METHODS OF COATING FABRICATION

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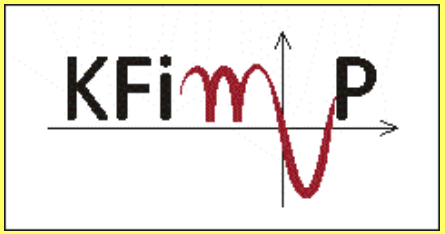


Department of Physical Chemistry and Modelling

DEFINITION

The coating is the thin outer layer of the object, which physiochemical properties and/or structure are different from those of the coated material.

METHODS OF COATINGS FABRICATION

1. Electrolytic method
2. Anodic oxide film
3. Chemical methods
4. Immersion method
5. Thermal spraying
6. Diffusion methods
7. Platering
8. Vacuum deposition of electroless methods

THE SURFACE PREPARATION METHODS OF STEEL FOR COATINGS

1. Mechanical methods:
   - abrasing and/or polishing,
   - brushing
2. Physico-chemical methods:
   - degreasing in solvents
   - emulsion degreasing,
   - alkaline degreasing,
   - etching in acids and bases (removing of oxides and hydroxides)
   - electrolytic degreasing,
   - degreasing using ultrasounds
3. Thermal methods – flame desurfacing.

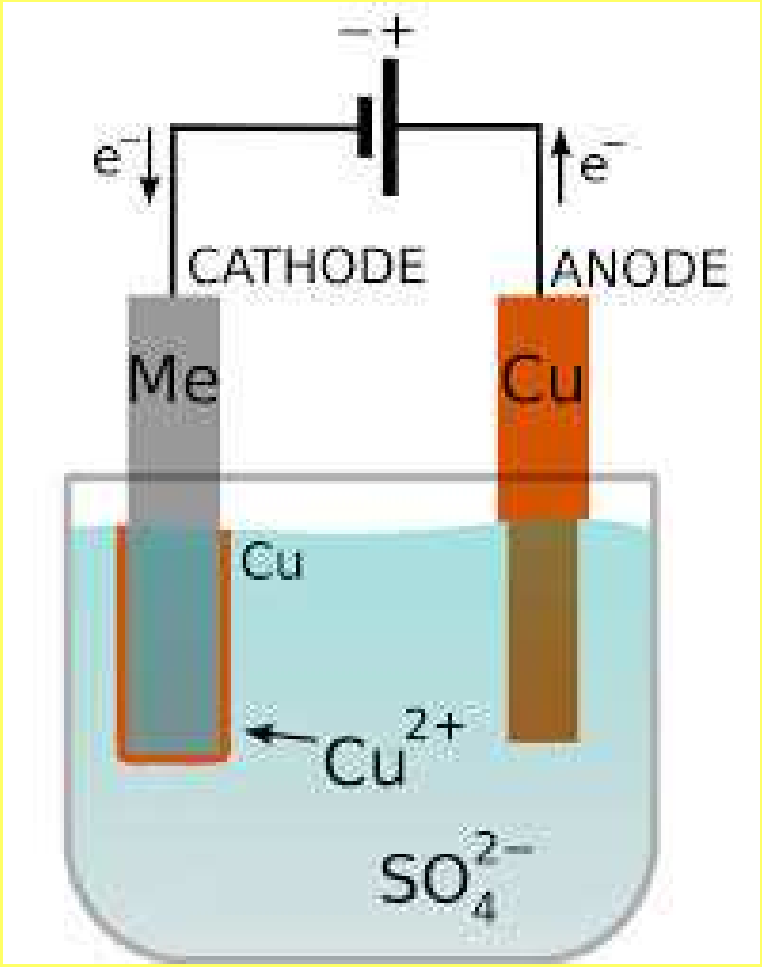
ELECTROLYTIC COATINGS (GALVANIC)

Electrolytic metal coatings produced on the conductive substrate are obtained by deposition of metals from a solution of their salts or anodes made from appropriate metal, using electric current. The coated object is the cathode and the anode constitutes the plating material.

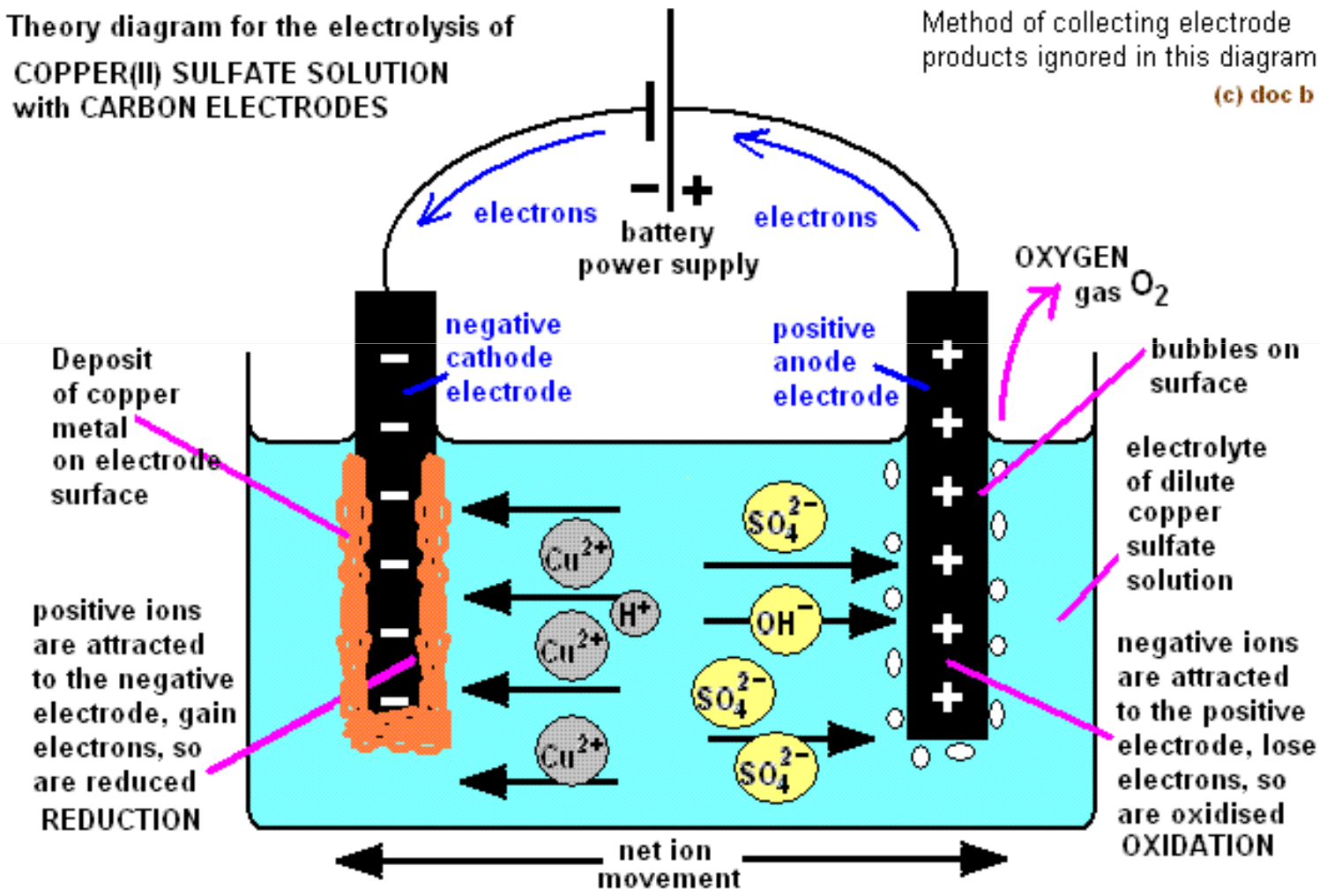
Coatings are obtained in the first stage by the formation of crystallization centers, which subsequently grow to form a continuous layer with required thickness.

Factors affecting the properties of the coatings: the type of metal substrate, type and concentration of additives (eg, increasing the electrical conductivity of the bath, causing the formation of finely coating or brightening shell), current density, bath temperature, time of the process and methods of mixing the bath (mechanical, compressed air, etc.).

