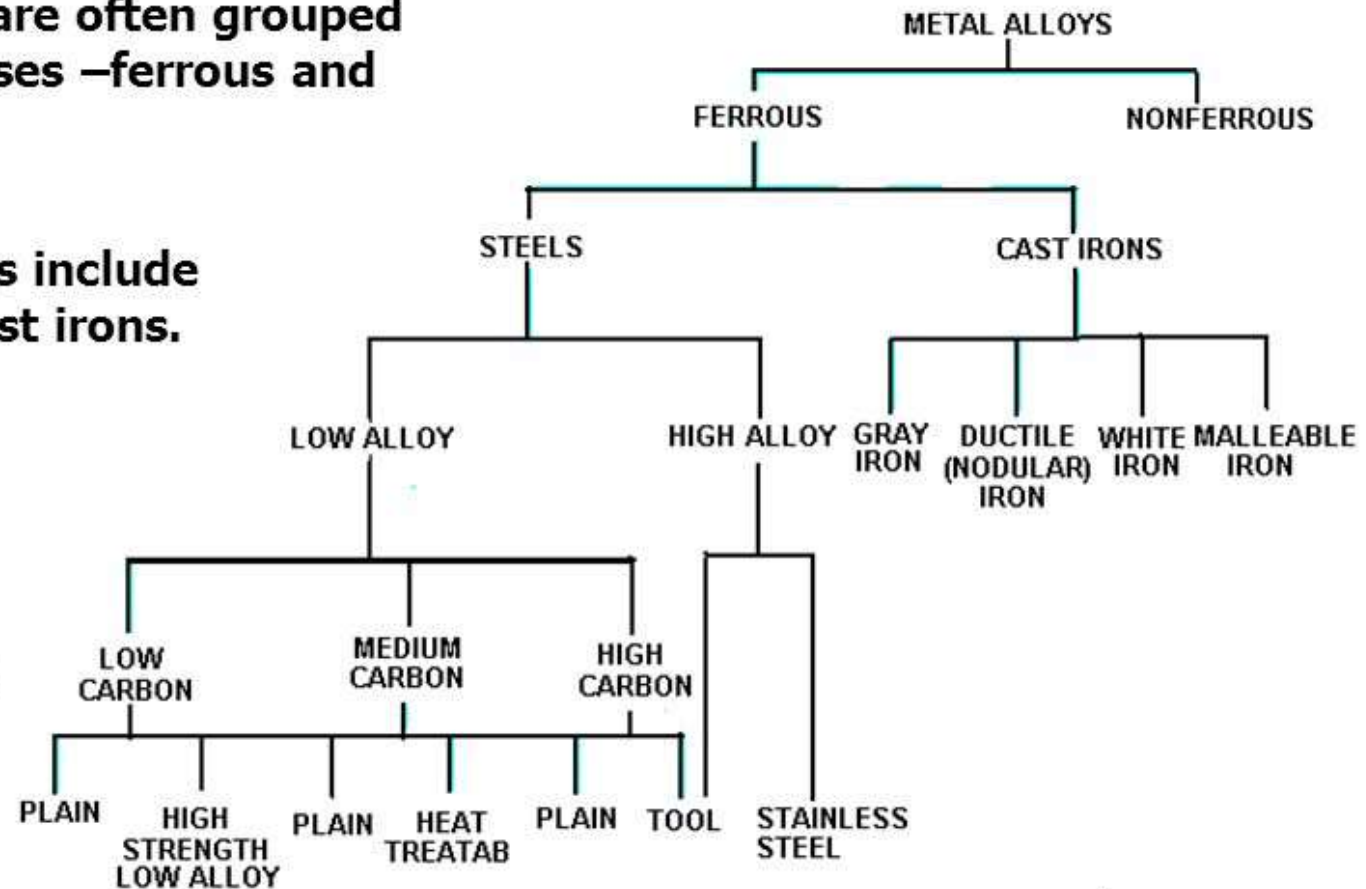
- These contain Cr, together with other elements such as Ni, Mo, with carbon content ranging from 0.3 to 1.5%
- Cr is effective if its content is 16% or more
- Corrosion resistance is mainly by the formation of a dense, non-porous film of chromium oxide at the surface of the metal

5.1 TYPES OF METAL ALLOYS

Metal alloys are often grouped into two classes –ferrous and nonferrous.

