DIGITAL ASSIGNMENT-2

Course : Engineering Chemistry

Course Code : CHY1701

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Advanced Protective Coatings

There are many methods to reduce corrosion in all types of structures. By far the most important protective method is some kind of coating.

Protective coatings function by the virtue of the interposition of continuous physical-barriers between the coated surface and its environment. Such coatings must be chemically inert to the environment under particular conditions of temperature and pressure and prevent the penetration of the environment to the base material, which they protect.

Coatings with anti-corrosive properties ensure metal components have the longest possible lifespan. Metal Coatings provides the most widely used corrosion protection coatings in the industry. Whether the coatings are used in harsh-off-shore, industrial or chemical environments, the metal coatings provide corrosion protection against humidity, saltwater, and chemicals.

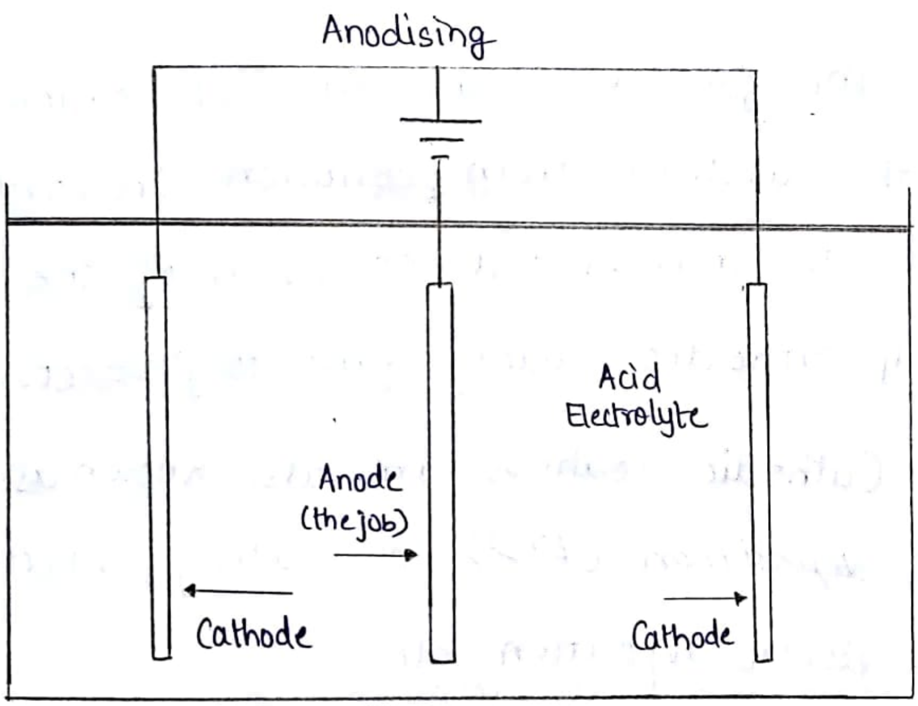
ANODIC COATINGS:-

An anodic coating is a type of coating material that utilizes anodizing to provide increased thickness, colour and protection to aluminium or any type of substrate. This coating consists of the oxide film that is created on metal through electrolysis, with metal acting as anode.

An anodic coating is produced through the process of anodizing, or reversed electroplating. In anodizing, the surface serves as the anode, or positive electrode, within the electrolytic cell. The consistency of coating will depend on the controlled temperature.

The anodic coating can be very permeable and will trap or accept almost all materials that pass through its pores. This can be either advantageous or disadvantageous to the existing properties. In order to prevent this, the coatings or pores are sealed through hydrolizing, or the addition of water to the oxide.

The resultant coating will become hard, smooth, transparent and homogeneous.



CATHODIC COATINGS:-

Cathodic coatings involve coating metal, which is cathodic with respect to the substrate in an electrochemical cell.

The purpose of this type of coating is to protect the substrate from corrosion. In corrosive environments, accelerated corrosion of the substrate occurs if cathodic coating fails to protect.

