

TALAT Lecture 5105

Surface Treatment of Aluminium

15 pages, 15 figures

Basic Level

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Objectives:

- to understand the general principles, methods, properties and applications of plating on aluminium

Prerequisites:

- General electrochemistry

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5105 Surface Treatment of Aluminium

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5105.00 Introduction

The processes for surface treatment of aluminium can be divided into the following groups


- I. Non-galvanic methods
- II. Chemical methods
- III. Electrolytic methods (**Figure 5105.00.01**),

where the group of non-galvanic methods can be defined as surface treatment of aluminium which does not involve chemical or electrolytic action.

The group of chemical methods can be defined as reactions taking place as a result of chemical action, i.e. no external source of electric power is present.

The group of electrolytic methods can be defined as reactions taking place as a result of electrochemical action, i.e. an external power supply is used.

These definitions may overlap, but can be used for a preliminary division into groups.

Methods of Surface Treatment for Aluminium		
I	Non-galvanic methods Mechanical finishes Organic finishes	
II	Chemical methods Pickling and etching Polishing Chemical conversion coatings Electroless plating	
III	Electrolytic methods Electro-polishing Electroplating Anodizing	
	Methods of Surface Treatment for Aluminium	5105.00.01


5105.01 Non-Galvanic Methods

- Mechanical finishes
- Organic finishes

Group I can be subdivided into mechanical finishes and organic finishes.

Mechanical Finishes


Mechanical finishes cover processes such as grinding, polishing, buffing, rolling or blasting with sand, glass or metal beads. These processes are used to remove scratches, stains, skin from casting etc. A uniform surface, which spans from satin to mirror-quality, is produced. The resulting surface may be post-treated, or it can be used as the desired finish (**Figure 5105.01.01**).

Mechanical Finishes		
Methods:	Grinding / polishing Buffing Matt finishing satin finish blasting Rolling	
Properties:	Elimination of scratches, pits, tarnish etc. Production of a smooth or lustrous surface	
Use:	Used as pre-treatment to anodizing, organic coatings or electroplating (reflectors, cabinets, kitchenware etc.) Surfaces are left unprotected	
	Mechanical Finishes	5105.01.01

Organic Finishes

Organic finishes cover processes such as primers / top-coats, heavy plastic coatings, protective coatings, powder coatings, porcelain enamelling or lacquer. These processes are used in architecture for windows, doors, facings, panels etc. All colours of the colour palette are possible to apply (**Figure 5105.01.02**). As a pretreatment to these processes, chemical conversion coatings (chromate or chromate/phosphate) are frequently used, but also mechanical finishes or anodising can be used as a pre-treatment to organic coating.

Organic finishes are of huge commercial importance.

<h2 style="color: blue;">Organic Finishes</h2>		
Methods :	<ul style="list-style-type: none"> Primers Top coats Heavy plastic coatings Protective coatings Powder coatings Porcelain enameling 	
Properties :	<ul style="list-style-type: none"> Prevents corrosion Decorative 	
Use :	<ul style="list-style-type: none"> Architectural (windows, doors, facing etc.) Machine parts Cabinets 	
	Organic Finishes	5105.01.02

5105.02 Chemical Methods

- Pickling and etching
- Chemical polishing
- Chemical conversion coating
- Electroless plating
 - Autocatalytic plating
 - Ion-exchange plating

Group II can be subdivided into pickling and etching, polishing, chemical conversion coatings and electroless plating i.e. autocatalytic and ion-exchange plating.

Pickling and Etching

Pickling and etching are primarily used as pretreatment to most other finishing processes. During the processes deposits, oxide, scale and skin are dissolved and removed from the surface (**Figure 5105.02.01**).

Chemical Polishing

Chemical polishing is a controlled dissolution of the basis metal, by which a semi- to mirror-bright surface can be produced. Since the polished surface is vulnerable to scratches and corrosion, it is usually combined with anodising or transparent organic finishing. The process is used for producing reflectors and decorative components. The best result is obtained by using pure aluminium (Al > 99,9%) (**Figure 5105.02.02**).