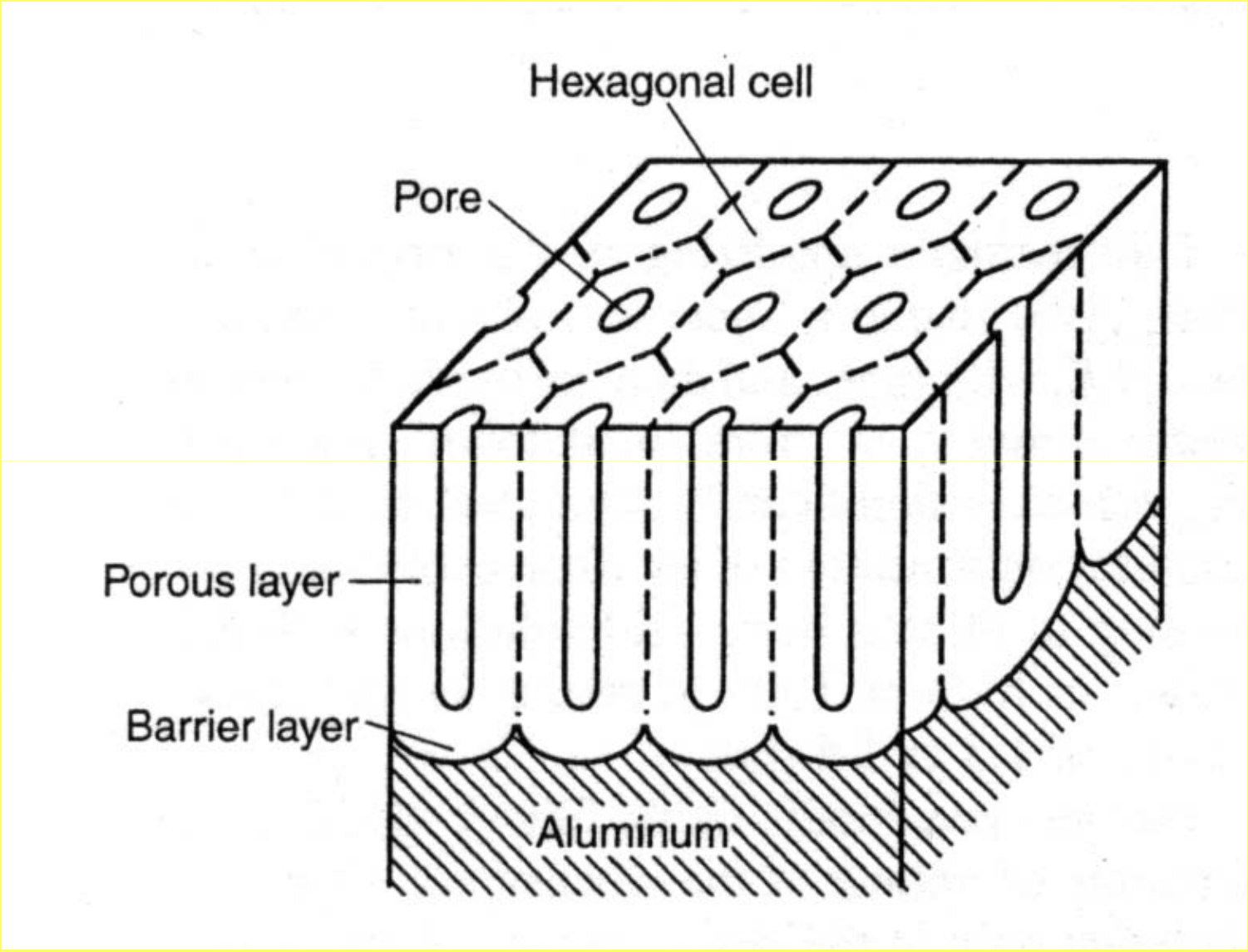
ELECTROLYTIC COATINGS (GALVANIC)



ELECTROLYTIC COATINGS (GALVANIC)

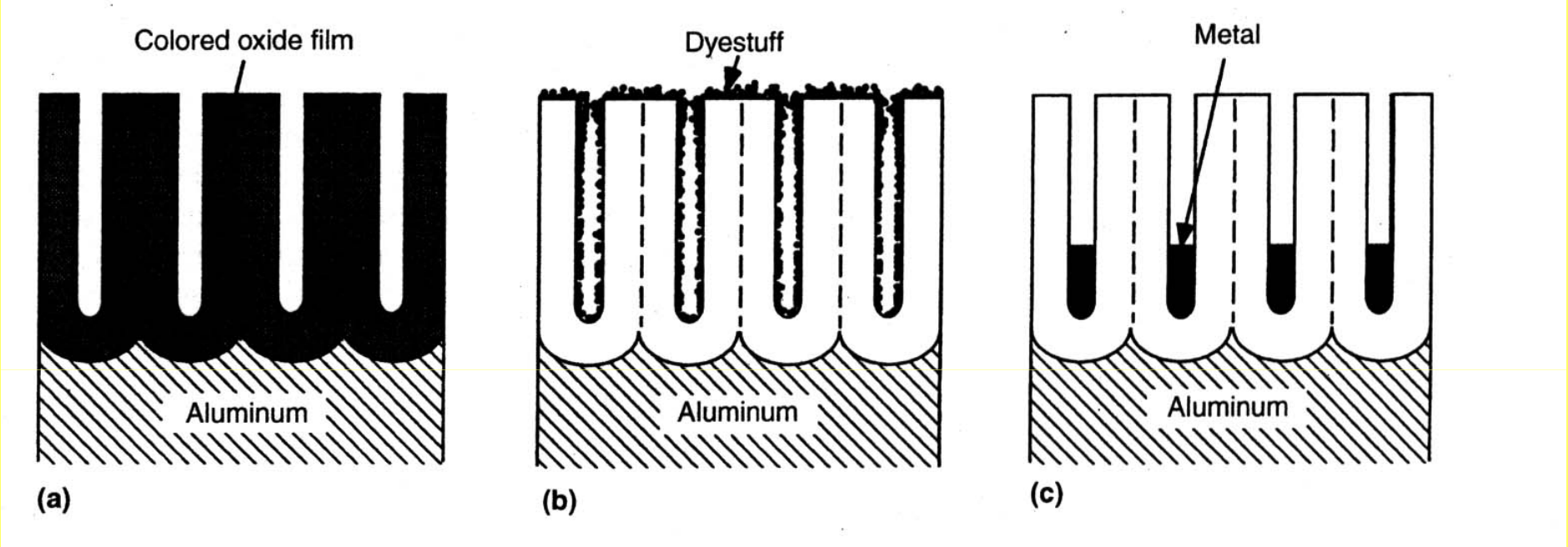


Anodic oxide film



Structure of porous anodic oxide film, formed on aluminum in acid solutions

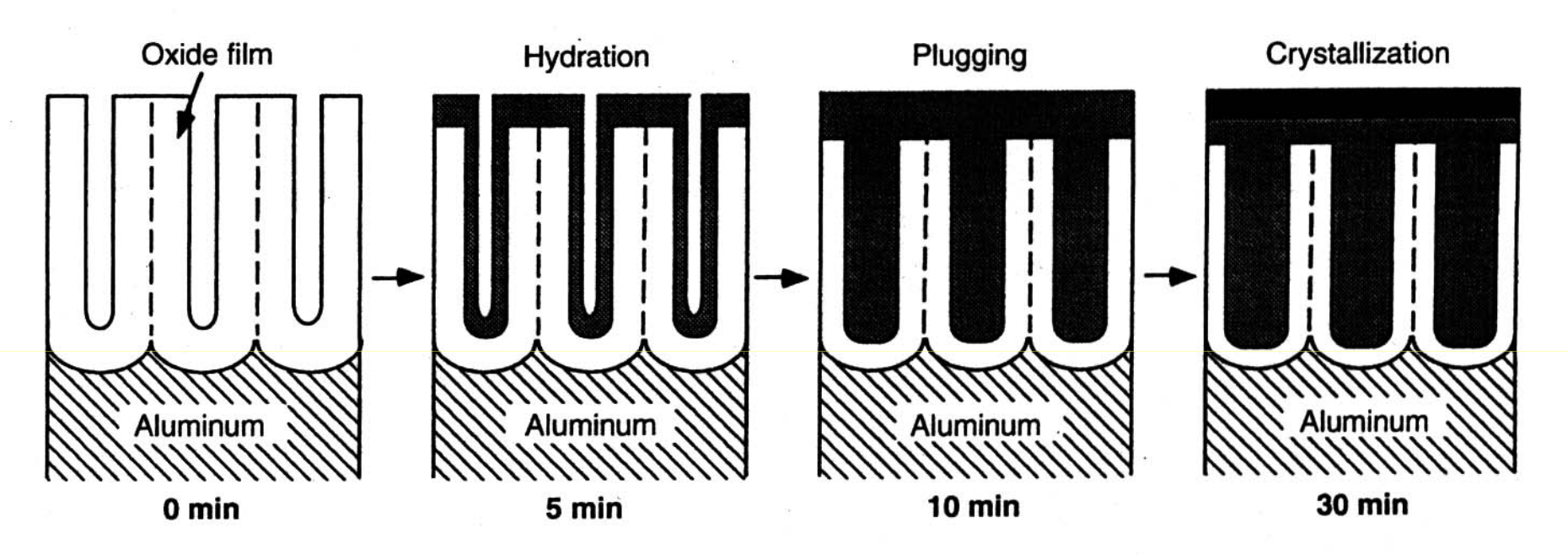
Anodic oxide film



Coloring of porous type anodic oxide films on aluminum:

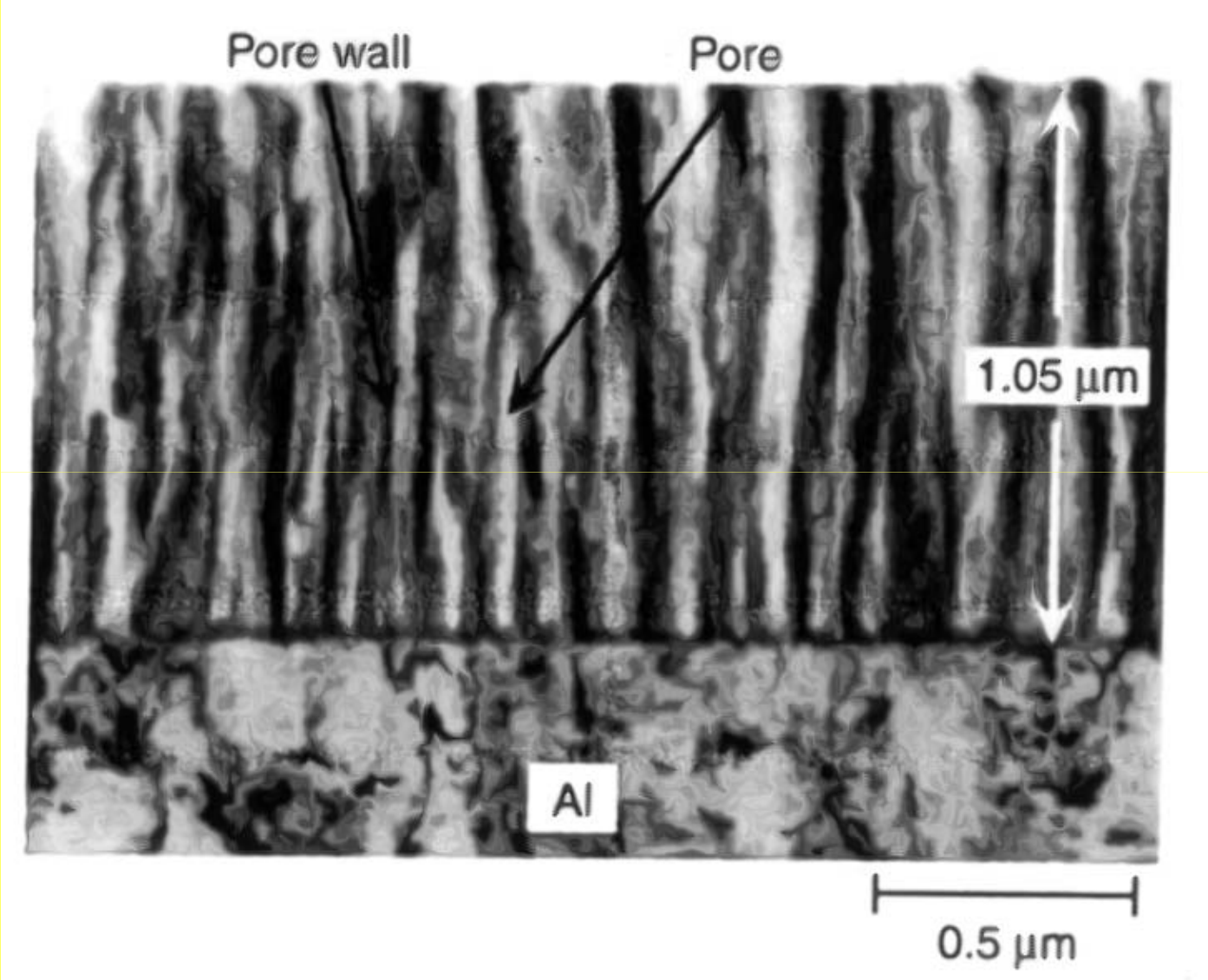
a) integral coloring,
b) dyeing
c) electrolytic coloring

Anodic oxide film



Process of pore sealing with hydroxide during dipping in boiling pure water

Anodic oxide film



TEM image of the vertical section of a porous type anodic film on aluminum

CHEMICAL COATINGS

Chemical (electroless) imposition of metals involves the reduction of metal compounds from solutions of their salts by using reducers (hypophosphoric acid salts, or other). Until now chemical methods are developed, consisting in chemical vapor deposition of nickel, cobalt, tin, copper, silver, gold, palladium or platinum. The contact coating method consists in displacement of the metal ions from solution by the metal substrate.

Metallic coatings deposited by chemical methods are rarely used for protection against high temperature corrosion.

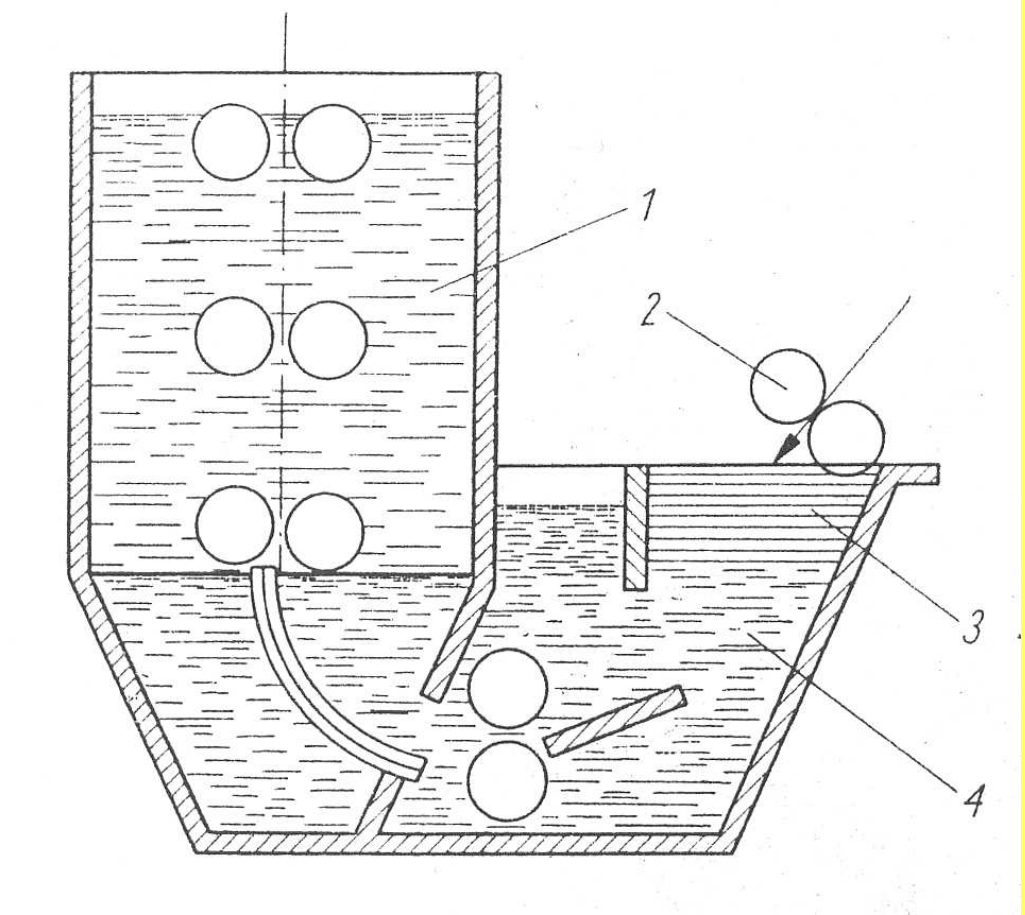
$$M^{z+} + Red_{solution} \xrightarrow{\text{catalytic surface}} M_{solid} + Oxy_{solution}$$

HOT-DIP COATINGS (IMMERSION)

Hot-dip coatings are obtained by immersion of a given material in a molten metal bath. This method is the oldest and cheapest one, currently utilized in obtaining metallic coatings, well adherent to the substrate.
This method is mainly used in those cases when the material shows considerable length (tapes, wires).

This method can be applied only when the melting point of a given material is higher then that of the coating. In practice, this method is used for coating tin (232°C), lead (327°C), zinc (419°C) and aluminum (660°C).