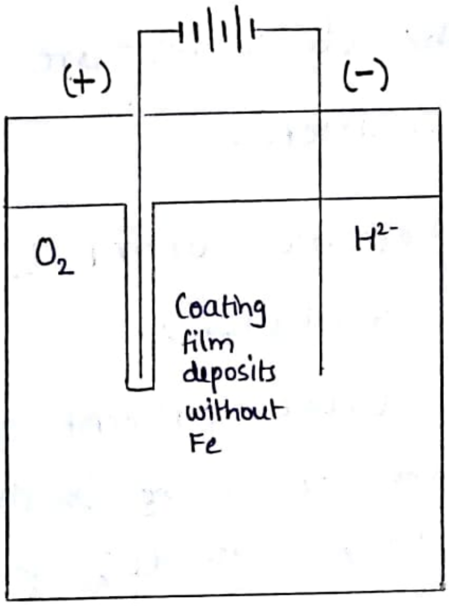
Cathodic coatings are also known as electrophoretic deposition (EPD), e-coating, electro-coating, cathodic electro deposition etc.

The process involves submerging a part into a container which holds the coating bath or solution and applying direct current through the cathodic electro-deposition bath using electrodes. Typically voltages of 25-400 volts are used in electro-coating. The object to be coated is one of the electrodes (cathode), and a set of counter electrodes are used to complete the circuit.

After deposition, the object is rinsed to remove the undeposited bath. The coating is finally subjected to a curing process in which reduction of porosity and cross-linking of coating material takes place. This makes the surface smooth and continuous.

Cathodic coatings are used in the following:

- Hybrid electric vehicles
- Portable electronic devices
- Medical devices
- Space and defense related devices



ELECTROPLATING:-

What is electroplating?

Electroplating is known as electrodeposition because the process involves depositing a thin layer of metal onto the surface of a work piece, which is referred to as the substracte. An electric current is used to cause the desired reaction.

How does electroplating work?

A cell consists of two electrodes (conductors), usually made of metal, which are held apart from one another. The electrodes are immersed in an electrolyte (a solution).

When an electric current is turned on, positive ions in the electrolyte (a solution).

When an electric current is turned on, positive ions in the electrolyte move to the negatively charged electrode (called the cathode). Positive ions are atoms with one electron too few. When they reach the cathode, they combine with electrons and lose their positive charge

At the same time, negatively charged ions move to the positive electrode (called the anode). Negatively charged ions are atoms with one electron too many. When they reach the positive anode, they transfer their electrons to it and lose their negative charge.

In the form of electroplating, the metal to be plated is located at the anode of the circuit, with the item to be plated located at the cathode. Both the anode and the cathode are immersed in a solution which contains a dissolved metal salt. (e.g. an ~~iron~~ of the metal being plated) and other ions ions which act to permit the flow of electricity through the circuit.

Direct current is supplied to the anode, oxidizing its metal atoms and dissolving them in the electrolyte solution. The dissolved metal ions are reduced ~~ato~~ the cathode, plating the metal onto the item. The current through the circuit is such that the rate at which the anode is dissolved is equal the rate at which the cathode is plated.

Why electroplating is done?

Silver plating and gold plating of jewelry or silver-ware typically are done to improve the appearance and value of the items. Chromium plating improves the appearance of objects and also improves its wear. Zinc or tin coatings may be applied to confer corrosion resistance. Sometimes electro-plating is done simply to increase the thickness of an item.

An example of electroplating :-

Electroplating of copper (Cu) in which the metal to be plated (Cu) is used as the anode and the electrolyte solution contains the ion of the metal to be plated (Cu^{2+}). Copper goes into solution at the anode as it is plated at the cathode. A constant concentration of Cu^{2+} is maintained in the electrolyte solution surrounding the electrodes:

Anode : $Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^{\ominus}$

Cathode : $Cu^{2+}(aq) + 2e^{\ominus} \longrightarrow Cu(s)$

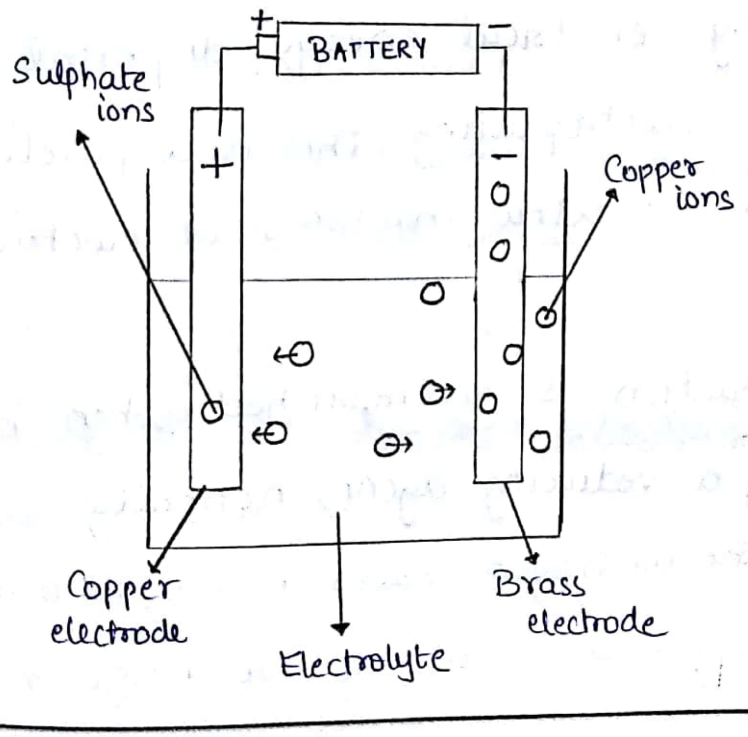
Advantages of electroplating :-

Corrosion resistance : Iron can be coated with a layer of non-corrosive material, thereby protecting the original material.

Decorative items : Shine and lustre can be imparted to otherwise dull surfaces. This makes for great decorative items.

Cheaper Ornaments : One can make ornaments using cheaper metals and electroplate them with gold. This reduces the cost of ornaments greatly.

Improving mechanical characteristics : Can improve hardness, wear resistance etc. of metals.



ELECTROLESS PLATING :-

What is electroless plating?

Electroless plating is a non-galvanic plating method that involves several simultaneous reactions in an aqueous solution, which occur without the use of external electric power.

How electroless plating works?

Electroless plating involves placing the part in an aqueous solution and depositing nickel, creating a catalytic reduction of nickel ions to plate the part without any electrical energy dispersal.

Unlike electroplating, this is a purely chemical process, with no extra machines or electrical power necessary.

The reaction is accomplished when hydrogen is released by a reducing agent, normally sodium hypophosphite (the hydrogen leaves as a hydride ion), and oxidized, thus producing a negative charge on the surface of the part.

Why electroless plating is done?

Because electroless plating allows a consistant metal ion concentration to bathe all parts of the object, it deposits metal evenly along the edges, inside holes and over irregularly shaped objects which are difficult to plate evenly with electroplating. Electroless plating is also applied to deposit a conductive surface on a non-conductive object to allow it to be electroplated.

Advantages :-

- Does not use electrical power
- Even coating
- No sophisticated jigs or racks required
- Flexibility in plating volume and thickness
- Chemical replenishment monitored automatically
- Complex filtration method is not required.
- Matte, semi-bright or bright finishes available

An example of electroless plating :-

"Electroless Nickel Plating"

- The surface to be treated is first degreased followed by acid treatment (surface preparation).

- Coating solution - $NiCl_2$ solution (20g/L)

  Reducing agent - $NaPO_2H_2$ (20g/L)

  Buffer - CH_3COONa (10g/L)

  Complexing agent / Exhaltant - $C_4H_5NaO_4$ (15g/L)