Pickling and Etching

Method: Surface is removed chemically
Caustic etch
Acid etch

Properties : Removes oxides etc.
Removes small burrs
Matt finish, especially if long time in aggressive etch

Use : Fundamental pre-treatment to most surface treatments
Difficult if alloyed aluminium is used (special etch needed)



Pickling and Etching

5105.02.01

Chemical Polishing

Method: Surface metal is removed chemically

Properties : Bright finish
Specular reflectivity
Improve surface smoothness
Decorative surface
Uniform attack on whole surface (also inside holes)

Use : Substitution of mechanical polishing
Before anodizing or lacquer
Decorative components
Automotive applications (reflectors etc.)




Chemical Polishing

5105.02.02

Chemical Conversion Coating

Chemical conversion coating is a controlled dissolution and formation of insoluble salts, which reduce the risk of corrosion and improve the adhesion of organic coatings. During the process a coloured surface is formed, ranging from pale yellow to dark brown / black. The colour is due to light interference in the semi transparent coating so the colour is also a measure for the coating thickness. In general the darker the conversion layer is the thicker it is, and thereby gives a better protection.

There are three types of chemical conversion solutions: They are based on chromate, on chromate and phosphate and chromate-free solutions (**Figure 5105.02.03**).

Chemical Conversion Coatings (Methods)		
Methods:		
♦ With chromate		
chromate processes		
chromate-phosphate processes		
♦ Non-chromate		
phosphate processes		
molybdate-phosphate process		
oxide processes		
	Chemical Conversion Coatings (Methods)	5105.02.03

For applications such as aerospace and military, chromate conversion coating is extensively used. Also car components and other parts subjected to corrosion are protected this way. Chemical conversion coatings are used either as pretreatment to organic finishes, or it can be used alone for temporary or permanent protection against corrosion (**Figure 5105.02.04**). Chemical conversion coatings based on chromate and chromate / phosphate have a "self-curing" effect, i.e. scratches in the conversion coating are cured by chromate migrating to the scratch.

Chemical Conversion Coatings (Properties)

Properties :

Coloured surface

Reacts with the surface and forms insoluble salts of phosphates chromates or others

Use :

Pre-treatment to organic finishes
Corrosion protection
Temporary or permanent protection



Chemical Conversion Coatings (Properties)

5105.02.04

Electroless Plating

Electroless plating is used for engineering and electronic parts to give increased wear-resistance and in some cases corrosion resistance (special pretreatment) or the technique can be used as the primary step in a conventional electroplating sequence. The process has an excellent throwing power independent of the specimen geometry. For example electroless nickel is used for computer hard-discs in combination with a magnetic material such as cobalt. Many mechanical precision parts are plated with electroless nickel to maintain strict dimensional tolerances. Composites of electroless nickel containing silicon carbide (SiC) or teflon (PTFE) particles can increase wear resistance and decrease the coefficient of friction, respectively (**Figure 5105.02.05**).

Electroless Plating (Properties)

Plated metal :

- ♦ Ni, Cu, Sn, Zn, (Ag, Co)

Properties :

- ♦ Increased hardness and wear resistance
- ♦ Increased corrosion resistance
- ♦ Good throwing power (uniform coating regardless of sample geometry)
- ♦ Composite plating of particles (SiC or PTFE) is possible to increase the wear resistance or to obtain lower surface friction

Use :