Ferrous alloys include steels and cast irons.

Low Alloy steels are usually considered to be those containing a total of less than 5% of such added constituents.



Non-ferrous alloys

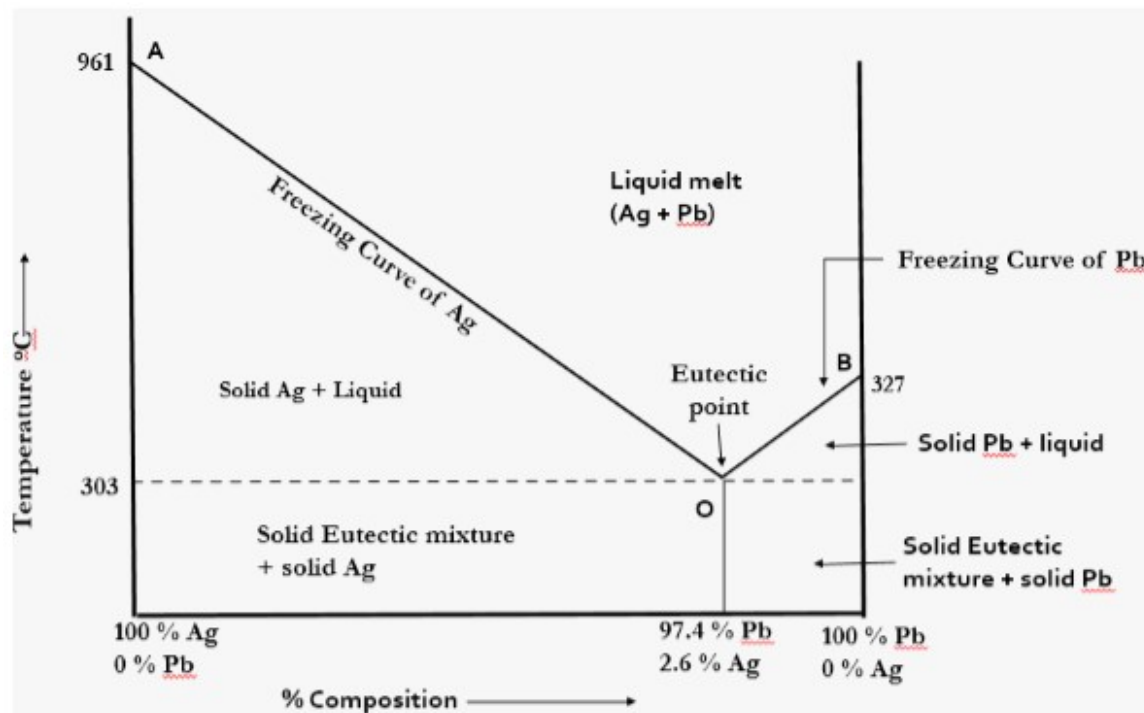
These alloys do not contain iron and may be based on copper, aluminium, lead, tin as the main constituent

They show excellent corrosion resistance

Alloy	composition
Brass	Cu- 60 - 90% Zn - 10 - 40%
commercial brass	Cu- 90% Zn - 10%
Dutch metal	Cu- 80% Zn - 20%
cartridge or spinning brass	Cu- 70% Zn - 30%
Coinage or common bronze	Cu- 89 - 92% Sn - 8 - 11%
Gun metal	Cu- 85% Sn - 8% Zn- 4% Pb- 3%
Aluminium bronze	Cu- 90 - 93% Al - 7 - 10%