  Optimum pH - 4.5

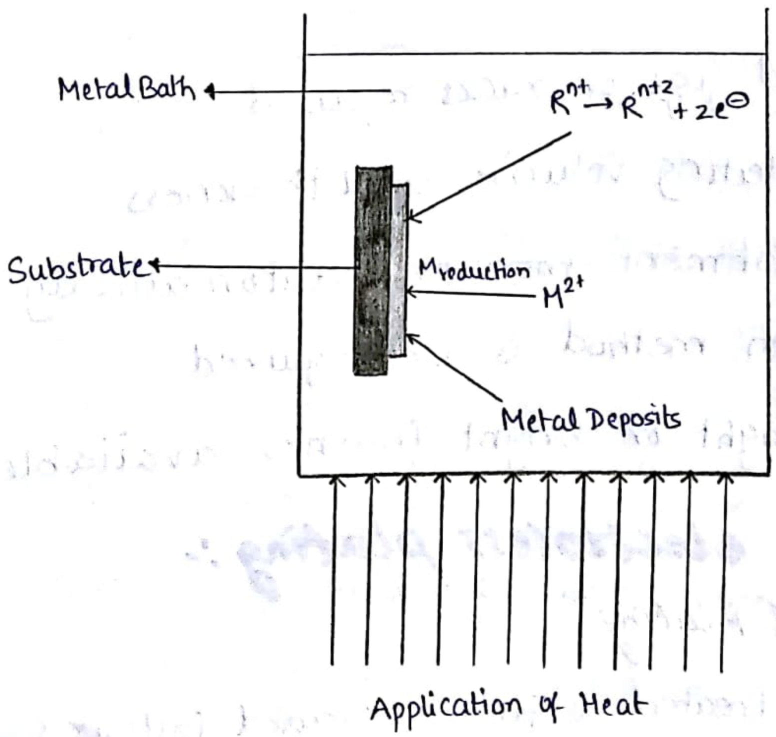
  Optimum temperature - 93°C

- *Reactions* :-

Cathode : $Ni^{2+} + 2e^{\ominus} \longrightarrow Ni$

Anode : $H_2PO_2^- + H_2O \longrightarrow H_2PO_3^- + 2H^+ + 2e^{\ominus}$

Net Redox : $Ni^{2+} + H_2PO_2^- + H_2O \longrightarrow Ni + H_2PO_3^- + 2H^+$



PHYSICAL VAPOUR DEPOSITION

What is PVD?

Physical vapour deposition (PVD) describes a variety of vacuum deposition methods which can be used to produce thin films and coatings. PVD is characterized by a process in which the material goes from a condensed phase to a vapour phase and then back to a thin film condensed phase.

How PVD works?

PVD coating vaporizes specialized materials through a high tech vacuum process. The vaporized material is deposited through a thin layer on selected objects. When a reactive gas, such as nitrogen, oxygen or a hydrocarbon based gas is introduced to the metallic vapour, it creates nitride, oxide or carbide coatings as the metallic vapour stream chemically reacts with the gasses. PVD coating must be done in a specialized reaction chambers so that the vaporized material doesn't react with any contaminants that would otherwise be present in the room.

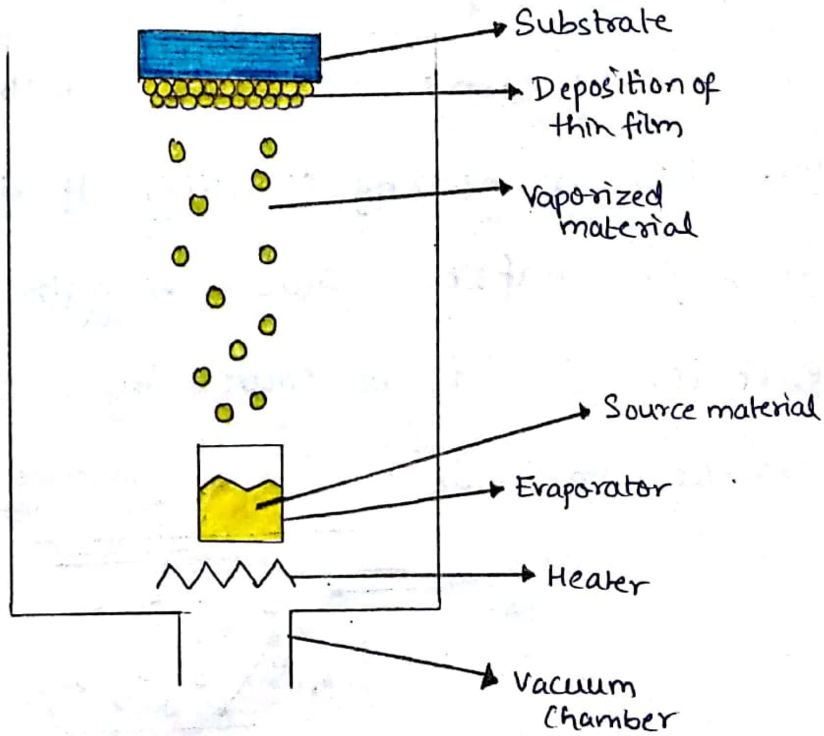
During the process of PVD coating the process parameters are closely monitored and controlled so that the resulting film hardness, adhesion, chemical resistance, film structure, and other properties are repeatable run to run. Various PVD coatings are used to increase wear resistance, reduce friction, improve appearance, and achieve other performance enhancements.