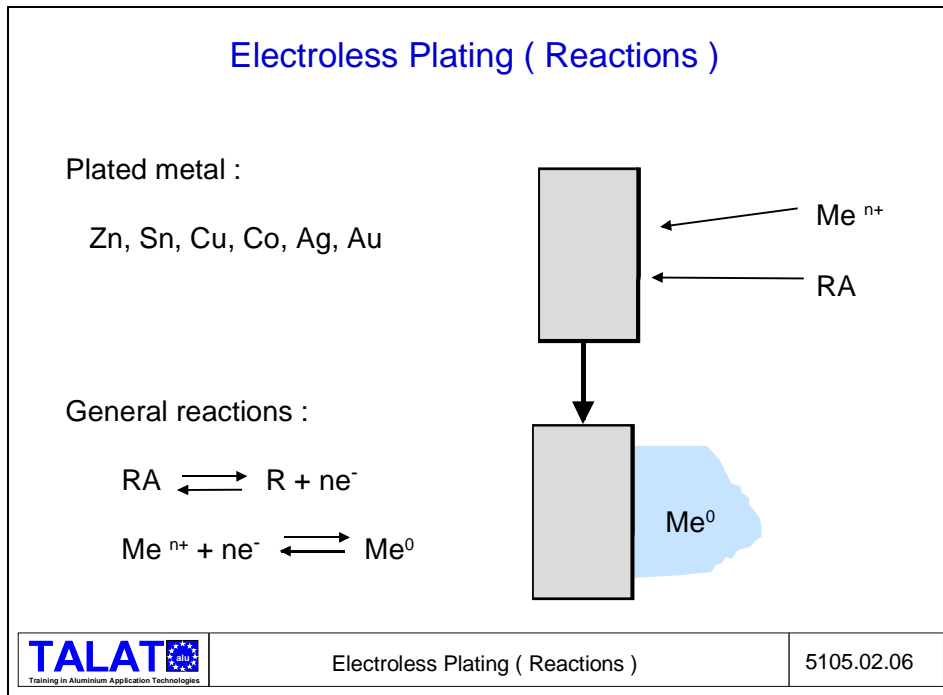
- ♦ Engineering parts where high precision is required
- ♦ Surfaces subjected to wear



Electroless Plating (Properties)

5105.02.05

Electroless plating is deposition of metal, usually nickel or copper from an aqueous solution by use of a reducing agent RA in the solution or by dissolution of the substrate whereby electrons are freed. The plated metal is dissolved in the plating solution as metal ions which plate on the surface (**Figure 5105.02.06**).



Electroless plating can be subdivided into autocatalytic plating and ion-exchange plating.

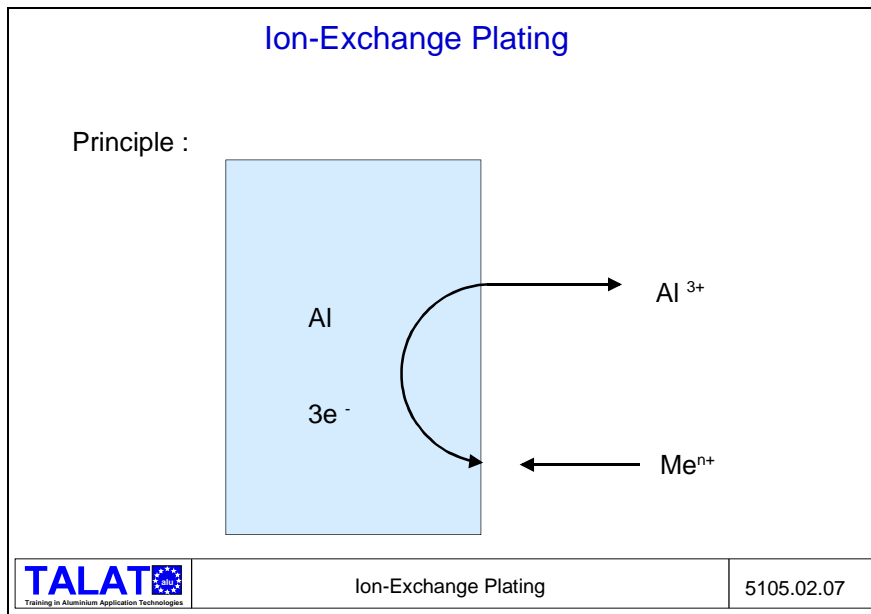
Autocatalytic Plating

The autocatalytic plating process is driven by electrons freed by reduction of the reducing agent RA. These freed electrons join the metal ions in the solution and form solid metal on the surface. Because the electrons are coming from the reducing agent the process can keep on running also after the substrate is covered, i.e. high coating thicknesses are possible. Electroless nickel is an example of autocatalytic plating.