Eutectic system

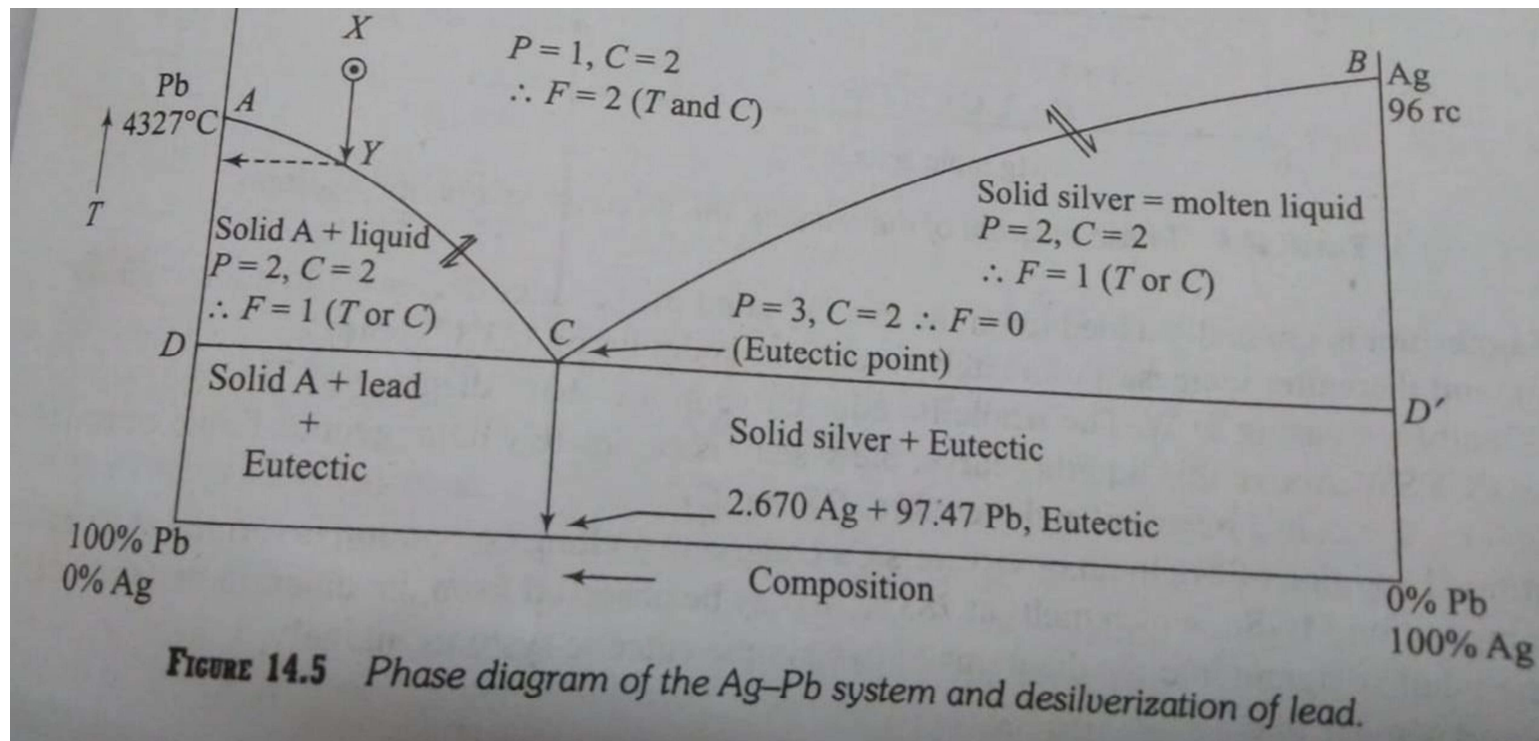
- A binary system consisting of two substances which are miscible in all proportions in the liquid phase, but which do not react chemically is known as Eutectic (easy to melt) system, e.g., a mixture of lead and silver comprise such a system
- **Eutectic mixture** is a solid solution of two or more substances having the lowest freezing point of all the possible mixture of the components.
- This is taken advantage of in alloys of low melting point which are generally eutectic mixtures
- **Eutectic point:** Two or more solid substances capable of forming solid solutions with each other have the property of lowering each other's melting point and the minimum freezing point attainable corresponding to the eutectic mixture is known as eutectic point



Phase diagram

Desilverisation of lead

- If a molten liquid of argentiferous lead of 'x' composition (~0.1%) is allowed to cool, Pb solid crystallises at point 'y'.
- The composition of argentiferous lead changes along YC with the enrichment of Ag.
- The crystallised Pb is constantly removed
- Pattinson's process



6.7.2 Eutectic Compositions and Temperatures of Some Alloys

Component metals and Melting points	Eutectic temperature	Eutectic compositions
Ag (961°C) Cu (1083°C)	778°C	71.8% Ag + 28.2% Cu
Bi (273°C) Cd (321°C)	140°C	60% Bi + 40% Cd
Zn (419°C) Al (658.7°C)	280°C	95.6% Zn + 4.4% Al
Pb (327°C) Sb (631°C)	245°C	87% Pb + 13% Sb