HOT–DIP COATING (DIP COATING)
- scheme of device for hot-dip tinning

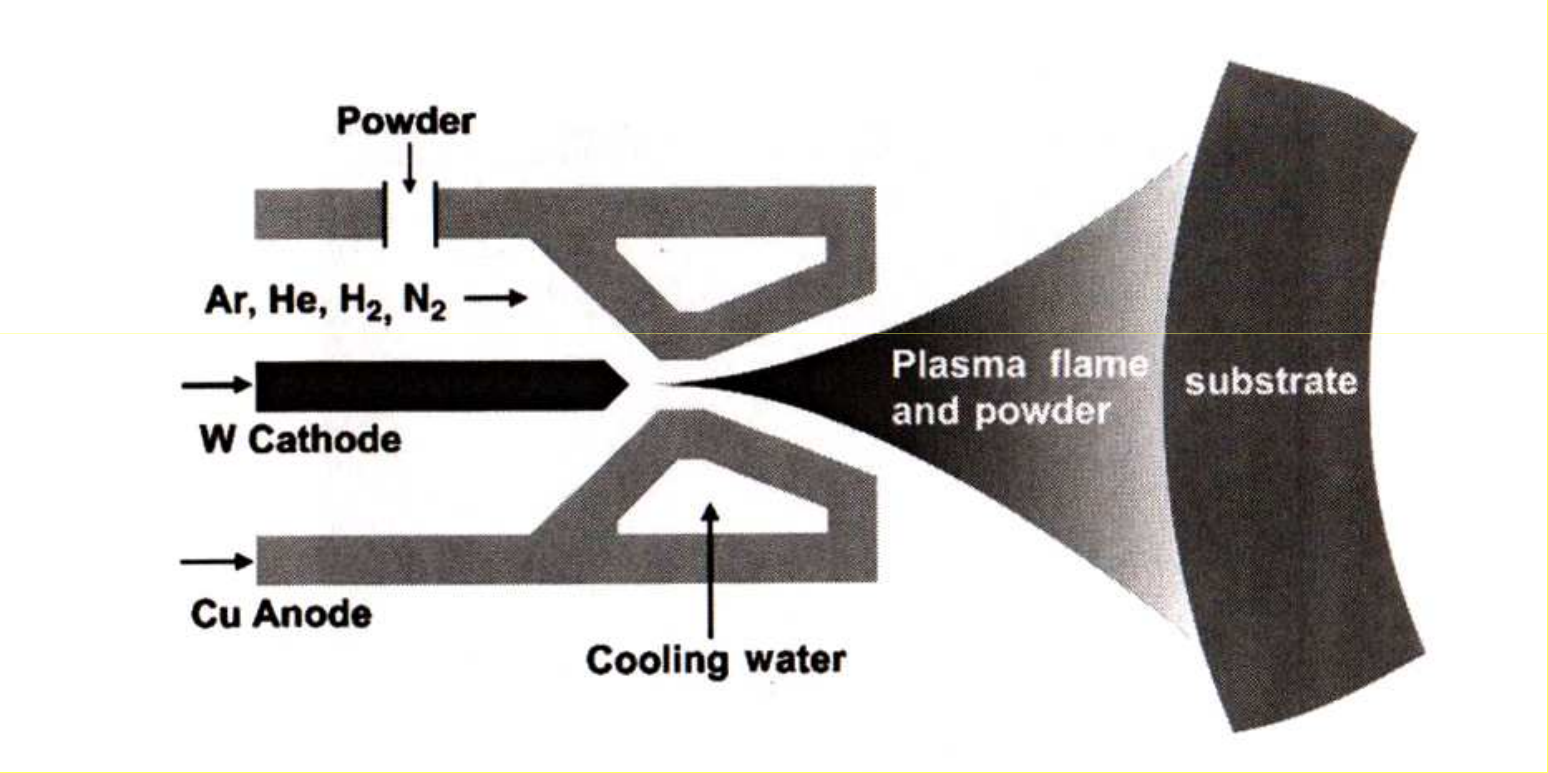


1 – oil, 2 - cylinder head, 3 – fluxing agent, 4 - molten tin

THERMAL SPRAY COATINGS

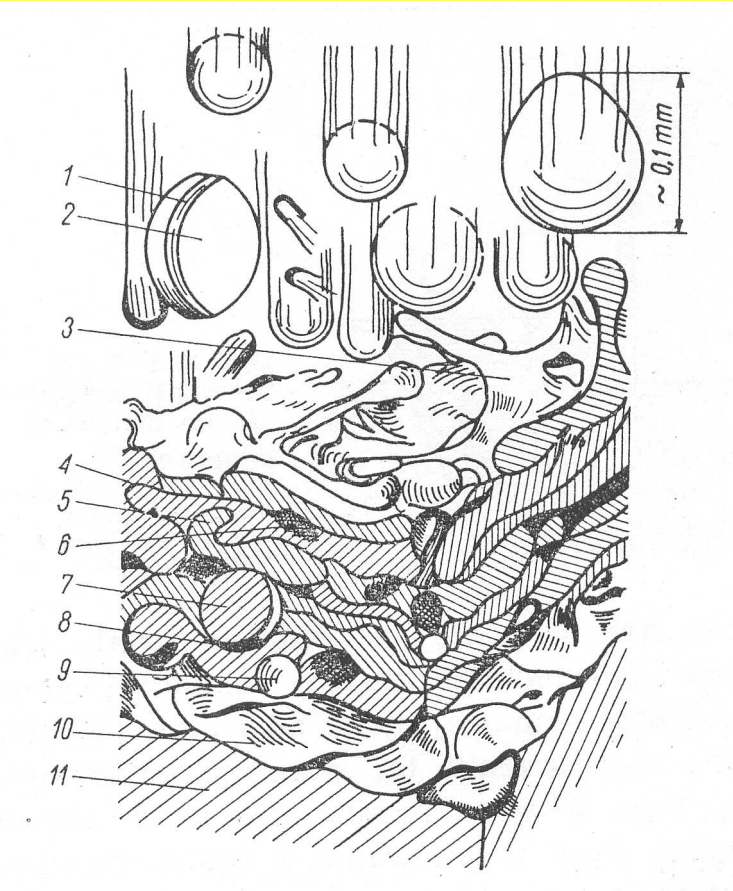
Thermal metal spraying involves melting, using different heat sources (flame, electric arc, plasma arc or high-frequency current). The metal for coating production is used in the form of wire or powder, which after melting is directed to the substrate in a stream of compressed gas (usually air). In the high temperature flame or arc, metal particles are partially oxidized, and after hitting the ground are flattened. During hitting of the ground the oxide thin film is cracking and consequently the coating constitutes a shell of sprayed metal, its oxide and pores. The total pore volume generally does not exceed 15%.

SCHEMATIC DIAGRAM OF A PLASMA TORCH



THERMALLY SPRAYED COATING

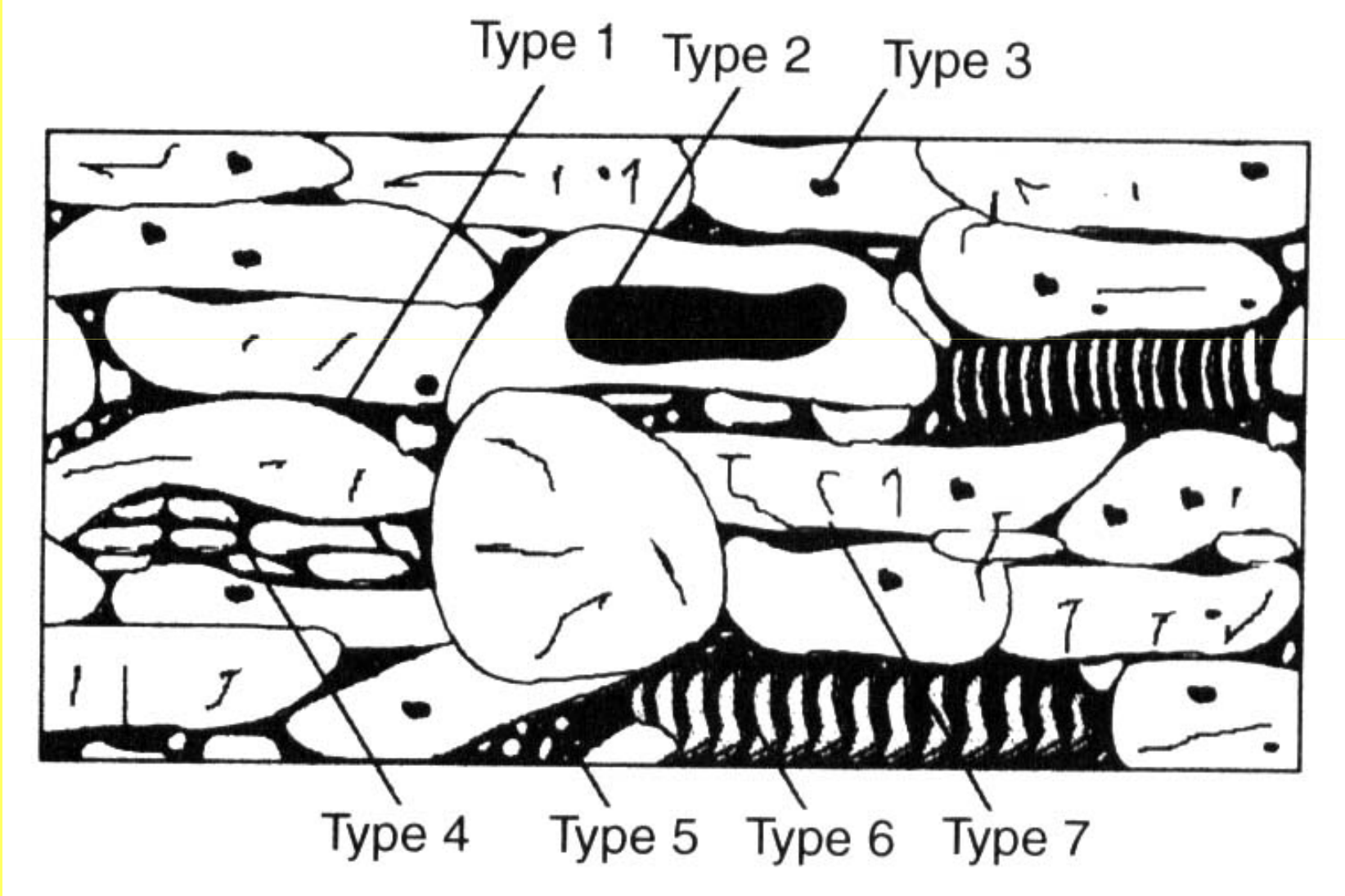
Scheme formation of the sprayed metal layer



