UMONS
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Overview of surface treatments

principles and use

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Alt Ctrl Trans

Surface treatment and coating processes?

Processes

- Physical
- Chemical
- Electrochemical
- Mechanical

That modifies the surface of an object

- Aspect
- Properties
- Functions

To make it more suitable for in use conditions

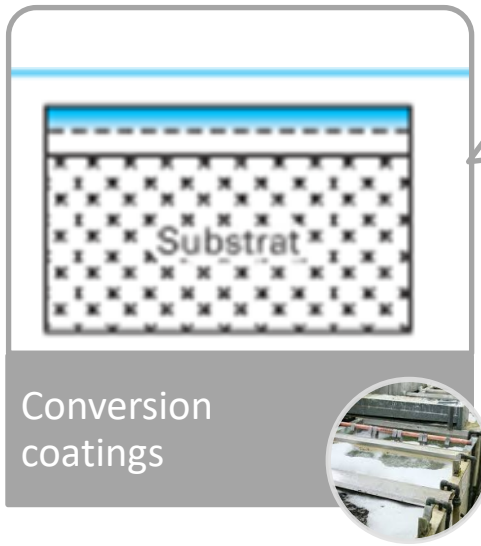
- Wear
- Corrosion
- Esthetics

The various types of surface treatment

Matter is added on the surface, without interaction

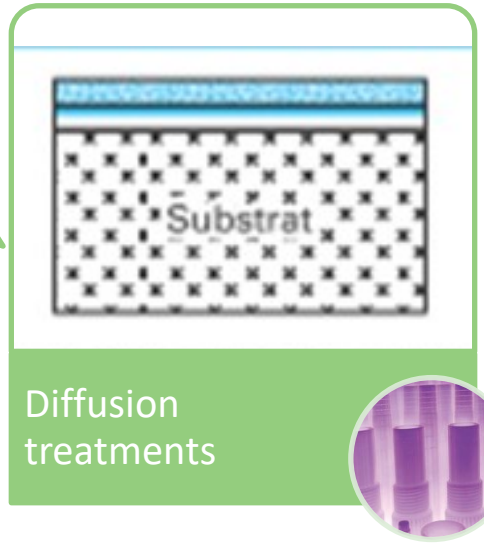
Coatings

Matter is added on the surface by interaction with the surface



Conversion coatings

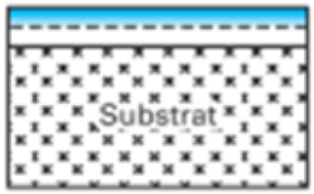
The chemistry of the surface and subsurface is modified



Diffusion treatments

The structure of the surface and subsurface is modified

Structural modification treatments

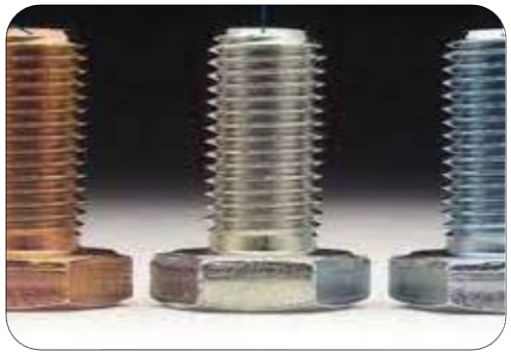


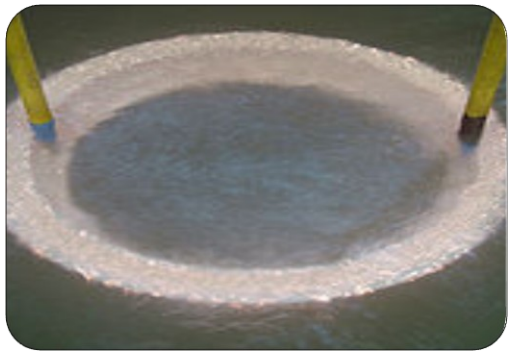
Conversion treatments

Conversion treatments

Chemical or electrochemical treatments during which the substrate reacts with a solution for form a **chemically modified layer** at the surface of the part.

Chemical treatments	Electrochemical treatments	
CHROMATATION/ PHOSPHATATION/ BURNISHING	ANODISATION	PLASMA ELECTROLYTIC OXIDATION





Conversion treatments

General principle

- Immersion in a bath that contains reactive.
- Chromatation = chromate solution (Cr VI)
  - Under REACH regulation
  - Contains chromic acid.
- Phosphatation = phosphoric acid solution
  - Suitable for steel and galvanized steel
  - Formation of a layer of metal phosphate on the surface after immersion in a phosphoric acid solution. Secondary and tertiary phosphates are prefered because they are insoluble : $Me_2(HPO_4)_2$ou $Me_3(PO_4)_2$)
- Alternates
  - Cr III chromatation baths
  - Use of Molybdates and molybdates/phosphates mixes
  - Treatment with cerium and zirconium salts

Main application

- Corrosion resistance.