In order to deposit high purity materials such as titanium, chromium or zirconium, the physical process of PVD coating utilizes one of several different methods, including:

- Thermal Evaporation
- Sputtering
- Ion Plating

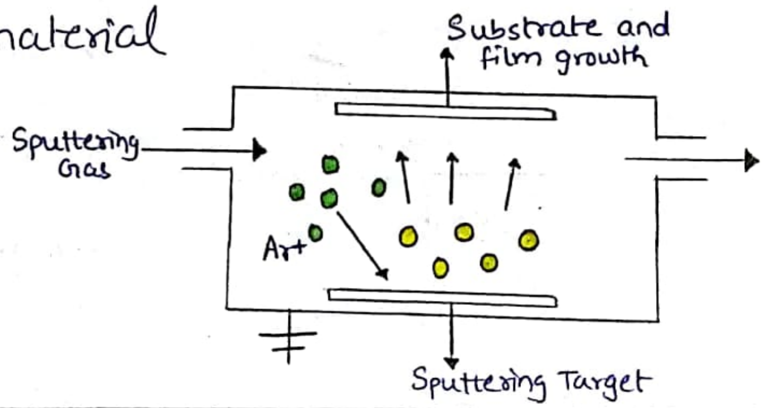
THERMAL EVAPORATION :-

Thermal evaporation is one of the simplest of PVD techniques. Basically, material is heated in a vacuum chamber until its surface atoms have sufficient energy to leave the surface. At this point they will traverse the vacuum chamber, at thermal energy (less than 1eV), and coat a substrate positioned above the evaporating material (average working distances are 200 mm to 1 meter).



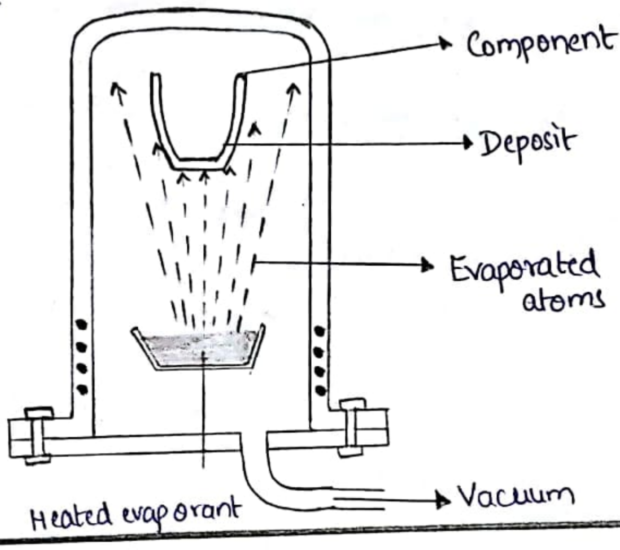
SPUTTERING:-

Sputtering is a technique used to deposit thin films of a material onto a surface (a.k.a. "substrate"). By first creating a gaseous plasma and the accelerating the ions from this plasma into some source material (a.k.a. "target"), the source material is eroded by the arriving ions via energy transfer and is rejected in the form of neutral particles - either individual atoms, cluster of atoms or molecules. As these neutral particles are ejected they will travel in a straight line unless they come into contact with something - other particles or nearby surfaces. If a "substrate" such as a Si - wafer is placed in path of these ejected particles, it will be coated by a thin film of the source material



ION PLATING:-

Ion plating (IP) is a PVD process that is sometimes called ion assisted deposition (IAD) or ion vapour deposition (CIVD) and is a version of vacuum deposition. Ion plating uses concurrent or periodic bombardment (prior to deposition is used to sputter clean the substrate surface.) of the substrate, and deposits film by atomic-sized energetic particles. During deposition, the bombardment is used to modify and control the properties of the depositing film. It is important that the bombardment be continuous between the cleaning and the deposition portions of the process to maintain an atomically clean interface.