1 - oxide on particle film, 2 - the liquid inside the particle, 3 - particle splash during impact,
4 - rest of the oxide film between sprayed particles, 5 - jamming the particles,
6 - particles coupled by mutual welding, 7 - particle at low temperature (not plastic),
8 - the gap between the particles (not plastic), 9 - micropores (developed due to traped of exhaust gas between particles, 10 - surface of the substrate, 11 - substrate

THERMALLY SPRAYED COATING

Forms of porosity in thermal spray coating



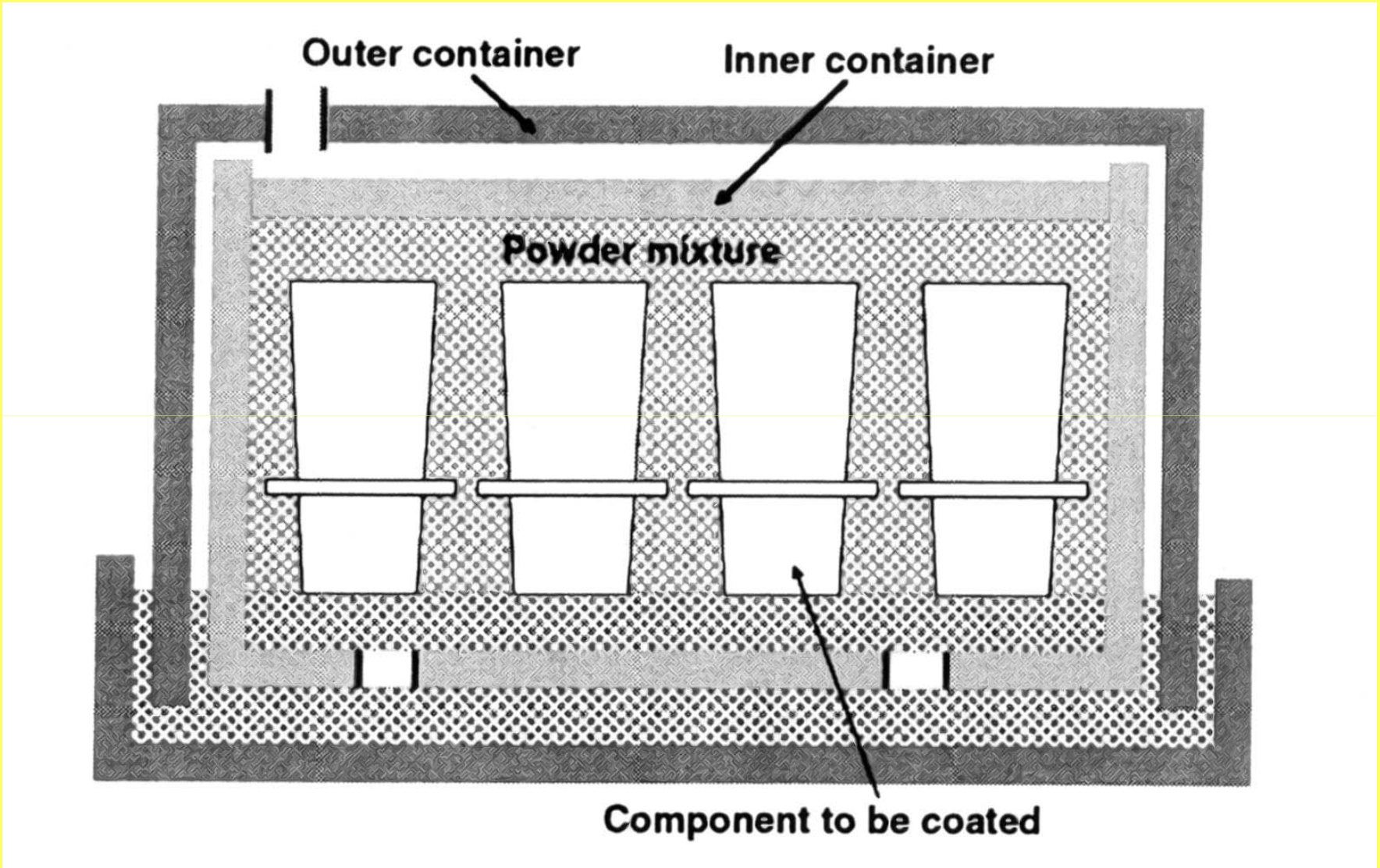
DIFFUSION COATINGS

Diffusion coatings are produced by changing the chemical composition of the surface layer of a given material as a result of the introduction of alien elements. Diffusion coating is a part of the substrate material saturated with alien elements, which cannot be separated from it. Metals plated on the substrate surface diffuse into the crystal lattice, not influencing the apparent changes of its dimensions.

Typical diffusion processes:

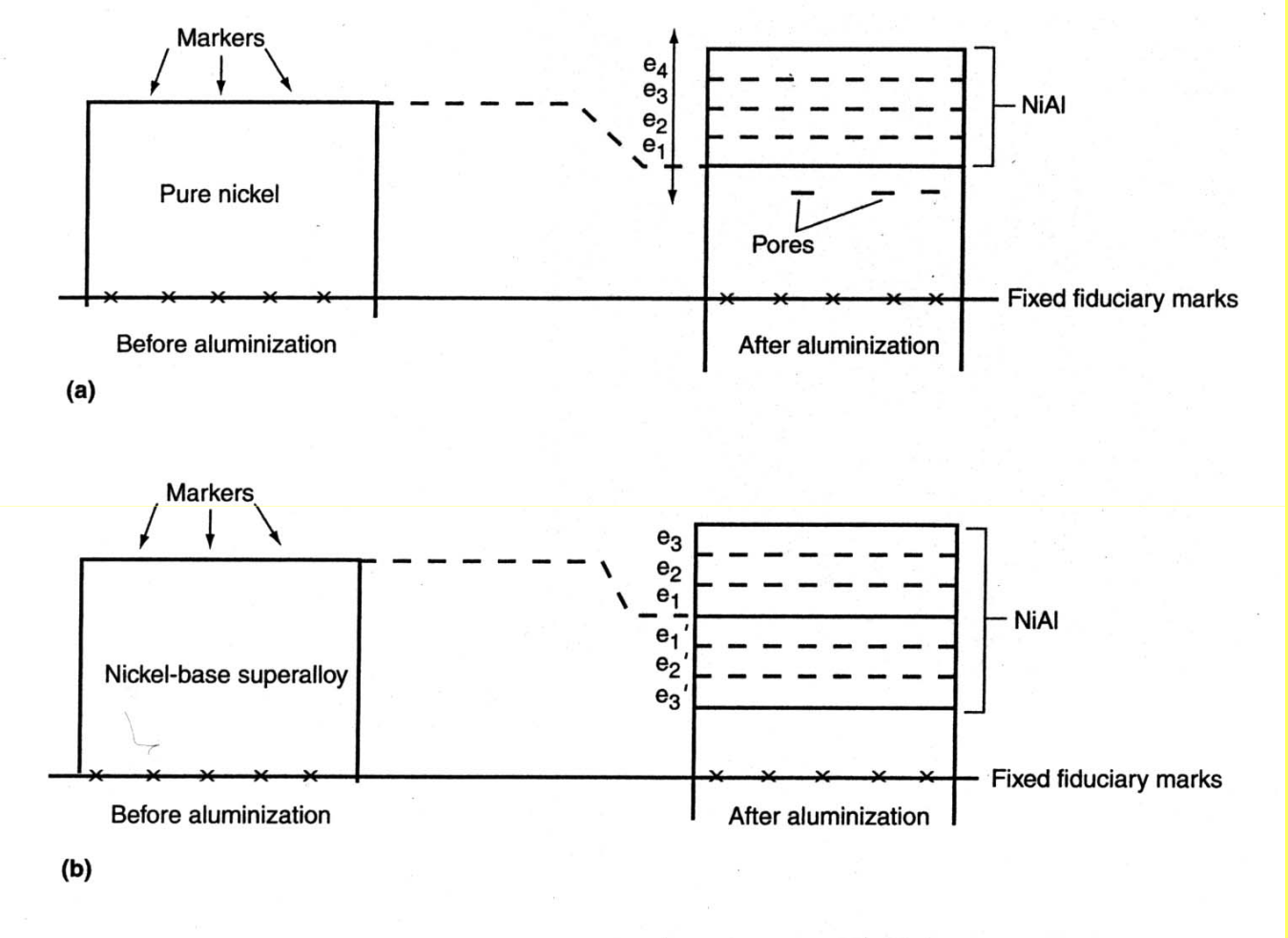
- Aluminizing
- Chrome plating
- Chrome aluminizing
- Galvanizing
- Chrome siliconizing