Anodisation

General principle

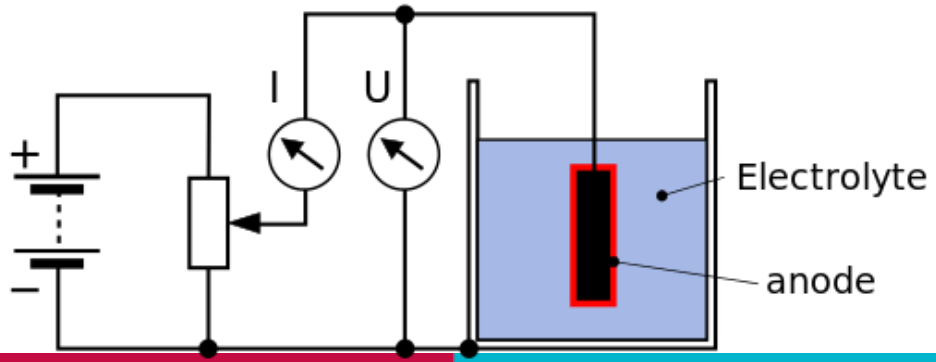
- Electrolytic growth of an oxide/hydroxide layer from the base metal. Used for Al, Mg, Ti, Zn
- Substrate is used as anode in an electrochemical system.
- Anodised layer can be colored or sealed (increases corrosion resistance)
- Reactions for Al

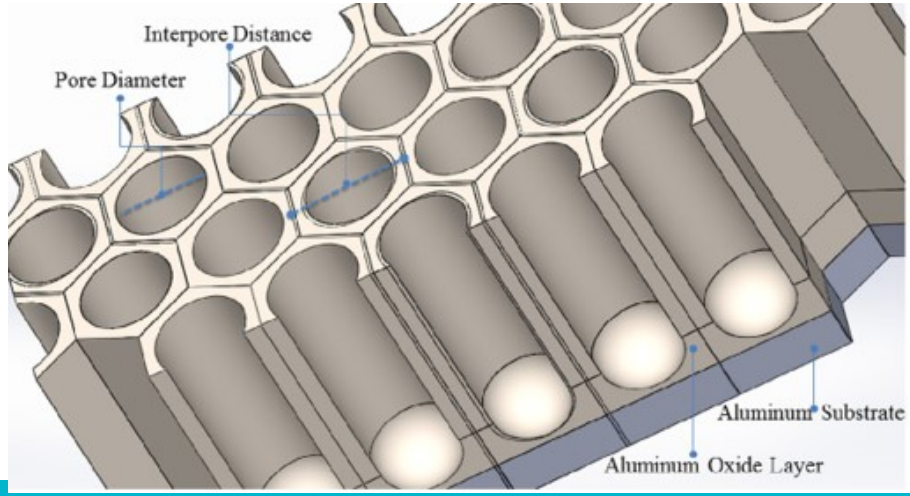
$2\,Al + 3O^{2-} \rightarrow 6\,e^- + Al_2O_3$ Anodic