What are the advantages of PVD?

PVD coating is good option to obtain extremely thin functional coating. PVD coating processes deposit a layer of high density material that's only a few microns thick. Once applied, the coating is nearly impossible to remove, and won't wear off on its own.

Additional benefits include:

- Clean & polished appearance. (over polished surface)
- Uniform, matte appearance (over a matte surface)
- Long-lasting, tough exterior, scratch resistant
- Completely eco-friendly
- Can be applied cost effectively

CHEMICAL VAPOUR DEPOSITION

What is CVD?

Chemical vapour deposition is a coating process that uses thermally induced chemical reactions at the surface of a heated substance (substrate), with reagents supplied in gaseous form. These reactions may involve the substrate itself, but often do not. The simplest CVD process involves the pyrolytic decomposition of a gaseous compound on the substrate to provide a coating of a solid reaction product.

How does CVD work?

Precursor gases (often diluted in carrier gases) are delivered into the reaction chamber at approximately ambient temperatures. As they pass over or come into contact with a heated substrate, they react or decompose forming a solid phase which are deposited onto the substrate. The substrate temperature is critical and can influence what reactions will take place.

Example of CVD :-

The following reactions are used to produce solid coatings of tungsten metal (W), titanium carbide (TiC) and titanium nitride (TiN) respectively:

$$WF_6 + 3H_2 \longrightarrow W(s) + 6HF(g)$$

$$TiCl_4 + CH_4 \longrightarrow TiC(s) + 4HCl(g)$$

$$TiCl_4 + \frac{1}{2}N_2 + 2H_2 \longrightarrow TiN(s) + 4HCl(g)$$

Alumina may be deposited by the reaction:

$$Al_2Cl_6 + 3CO_2 + 3H_2 \longrightarrow Al_2O_3(s) + 3CO(g) + 6HCl(g)$$

Although the reactions listed above involve only gaseous reagents, the substrate material in some cases also plays a significant role. For example, the rate controlling step in the growth of a TiC layer on carbon steels or cemented carbides from $TiCl_4$ is the reaction:

$$TiCl_4 + C + 2H_2 \longrightarrow TiC(s) + 4HCl(g)$$

This involves carbon from the substrate. This reaction can lead to decarburisation of the substrate immediately beneath the coating and must be taken into account when selecting a suitable substrate material.

PLASMA ASSISTED CVD :-

A common variant of CVD widely used in industry is plasma assisted CVD (PACVD). In the plasma assisted CVD process, an electrical discharge in a low pressure (<100Pa) gas is used to accelerate the kinetics of the CVD reaction. This can lower the reaction temperatures by several hundreds of degrees of Celsius. However PACVD coating rates are generally lower than CVD as a consequence of the lower gas pressure.

PACVD method is one of several related techniques used to deposit thin films of diamond, which have attractive tribological properties with very high ~~temp~~ hardness and low friction. Microwaves plasmas are currently of considerable interest for the activated manufacture of diamond films.

Other compounds that are deposited by include quartz, silicon, silicon nitride and titanium nitride as thin film substrates, dielectrics and insulating layers in electronic applications.

Advantages of CVD :-

A key advantage of the CVD process lies in the fact that the reactants used are gases, thereby taking advantage of the many characteristics of gases. One result is that CVD is not a line-of-sight process as are most other plating/coating processes and can be used to coat restricted access surfaces. CVD offers many advantages over other deposition processes. These include a wide range of coating materials based on metals, alloys and ceramics. The coatings can be deposited with very low porosity levels and with high purity. The process can be economical in production, with many parts coated at the same time in large batch numbers.

CVD coating processes employ temperatures typically in the range 600°C to 1100°C. ~~At~~ At these temperatures, significant thermal effects may occur in the substrate material. Steels, for example, will often be heated into the austenite phase region and coating process may need to be followed by suitable heat treatment to optimise the properties of the substrate.

- Uniform coating layer
- Thickness: 2–100 µm