

TALAT Lecture 5203

Anodizing of Aluminium

27 pages, 24 figures

Advanced Level

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Objectives:

- to describe the process of anodic oxidation of aluminium, which is one of the most unique and commonly used surface treatment techniques for aluminium
- to illustrate the weathering behaviour of anodized surfaces

Prerequisites:

- TALAT lectures 5101, 5102, 5103, 5104

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5203 Anodizing of Aluminium

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5203.01 Importance, Objectives and Methods of Surface Treatments for Aluminium

- The European aluminium consumption for building applications in 1990
- The aluminium surface treatment
- Dimensional effects of anodizing, plating and painting

Anodizing is an electrochemical process for producing stable oxide films on the surface of metals. Anodic coating can be produced on aluminium by using a wide variety of electrolytes with AC, DC or a combination of both. In order to generate an anodic film, the aluminium piece must be the anode and an other suitable metal or alloy the cathode.

Anodic coatings are classified according to the solvent action of the electrolyte used to produce the anodic film. Some of them are of porous nature as for example in phosphoric and sulphuric electrolytes. Others are essentially non-porous and are called "barrier layer" films and are generated in "low solvents power" electrolytes such as ammonium tartrate, ammonium borate, etc.

Sulphuric acid is by far the most important anodizing process due to the characteristics of the process (allows a wide variety of thickness) and the properties of the film (produce a clear coating than can be easily coloured by many different ways and sealed).

The European Aluminium Consumption for Building Applications in 1990

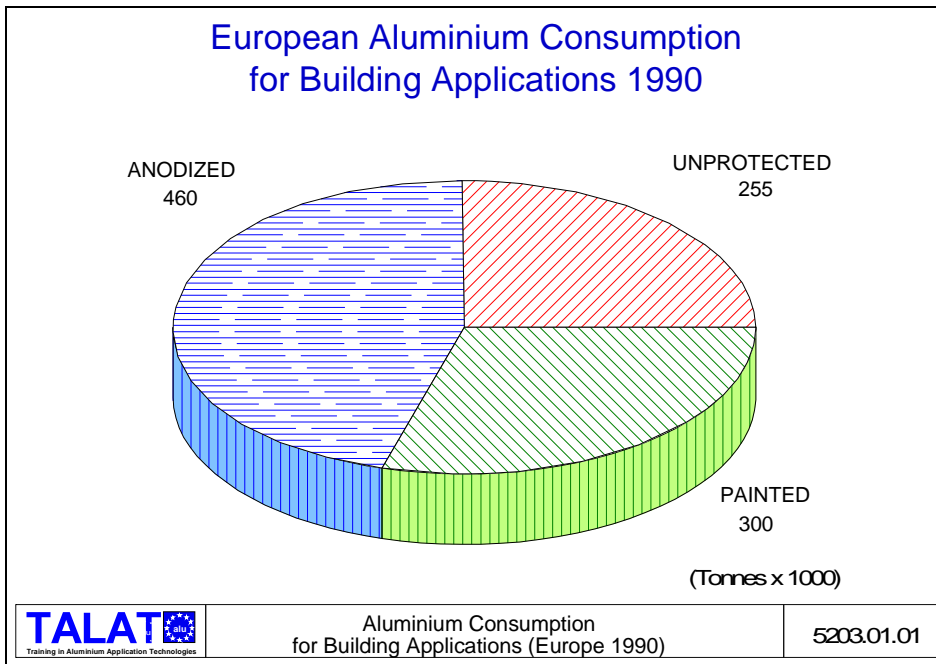
The European consumption of aluminium for building in 1990 has been around one million tonnes. Around 45% of the total has been anodized and around 30% has been painted, using a 25% of material without any surface protection (**Figure 5203.01.01**).

The EEC market for architectural anodizing total estimated is 200 millions m² by year.