$2\,H^+ + 2e^- \rightarrow H_2\uparrow$ Cathodic

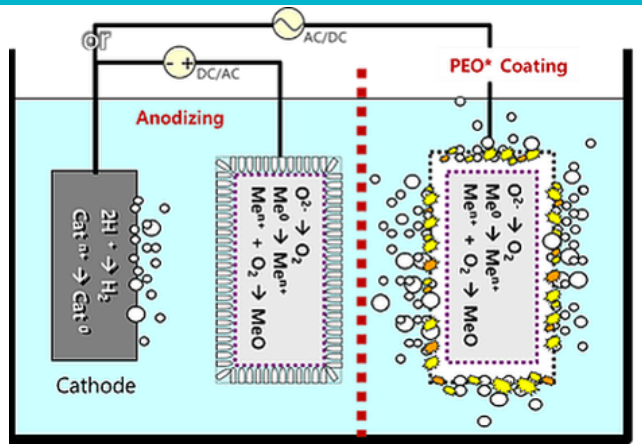
Main applications

- Aesthetics, better aptitude for gluing, corrosion resistance



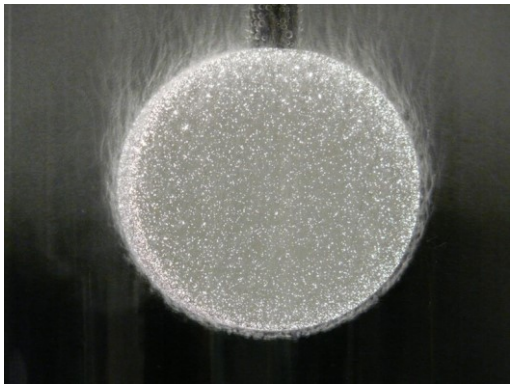


PEO



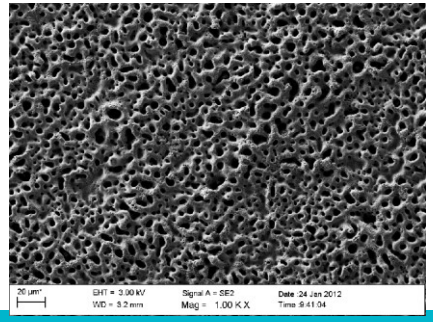
General principle

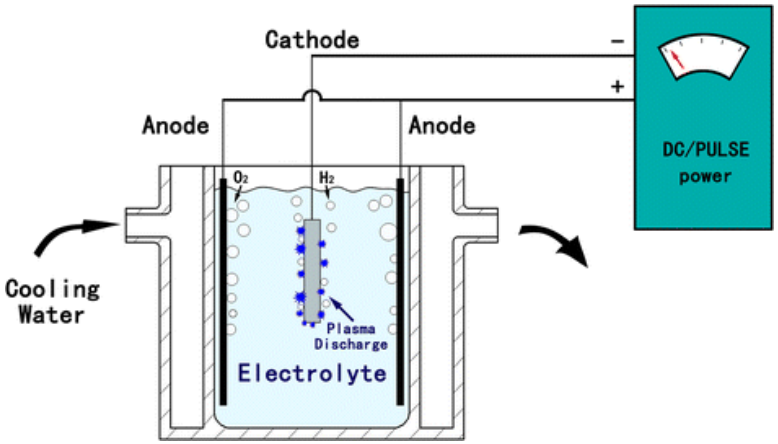
- Similar to anodisation, aprt is placed at the anode of an electrochemical system.
- Higher voltage (at least 200V for Al) to reach the breakdown potential of the growing film and create discharges in the electrolyte (usually alkaline solution eg: KOH)
- Localized plasma reactions → high temperature and pressure that modify the growing oxide (melting,….), leading to partial crystallization and harder coating.



Main applications

- Wear resistance (high hardness)
- Corrosion

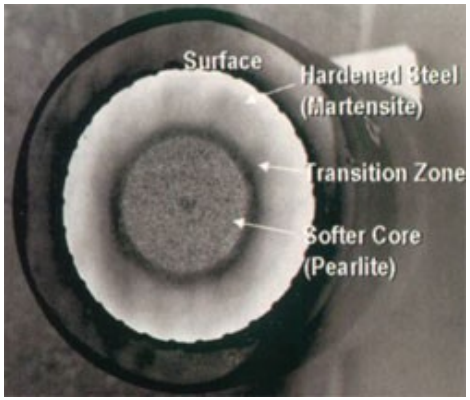




Diffusion treatments

Le matériau d'apport diffuse dans le substrat et réagit (ou non) avec lui

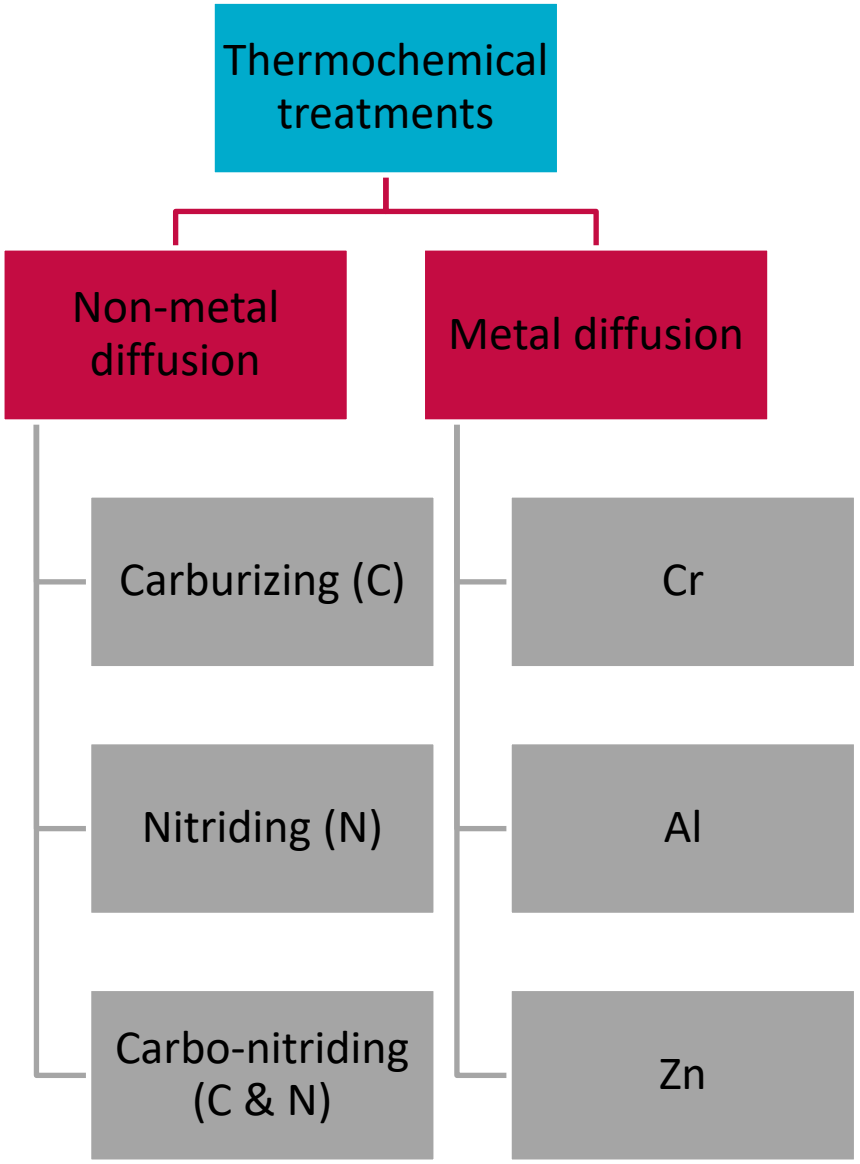
Diffusion treatments



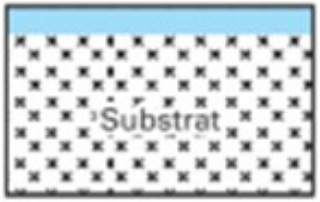
Doping of surface by metal or non-metal element to increase surface properties while keeping the bulk characteristics