DIFFUSION COATINGS



Schematic diagram of the apparatus used for aluminizing by pack cementation

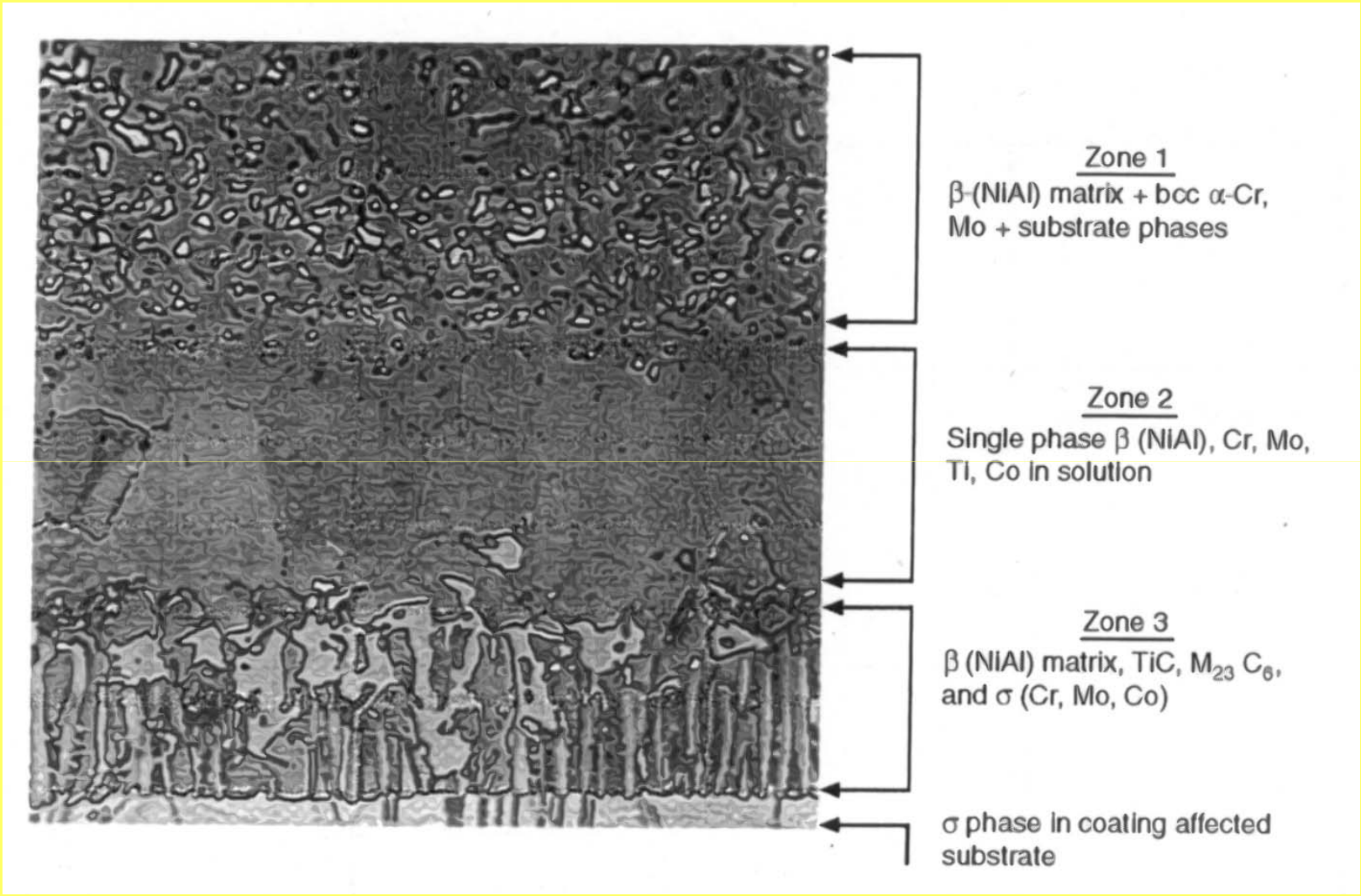
DIFFUSION COATINGS



Progressive stages of aluminization in a low-activity aluminum pack:

a) pure nickel
b) nickel-base superalloy

DIFFUSION COATINGS

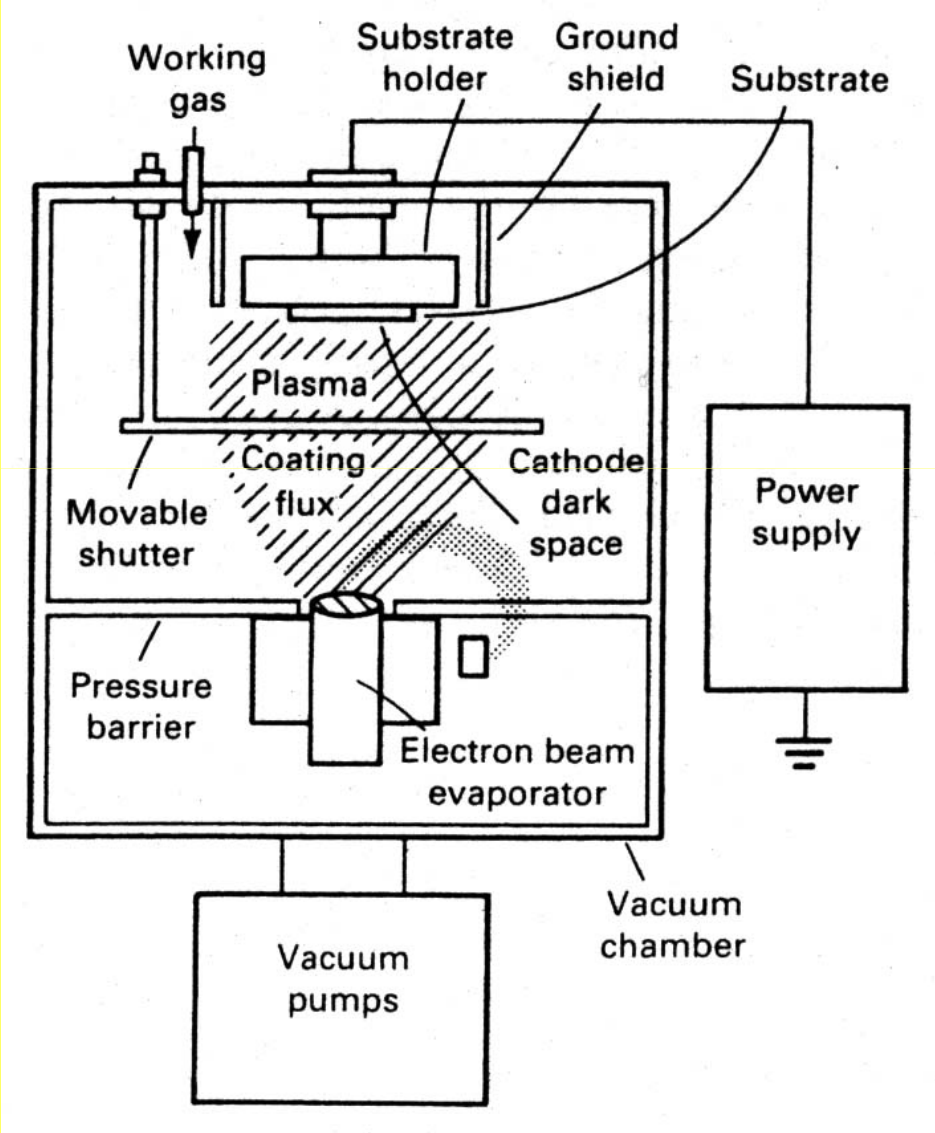


Microstructure of a cross-section of a nickel-base superalloy aluminized in a high activity aluminum pack followed by heat treatment

