Major Surface Coating: Classified into many categories: some of them are in following way:

- Conversion Coatings (Phosphate coatings, oxidation , chrome coating, anodizing coating)
- Thermal Coatings (it can be divided into diffusion, carburizing, flame, spaying etc)
- Meta Coatings (it may be electroplating, electroless plating but electrical energy not required)
- Deposition Coatings (it can be divided into Physical Vapour Deposition and Chemical Vapour Deposition
- Organic barrier such as paint, enamel etc.

Conversion Coatings

- These are basically inorganic surface barriers produced by chemical or electro chemical reactions brought at the surface of base metal. It serves as excellent base for paint, lacquer, oil etc.

Phosphate coatings:

- Chemical reaction of base metal with phosphate of Fe, Mn or Zn with phosphoric acid causes growth of a crystalline layer of base metal.
- Depending upon the type of phosphate selecting iron, zinc or manganese phosphate layer is formed.
- This typically coating applied to Carbon steel, low alloy steel and cast irons.
- Sometime also applied to Cadmium, Aluminium and Tin for protection
- Layer typically very thin ~ 2.5mm, usually grey in colour.
- Used as primer coat for paint.
- It can be applied by either immersion method, spraying or brushing method.

Oxidation coatings:

- Treatment of base metal with alkaline oxidizing solution or gas is done.
- Increased thickness of oxide film
- Corrosion resistant
- Serves as good base for paint, oil etc but less absorptive power than phosphate coating
- Oxide coating on steel with verity of colour ranging from straw yellow to blue are obtained.

Chrome coatings:

- ✓ Immersion in chromic acid bath (pH~1.8) with other chemicals to coat surface is done. It is done only strong acidic condition.
- ✓ Surface film consisting mixture of Cr(III) and Cr(VI) is obtained.
- ✓ As we know that Cr(VI) is a carcinogenic chemicals, so alternatives paths are find out currently under research
    - Molybdate chemicals are currently best substitute for coating of Al.
- ✓ Very good to minimize atmospheric corrosion
- ✓ It used for protection of Zn, Al, Mg and many more alloys
- ✓ It is applied to everyday items such as hardware and tools which are exposed to the environment and can usually be recognized by their distinctively iridescent, greenish-yellow colour.

Anodized coatings:

- ➢ Surface of non ferrous metals like Al, Zn, Mg and their alloys are coated
- ➢ Anodic oxidation process on a base metal is followed and this base metal treated as anode
- ➢ Base methods are suspended in sulphuric, phosphoric, oxalic or chromic acid bath

- Get thicker than nature oxide films hence shows improved resistance to corrosion and mechanical injury

Thermal Coating

It is again divided into four types

- Surface Heat Treatment
- Diffusion Coating
- Hot-Dip Coating
- Metal Spraying

Surface Heat Treatment:

- Basic concept is to heat the surface of substance to austenitic range then it quenched to form martensite surface –example steel
- Various types of heating method can be used

  1. Flame Treatment
  2. Induction Heating

Diffusion Coating:

- ✓ With low carbon steel as substrate, the surface can be enriched by diffusion of C or N
- ✓ Diffusion of carbon i.e carburizing
  - Steel is heated to austenitic range ($850^{o}C$- $950^{o}C$) in a carbon rich environment, then it is quenched and temper
- ✓ Nitriding method
  - Nitrogen is diffused into steel which occurs around $500^{o}C$-$550^{o}C$ to form a thin hard surface
  - This type of coating is good for Cr, V, W and Mo steels.
- ✓ Metal Diffusion (Metal such as Cr, Al are diffused into surface)

- Chromizing- Chromium diffuses into surface to form corrosion resistant layer
- Aluminizing- Aluminium used to increase the high temperature corrosion resistance of steels and super alloys

Hot-Dip Coating

- These coating are used for corrosion protection
- First of all, Galvanizing
    - Parts as substrate are dipped into a molten zinc batch, layer of $ZnCO_3$ is formed which used for protecting steel.
- Galvanic-annealing
    - Galvanized parts are then heat treated to ~500^{o}C to form Fe-Zn inter-metallic state
    - Used for metal that need spot welded to protect copper electrode from alloying with zinc and reducing its life
- Aluminium Coating by hot dip method
    - It is alloyed with Si
    - Coatings is used on steel for high temperature applications that need a lustrous appearance
    - Example-Automobile exhaust

Metal Spraying

- Typically used to improve wear resistance by creating a hard surface over a tough bulk body
- In this process
    1. Molten particle deposition: a stream of molten metal particles from spray gun are deposited on the substrate surface
    2. Two methods of spraying: wire gun and powder metal

Wire gun method: metal wire melted in oxy acetylene flame and atomized by a blast of compressed air; widely used for common metals

Powder metal method: finely divided powdered metal is heated then passed through the flame of blow pipe, it results into cloud of molten globules which are then adsorbed on base metal surface; used for low melting metals like Zn, Pb, Sn.