Different processes

- Salt bath treatments
- Gas phase treatments
- Plasma treatments
- Ion implantation



Structural modification of surface



Il n'y a pas de matériau d'apport, seule la structure superficielle est modifiée

Structural modification

Surface quenching (for steel)

Hardening by local formation of hard phase (martensite)

No chemical modification of part

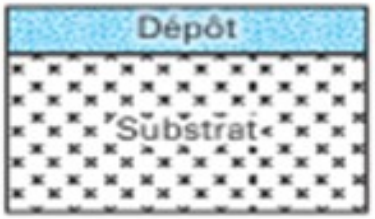
Induction | **Flame** | **High energy**

- **Laser**
- **Ion beam**
- **Arc plasma**

2 steps

- Local heating of surface
- Quenching (usually water quench)

Coatings



coatings

Synthesis routes for coatings

Dry coatings

- PVD
- CVD
- Ion implantation
- Thermal spraying

Wet coatings

- Electroplating
- Electroless plating
- Paints (organic coatings)
- Organometallic coatings (sol-gels)

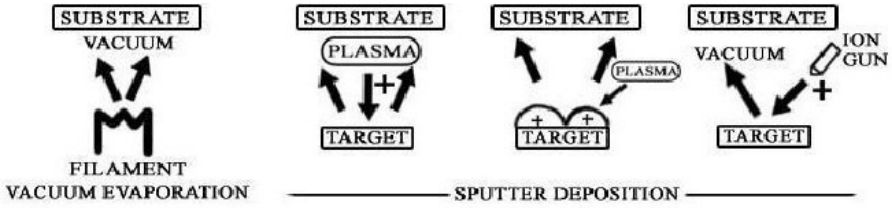
Others

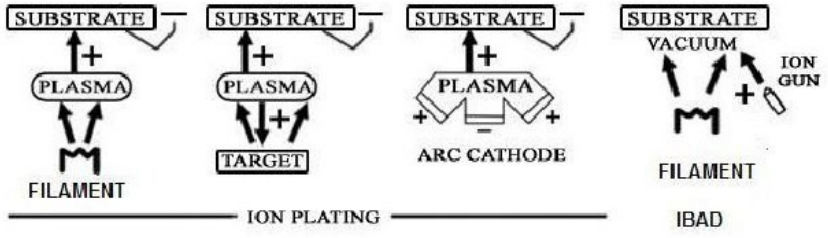
- Molten metal immersion
- Paste application
- Tribofinishing

PVD and CVD coatings

General principles

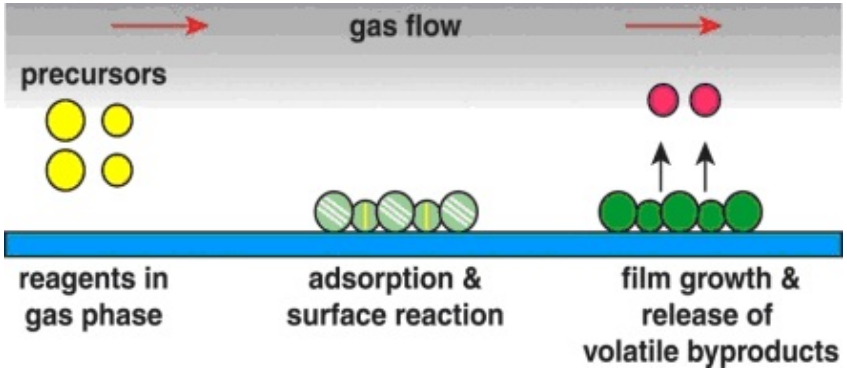
- PVD
  - Condensation of a metallic vapor in an inert rarefied gas.
  - Vapor is produced by thermal evapo-ration, sputtering or high energy beams.
- CVD
  - Reaction of precursor gas with hot surface to form stable compounds.
  - Various processes : atmospheric, low pressure, plasma enhanced, hot/cold walls





Main applications

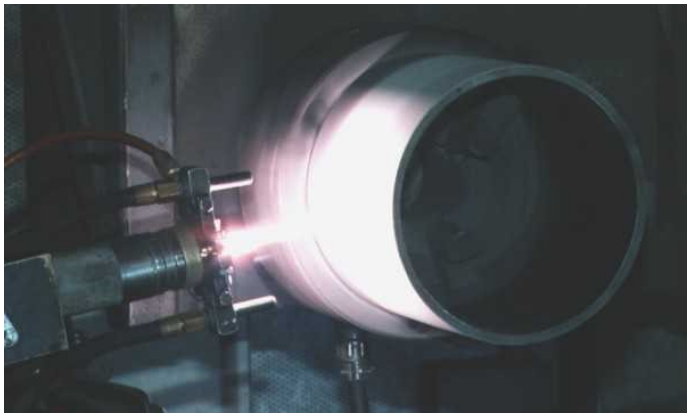
- Corrosion/wear resistance
- Aesthetics
- Optical properties