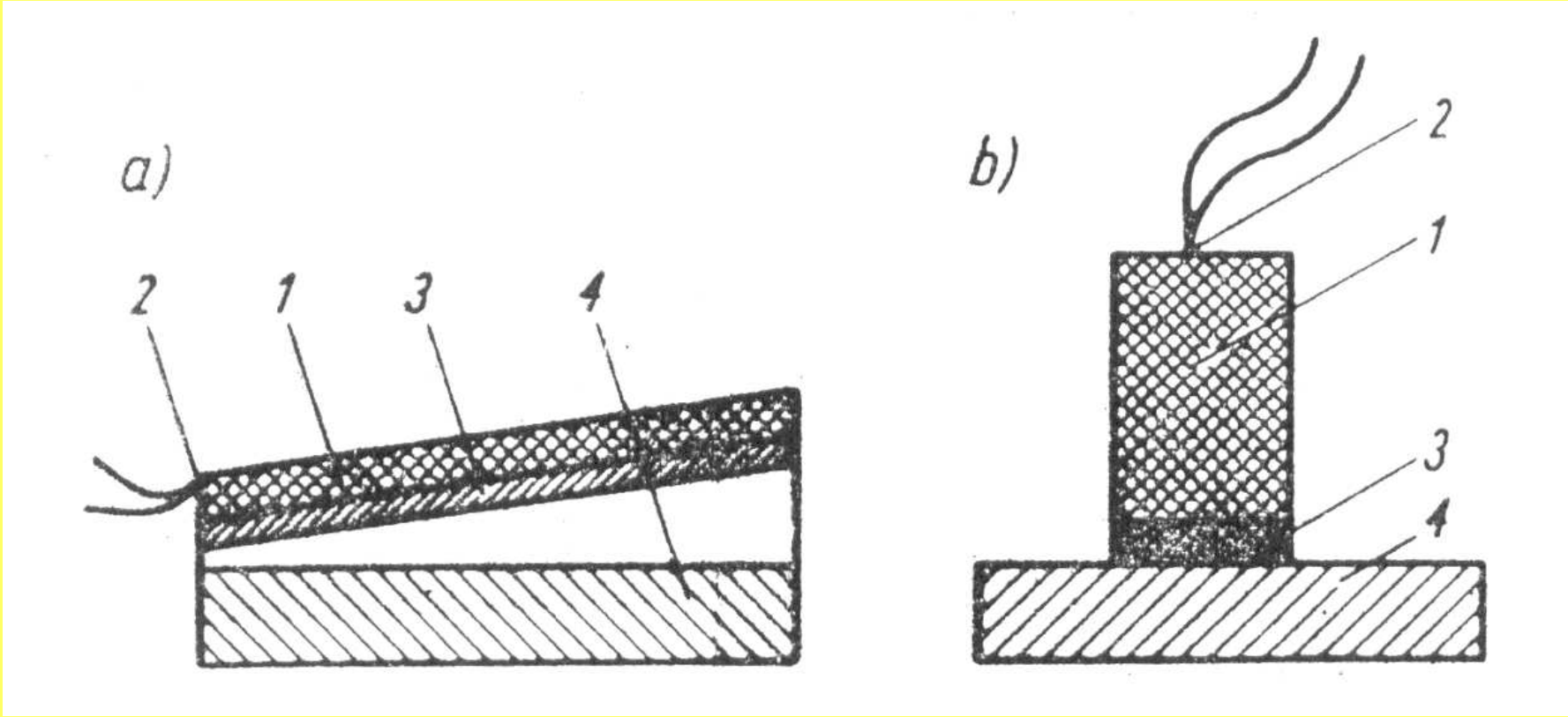
PLATING

Plating method consists in mechanical coating of a relatively thick layers of a given metal on protected substrate, being in the form of tape or wire. Metal coating (more noble or more decorative) can be obtained by casting, welding, soldering, rolling or explosive plating. The penetration of the coating metal into the substrate proceeds under the influence of pressure and temperature, providing the welding. Carbon steels are usually plating by copper, nickel, aluminum and acid resistant steels.

BASIC ION PLATING PROCESS



METHOD OF EXPLOSIVE PLATING



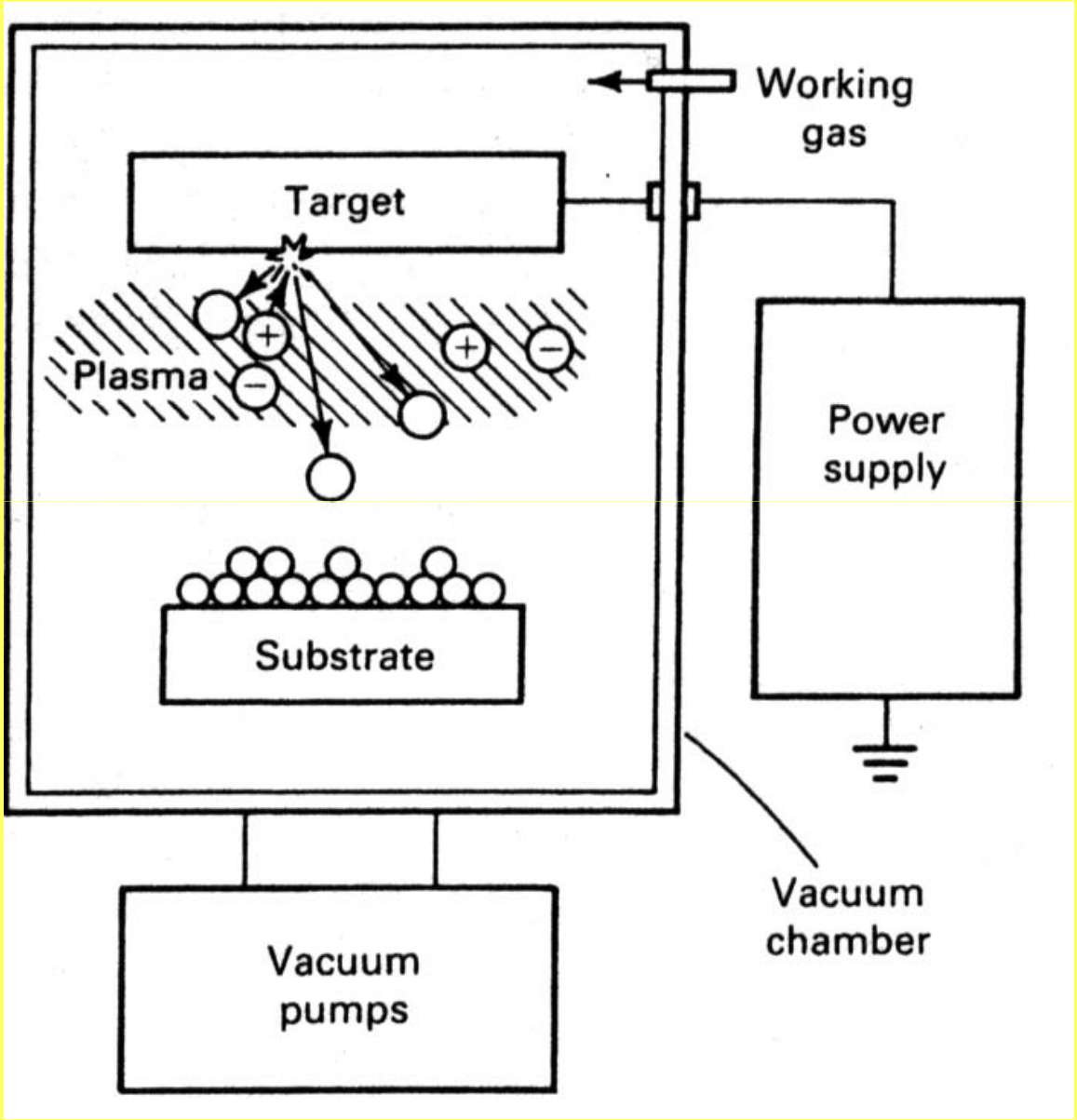
a) planar system, b) cylindrical system; 1 – explosive material
2 – detonator, 3 – material applied as a coating,
4 – substrate