Ion-Exchange Plating

The other type of electroless plating is ion-exchange plating. This process is based on oxidation (dissolution) of the aluminium substrate whereby electrons are freed so that a reduction (deposition) of another metal coming from the aqueous solution is possible. (**Figure 5105.02.07**). The metals deposited by this technique are usually zinc or tin. The layers deposited are thin, because the deposition stops, when the aluminium is all covered and can no more supply electrons by oxidation. The processes are used as a pretreatment to plating (electrolytic and electroless). These ion-exchange processes are known under the names: zincate-, stannate- or modified zincate/stannate-process. The

electrolytic plating processes often require this pretreatment to improve the adhesion and to avoid the aluminium from getting dissolved in the plating bath, because aluminium is amphoteric (dissolves in both alkaline and acid solution). When used as pretreatment to plating correct process parameters are of great importance to the adhesion and corrosion resistance of the plated coating. The standard ASTM B253-83 specifies the correct pretreatment process routines for aluminium (zincating etc).



5105.03 Electrolytic Methods


- Electropolishing
- Electroplating
- Platable metals on aluminium
- Anodizing

Group III can be subdivided into electropolishing, electroplating and anodizing.

Electropolishing

Electropolishing is a controlled electrochemical dissolution of the basis metal by which a semi- to mirror-bright surface can be produced. Electropolishing is a method by which surface metal is removed by applying an external power supply and letting the sample be the anode in the process. Actually, it is a kind of "reverse plating" where aluminium is dissolved into the electrolyte instead of metal being plated from an electrolyte. Its applications are much like those of the chemical polishing, but by electropolishing corners and burrs are attacked more than the flat surfaces. The process can be substituted by chemical polishing. Since the polished surface is vulnerable to scratches

and corrosion, it is usually combined with anodising or transparent organic finishing. The process is used for producing reflectors and decorative components. The best result is obtained by using pure aluminium (Al > 99,9%) (**Figure 5105.03.01**).

Electropolishing		
Principle :		
Surface metal removed electrochemically		
Properties :		
Similar to chemical polishing, except that corners and burrs are attacked more than surfaces Elimination of scratches and burrs Smoothing and brightening High reflectivity		
Use :		
Reflectors Decorative components Often before anodizing or lacquering		
 <small>TALAT Tabliting in Aluminium Application Technologies</small>	Electropolishing	5105.03.01

Electroplating

There are a number of difficulties to be considered when electroplating on aluminium:


1. Aluminium is amphoteric, i.e. it is dissolved in both alkali and acid.
2. The difference in potential, between the aluminium matrix and second phase constituents can affect the deposition reaction.
3. The position of aluminium in the electrochemical series can lead to formation of immersion deposits in the plating solution.
4. The coefficient of thermal expansion of aluminium and its alloys differs from most of the metals commonly deposited on it. This can lead to decohesion between coating and substrate when the plated aluminium part is subjected to high temperature elevations or to temperature shocks.
5. The difference in atomic diameter and crystal lattice structure between the aluminium substrate and the metal deposited on it.

One of the major problems when plating on aluminium is the readiness by which aluminium reacts with the air to form oxide. It is also a problem that aluminium is amphoteric, i.e. aluminium is dissolved in both acidic and alkaline plating baths. These problems can be overcome by removal of the oxide and electrodeposition of the metal in the same process, or, alternatively, by using an intermediate pretreatment layer deposited by ion-exchange plating (zincate or stannate processes as described earlier).

When the oxide is removed in the same bath as the electrodeposition takes place the

process is called a direct plating process. It is possible to electrodeposit copper, nickel, silver, brass and chromium by using the direct plating method. This technique has only limited use in the industry. The most frequent technique used is to plate an intermediate pretreatment layer, deposited by the ion-exchange technique as described earlier.

Though plating on aluminium is a relatively expensive technique, it is increasingly important because of the possibility of combining the low density of aluminium with the functional properties of the deposit. Good results can be obtained with a suitable combination of metal and process (**Figure 5105.03.02**).