Thermal spraying

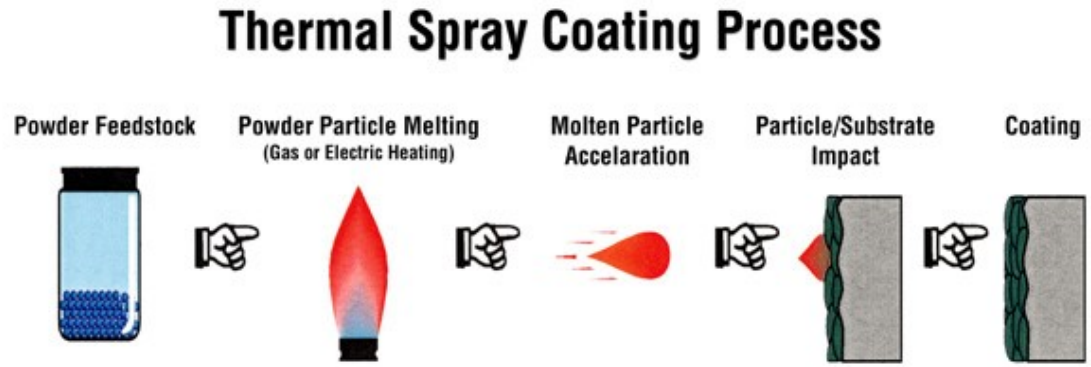
General principle

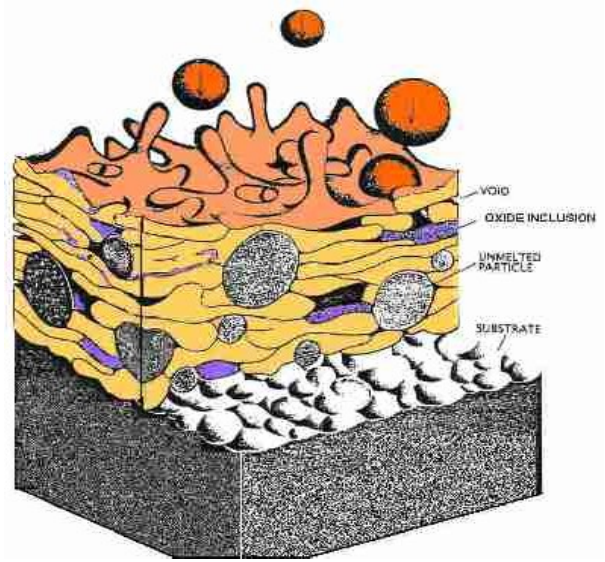
- Sprayed material is heated in a gaseous environment
- Molten drops of material are sprayed at high speed towards the substrate
- Quick solidification of splattered drops
- Sprayed material can be powder, wire, rod…



Main applications

- Wear resistance





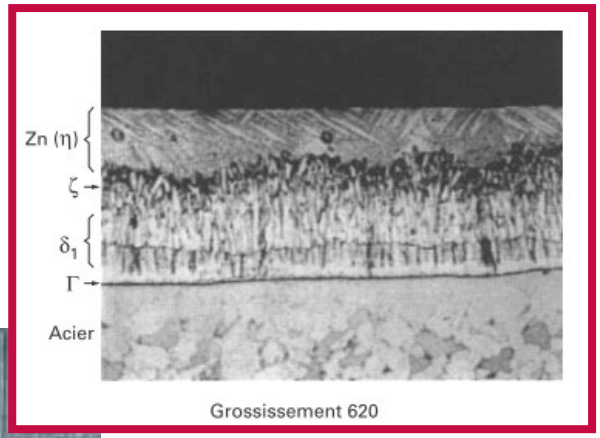
Molten metal deposition

General principle

- Immersion of the metal (usually steel) in a molten bath of Zn or Sn ➡ formation of continuous coating

Main applications

- Corrosion resistance



Paints (organic coatings)

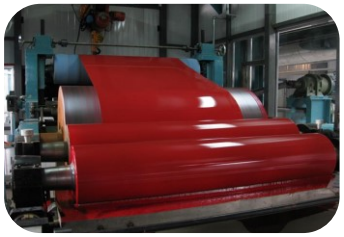
General principle

- Fluid, plastic material applied in a thin layer on the substrate that forms, after curing (or drying), a solid, adherent coating.
- Usually constituted of several layers (primer / intermediate/top coat).
- Several components : binder / dryer / solvent /additive /pigment/ filler
- Applied by several methods