VACUUM DEPOSITION COATINGS

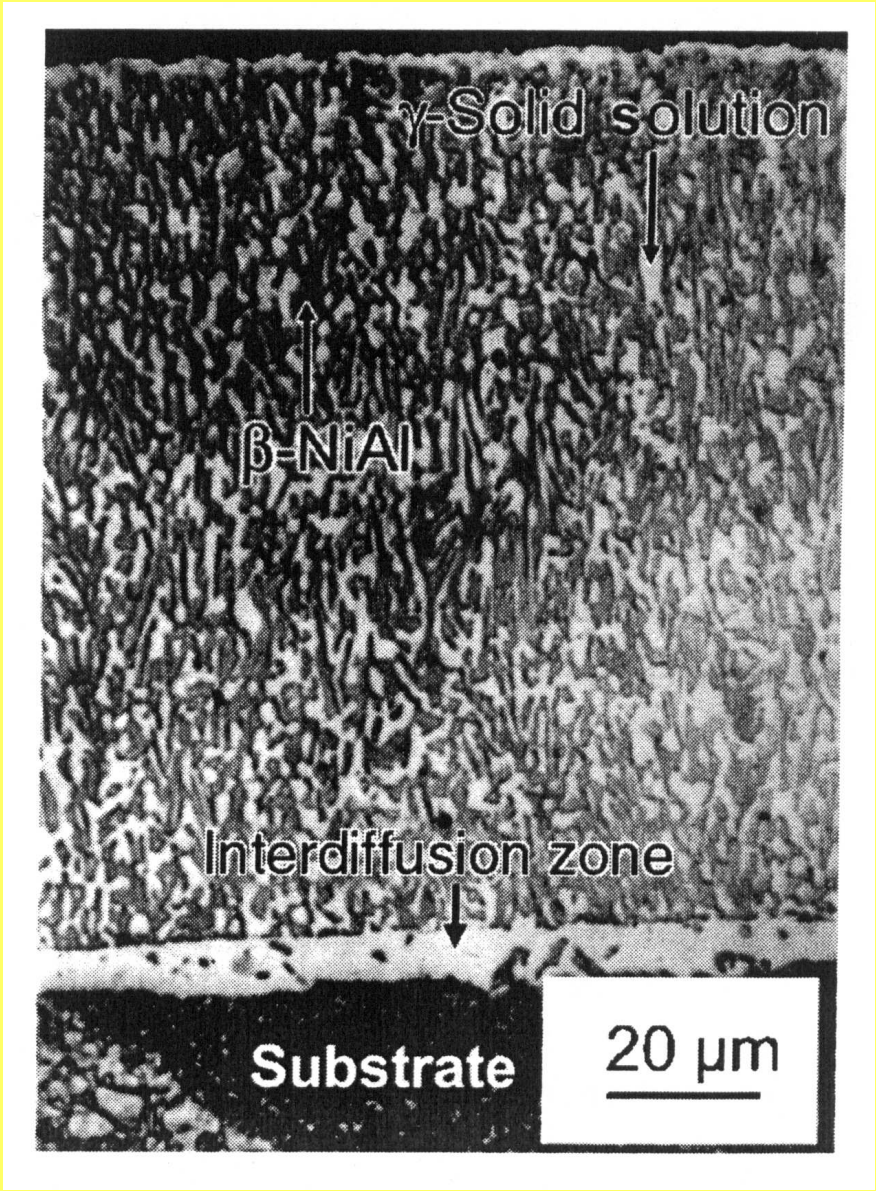
Methods of vacuum deposition of metals:

- Electroless vacuum deposition
- Cathodic sputtering
- Ionic metallization

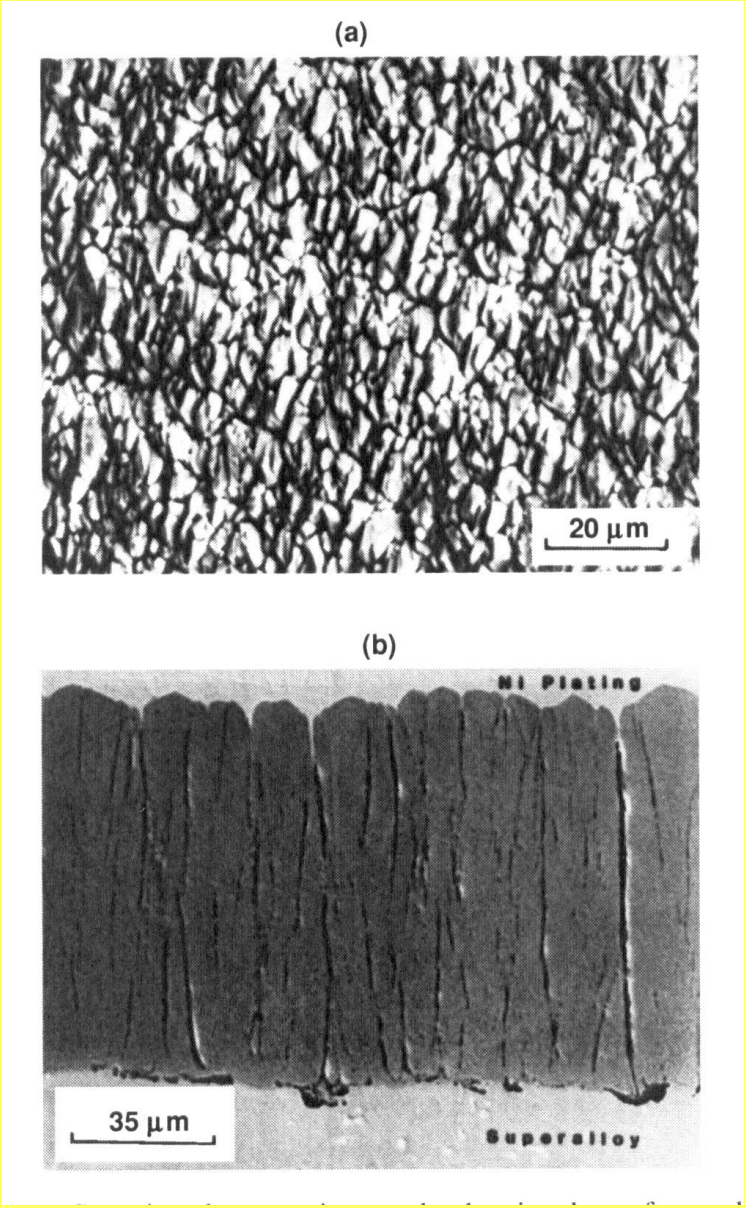
BASIC SPUTTERING PROCESS



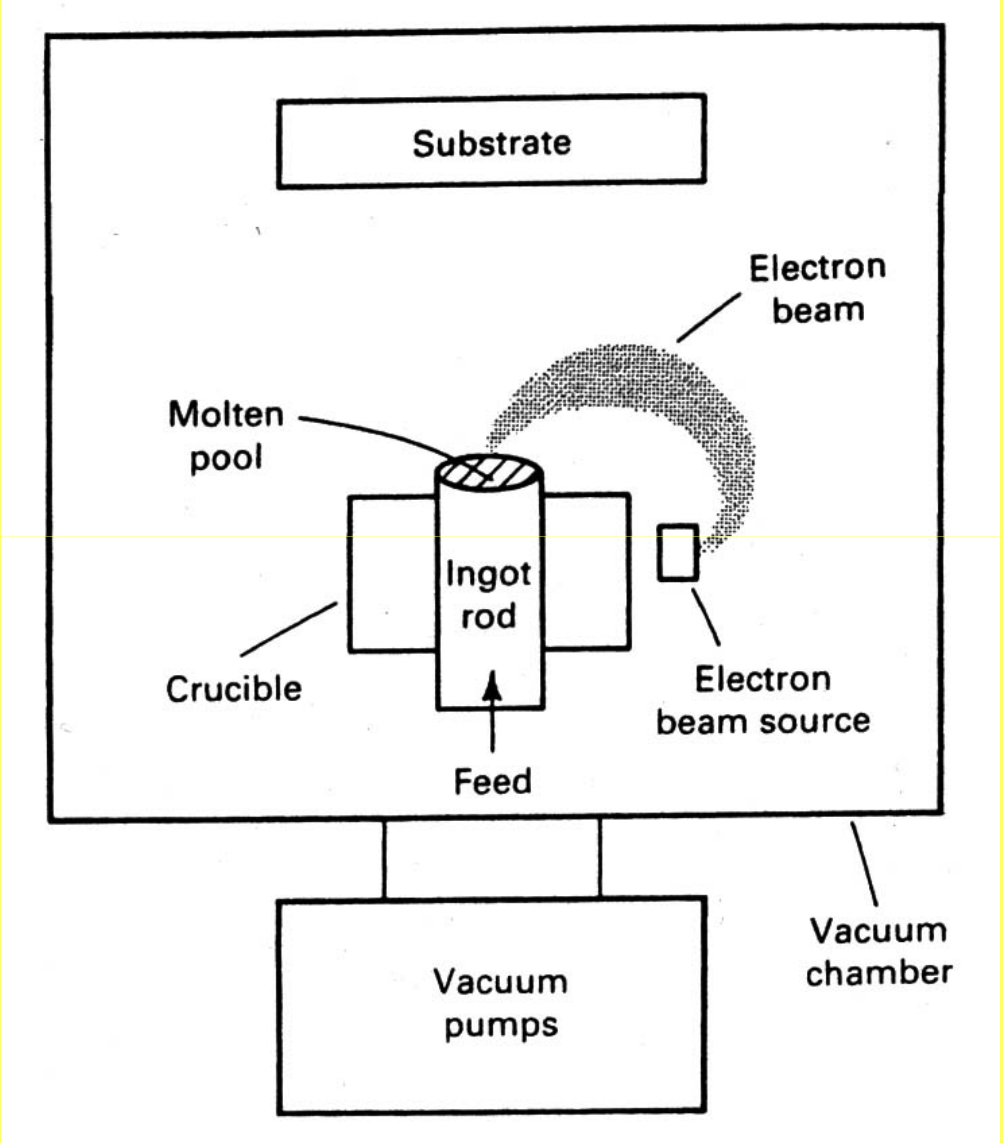
Cross-section of the Ni-Cr-Al-Y coating obtained by the EB-PVD method



Surface and cross-section of the Co-Cr-Al-Y coating obtained by the EB-PVD method on the IN-738 alloy



BASIC EVAPORATION PROCESS



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