Electroplating		
Methods :		
Direct plating		
Anodic preparation		
Zinc immersion		
Tin immersion		
Hard chromium		
Properties added by electroplating (examples) :		
Wear resistance, corrosion resistance, electrical properties, weldability, solderability, etc.		
Use :		
Portable computers, telephones etc.		
Computer harddisk		
General engineering applications like machine elements etc.		
 Training in Aluminium Application Technologies	Electroplating	5105.03.02

Platable Metals on Aluminium

As an example of the plating techniques, gold is deposited on aluminium for an aerospace application. The process is:

- Zincate / stannate
- electrolytic copper deposit, 5µm
- electrolytic nickel deposit, 10µm
- electrolytic gold deposit, 5µm


By using the above process sequence it is possible to eliminate the difficulties when plating aluminium that were listed earlier. The copper deposit has an excellent ability to absorb stress resulting from differences in the coefficient of thermal expansion. The nickel deposit eliminates the risk of galvanic corrosion by forming a dense and pit-free layer. The nickel layer is also necessary to prevent diffusion of copper into the gold. The gold is the desired top coating and by depositing 5µm a pit-free layer is obtained, i.e. no corrosion of the underlying layers is possible. The gold layer is 100% resistant to corrosion and has the desired electrical and thermal characteristics.

The above described gold-plating is tested by the following test sequence:

- 10 temperature-shocks (quick) from -55°C to +125°C.
- 200 temperature cycles (slow) from -55°C to +125°C.
- 240 hours at 95% relative humidity at 40°C.
- High temperature storage at 125°C for 1000 hours.

After this test cycle no visible or electrical changes can be allowed.

Other more common applications of plated aluminium coatings are machine elements and many light weight components. The metals that are platable on aluminium either directly or by use of an intermediate zincate or stannate layer are many. The most common ones are chromium, nickel, silver, gold tin, zinc and copper (**Figure 5105.03.03**).

Chemical Conversion Coatings (Methods)		
Methods:		
♦ With chromate		
chromate processes		
chromate-phosphate processes		
♦ Non-chromate		
phosphate processes		
molybdate-phosphate process		
oxide processes		
	Chemical Conversion Coatings (Methods)	5105.02.03

The obtainable properties by plating aluminium are changed wear resistance and friction. Thermal conductivity, solderability and electrical resistance are main properties in many electronics. The commercially most common reason for surface treatment are decorative or corrosion resistance related (**Figure 5105.03.04**).

Properties of Electrolytic Plated Metals on Aluminium										
	Cr	Ni	Cu	Ag	Sn	Pb	Cd	Zn	Au	Rh
Wear	◆	◆								◆
Friction				◆	◆		◆			
Thermal			◆	◆						
Electrical			◆	◆	◆				◆	◆
Decorative	◆	◆		◆	◆				◆	◆
Corrosion	◆	◆			◆	◆	◆	◆	◆	
Solderability			◆		◆	◆	◆		◆	

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Summary of Properties and Use

5105.03.04

Anodising

Anodising is a commonly used method for surface treatment of aluminium. This is due to a number of properties offered by this technique. Depending on the process conditions the following properties can be obtained:

- Corrosion resistance
- Decorative surfaces
- Surfaces in almost any colour on the palette, except white
- Hard and wear resistant surfaces
- Electrical and thermal insulation
- The surface can be used as a base for organic finishing and for plating

The anodising technique is expected to have an increasing advantage over many other surface treatment processes, because the technique does not require toxic chemicals, heavy metals etc., and the anodised aluminium is easily recycled (**Figure 5105.03.05**).

Anodizing		
Principle:	Controlled oxidation of the aluminium metal surface, forming aluminium oxide (alumina)	
Properties :	Increased wear resistance and hardness Corrosion protection Colourable to many colours High coefficient of heat emission and electrical isolating Improved adhesion for organic coatings Corner defects due to brittleness	
Use :	Architectural (house facing, window frames etc.) Cars and aerospace (structural, decorative, engine parts) Domestic, holloware, pots and pans	
TALAT Training in Aluminium Application Technologies	Anodizing	5105.03.05

5105.04 Literature

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