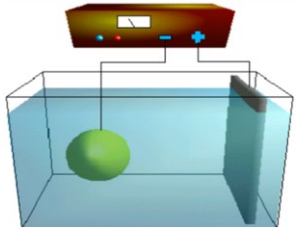
Main applications

- Aesthetics
- Corrosion resistance

Immersion



Roll to roll



electrolytic

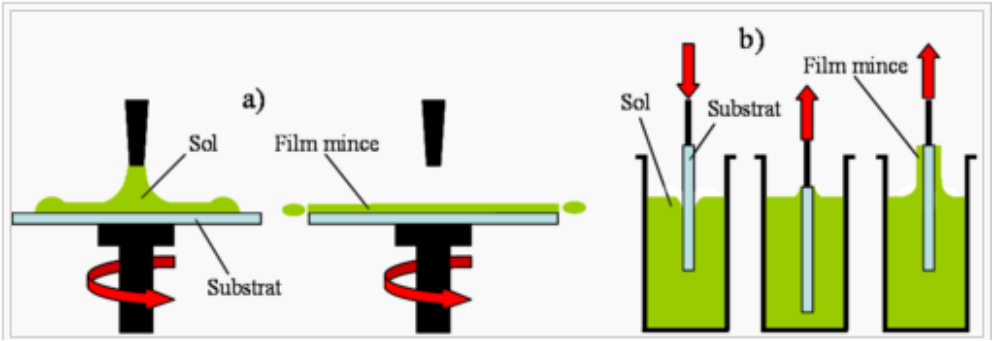
Spray

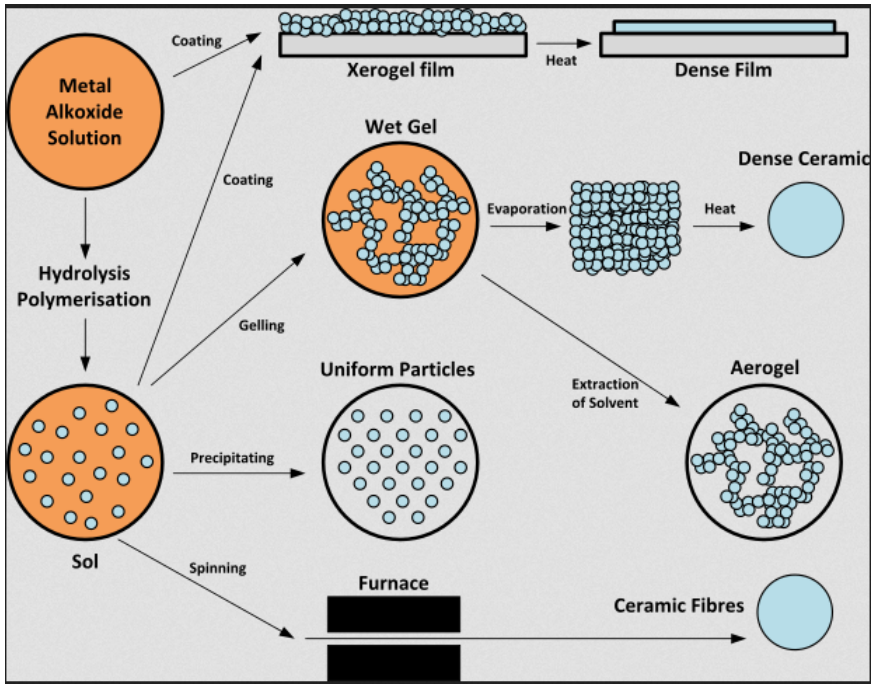
Powder coating

Sol-gel coatings (organometallics)

General principle

- ✓ Formation of coatings from colloidal or alkoxide solutions by polymerisation of organometallic precursors.
- ✓ The colloidal solution (sol) becomes a viscous gel then a solid material.
- ✓ Steps
  - ✓ Hydrolysis of precursors
  - ✓ Condensation
  - ✓ Polymerisation
- ✓ Application methods