- Process and its merit
    - Surface undergoes a bonding process with the molten particle
    - It gets continuous but porous coating. Since coating is porous so we need to seal the surface
    - Hence sealer oil or paint applied to provide for smoothness which give greater speed of working
    - It is very easy for applications
    - Adhesion strength is less than hot dipping or electroplating method

Metal Coating Method:

It is further divided into three types

1. Electroplating
2. Eectroless coating-- not required electrically energy
3. Metallizing of plastics and ceramics

1. Electroplating

- **Objective of electroplating: on Metals**
    - It is used to increase wear and corrosion resistance of metal
    - To improve physical appearance and to impart hardness
    - It is also used to increase the decorative and commercial value

- **Objective of electroplating: method applied on surface of non-metals**
    - To increase strength
    - To preserve objects like plastics, wood, glass etc from harsh and corrosive environments
    - This method also used to make surface of light material conductive since non material are non conductor of electricity so coating by non material acts as conductors

Main features of electroplating method:

- Electrochemical process used to create a thin coating bonding to surface of the substrate
- Quite uniform film with little pinholes per unit area is obtained
- Process is slow so coating thickness can be closely controlled (range: 10-500 μm)

Applications of electroplating method:

- Tin and zinc are deposited on steel for further working
- Zinc and cadmium are deposited on parts for corrosion resistance (Cadmium is toxic therefore it cannot be coated for the purpose of appliances which are used for food applications so it is not used for food applications)
- Copper is deposited for electrical contacts
- Nickel for corrosion resistance
- Chromium can be used to impart wear resistance to dies and reduce adhesion to work pieces such aluminium or zinc
- Precious metals can be electroplated for decoration or electronic device

Characteristics and factors of electrodeposits of electroplating method

- Thickness of coating
- Its adherence it should be properly bounded on substrates

- Hardness *i.e.* it should make the surface hard so it will become tough.
- Brightness *i.e.* it should look bright and provided glossy.
- Protective value
- Decorative value
- Throwing power *i.e*. ability to give uniform thickness
- It should be temperature range: 35-60^{o}C *i.e*. room temp or low warm conditions
- Cleaning of substrate *i.e.* if the surface is not properly clean then coating is not properly occurred
- Composition of electrolyte bath (types of salts, their concentration etc affected on the electroplating)
- Current density (low current density provides better diffusion, getting uniformed layer)
- pH of bath 4-8 (lower pH (acidic)- burnt deposit; higher pH- OH ion depositing on the surface)

Composition of the electroplating bath:

- **Plating metal ion salt solution:** Normally, metal ion concentration (either as simple or complex ion) is moderate (about 1-3 mol/L). By employing still higher metal-ion concentration, the mass transfer process decreases, thereby badly affecting the quality of deposit. So, moderate metal ion concentration yields very adherent coating films. Various non-participating electrolytes are added. This added electrolyte sometimes acts as buffer to control the pH of electrolyte path.
- **Complexing agent:** On the metal-ion with a complexing agent, then fire-grained and more adherent deposites are obtained. So, the complexing agents are employed.

  For example:

  During the plating of Cu on Fe, then plating ion Cu^{2+} is complexed with CN^{-} ions so as to avoid the reaction:

  Fe + Cu^{2+} (cupric ion) $\longrightarrow$ Fe^{2+} (ferrous ion) + Cu; this reaction occurs then deposition of cupper will be prevented. Therefore complexing agent CN- ion will be

complexed with cupric ion and then prevent this above reaction takes place. And leads to enhance the current efficiency thus get the uniform surface.

- **Organic additive:** Nature of electrodeposit is remarkably influenced by presence of certain organic compounds in the plating bath solution. Some of these organic additives are:

  Aromatic sulphonates or sulphones and compound containing –CN, -CO or –N=C=S groups (like coumarin, thiourea) are example of some brighteners.