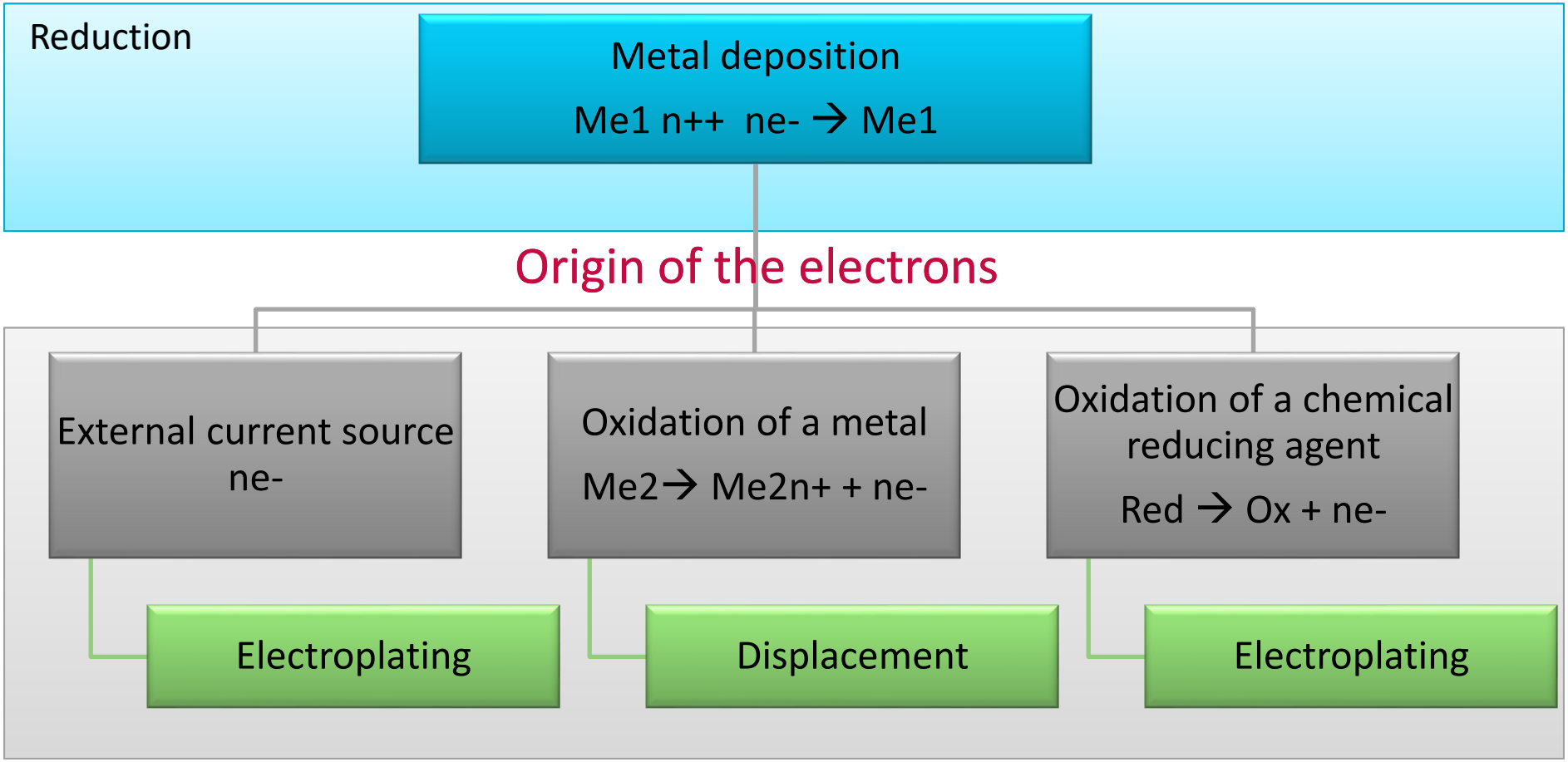


Main uses

- ✓ Corrosion resistance

Electrochemical coatings

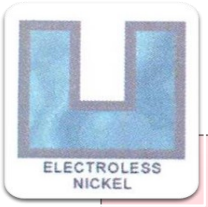
The different redox processes



Electrochemical coatings

General principle

The coating is formed by reduction of metallic salts in aqueous solution

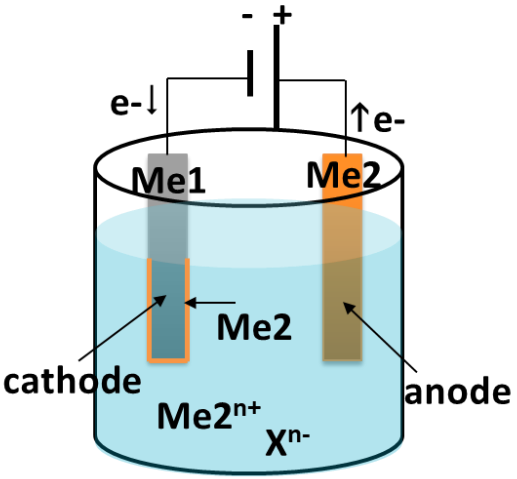


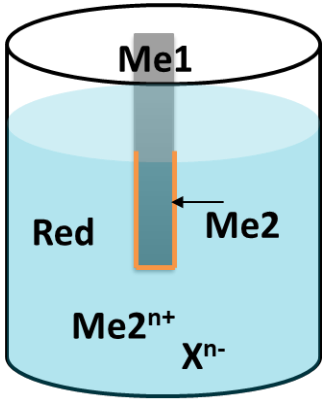
Electroless plating

- **No external current source - catalytic**
- OK for **conductive and insulating materials**
- Works for complex shapes – constant thickness
- All components including metallic ions are already in solution at the start

Electroplating

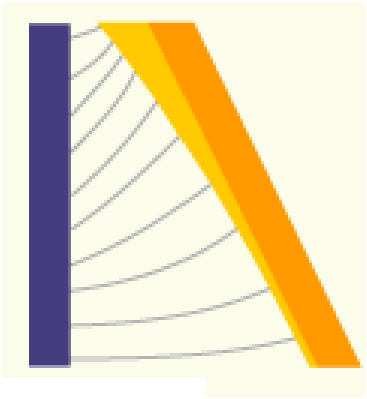
- **External current source – non catalytic**
- Only for **conductive materials**
- Difficult to use of complex shapes – edge effect on thickness
- Metallic ions come from oxidaiton of anode

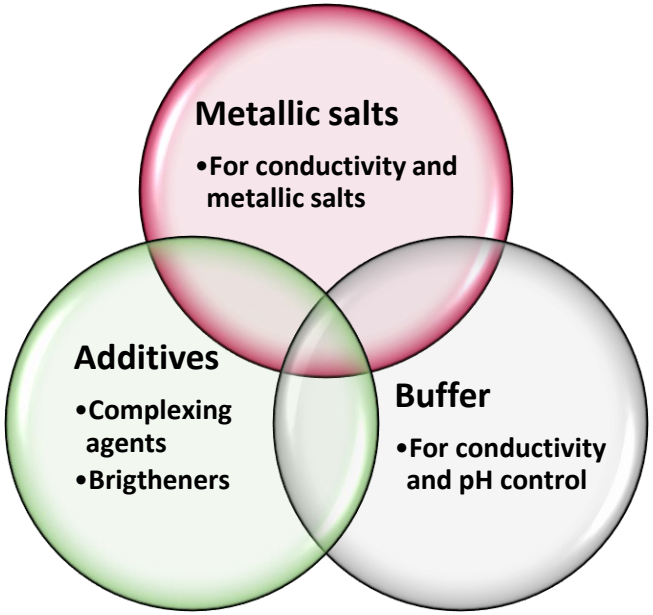


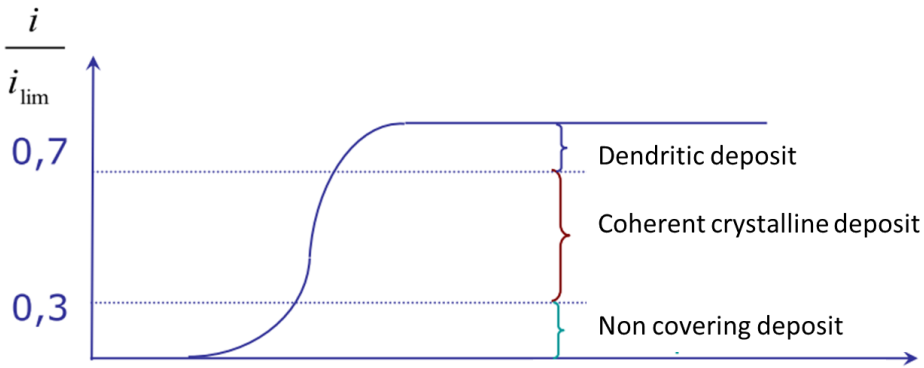


Practical aspects of electroplating

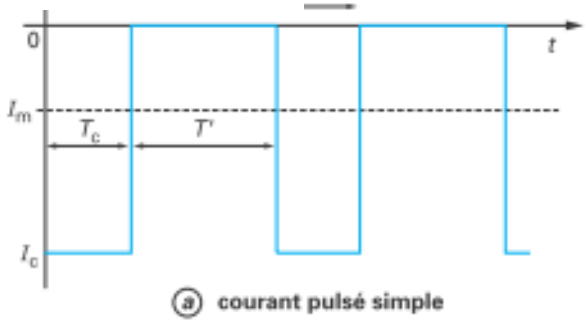
- **Optimisation of geometry and current :** Hull cell
- **Potential determination:** polarisation curves
- **Components of a bath**







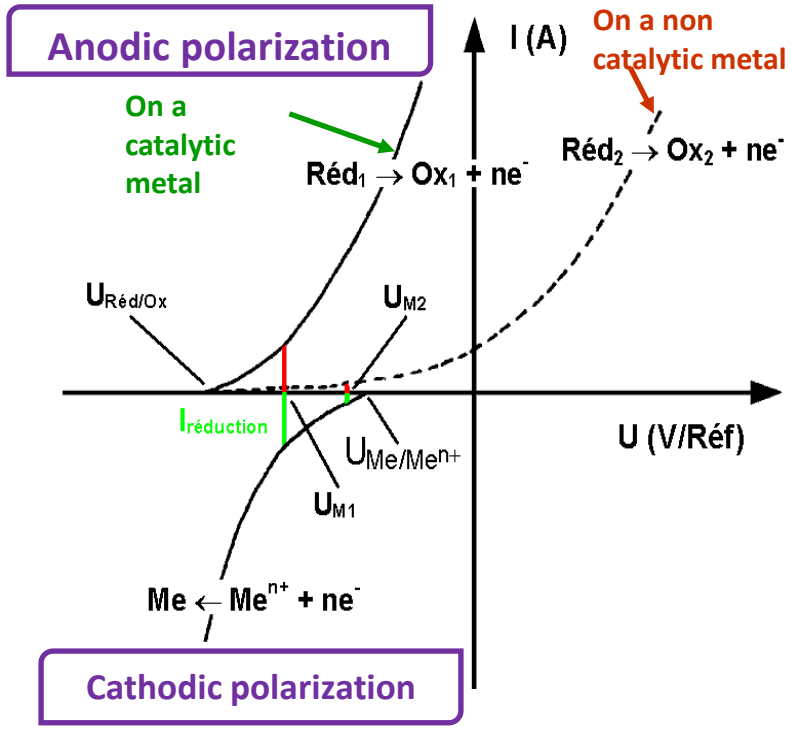
- **Power :** continuous or pulsed



Practical aspects of electroless plating

- **Process operates at mixed potential ($|i_a| = |i_c|$)**
- **Influence of overpotential**
- **Catalytic requirements**
  - Substrate
  - Previously deposited metal (autocatalytic)
- **Plating bath components**

Component	Role
Metallic ions	Metal source
Reducing agent	Source of electrons
Complexing agent	Increases solubility of metallic ions
Stabilizer	Catalysis and plating rate regulation
Buffer	pH regulation



Properties of electrochemical deposits

- ✓ Electroplated Chromium : wear and corrosion resistance – aesthetics
- ✓ Electroplated nickel : excellent resistance to atmospheric corrosion – wear resistance – magnetic – diffusion barrier – adhesion promoter
- ✓ Electroless nickel : wear and corrosion resistance – electronics (hard disks) – aesthetics
- ✓ Electroplated copper: high thermal and electrical conductivity - excellent adhesion
- ✓ Electroplated tin : corrosion resistance – Solderability – food industry (non toxic)
- ✓ Electroplated cadmium : corrosion resistance
- ✓ Electroplated zinc : sacrificial protection of steel against corrosion
- ✓ Precious metals (Ag – Au – Rh) : precision mechanics and electronics
- ✓ Electroplated gold : for conductivity and corrosion resistance – used in electronics
- ✓ Electroplated silver : high thermal and electrical conductivity – low contact resistance - bactericidal

Pre-treatments before electrochemical plating

- ✓ Most defects in wet plating are linked with surface preparation issues
- ✓ Preparation steps:
  - ✓ Polishing/grinding to specific roughness
  - ✓ Degreasing
  - ✓ Removal of surface oxides
    - Mechanical treatments
    - Chemical
    - Electrochemical
    - With high energy beams
  - ✓ Rinsing and drying

Conclusions