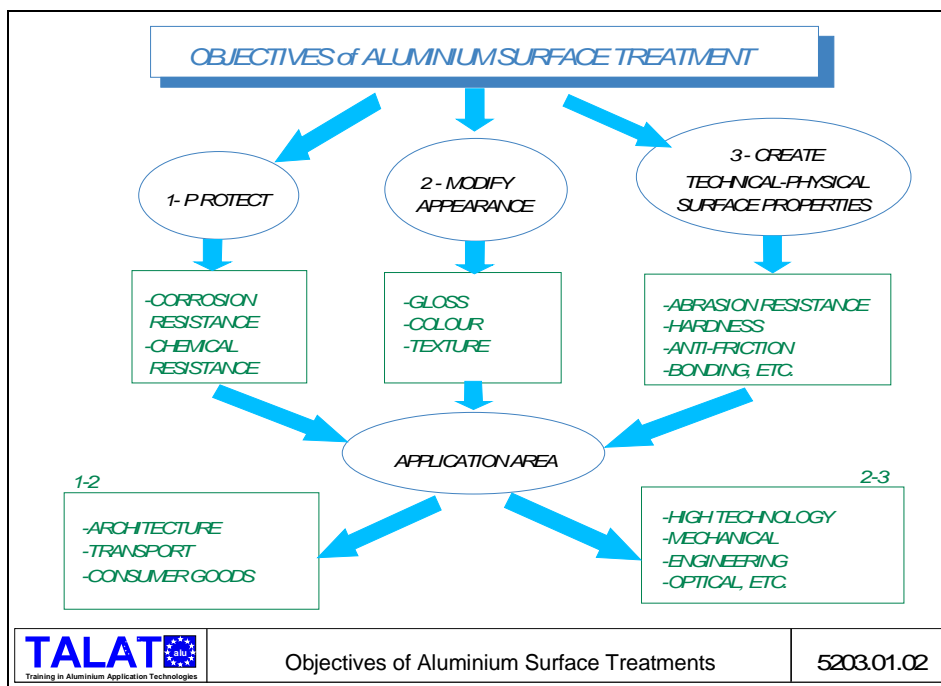
The Aluminium Surface Treatment

There are few people today who are not familiar with some modern applications of aluminium and its alloys and the enormous number of applications is mainly due to the excellent corrosion resistance of this metal.

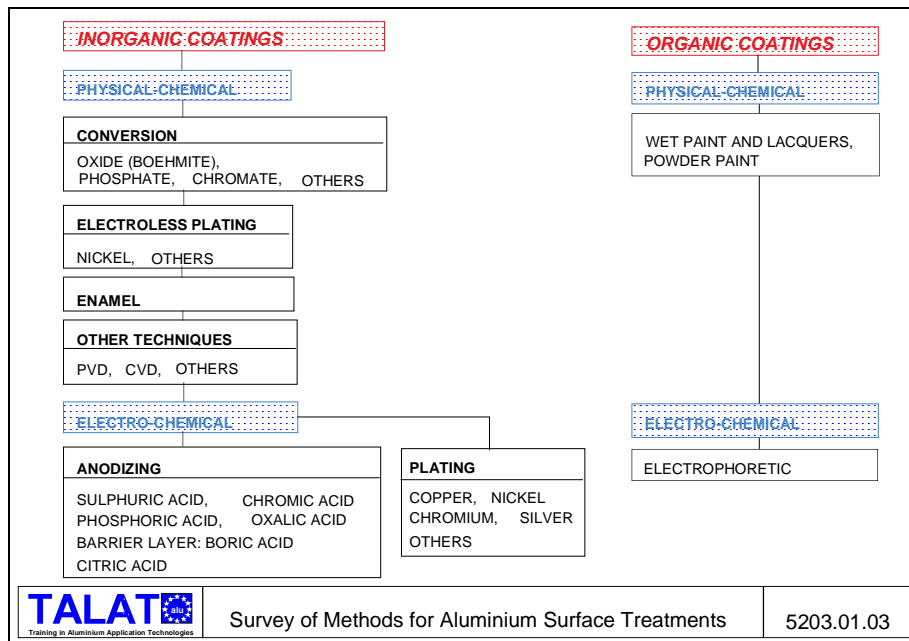
The corrosion resistance of aluminium is achieved due to the affinity of this metal for oxygen that generates on its surface a very thin oxide film which covers the surface of a freshly-cut piece of metal is exposed to the atmosphere. However, in some cases it is necessary to have a higher degree of protection (corrosion or chemical resistance) or to modify the surface appearance (changing, colour, texture, etc.) or creating technical-physical surface properties (increasing the abrasion resistance and hardness, achieving coating with anti-friction properties, getting coatings with increased bonding strength, etc.).



The application areas of aluminium surface treatment are very wide: e.g. it is used in architecture, transport, and consumer goods. Due to the characteristics of the surface after treatment aluminium can also be used as high efficiency reflectors or as solar selective surface with a high absorptivity and low emissivity values (see **Figure 5203.01.02**, also **Figure 5203.01.03**).



The first application of anodizing was for dielectric film produced by the boric acid process for use in electrolytic capacitors.



Dimensional Effects of Anodizing, Plating and Painting

Anodizing is an electrochemical process in which the part is made the anode. A potential is applied to this piece high enough to allow the development of oxygen on the aluminium surface.

In anodizing the coating is produced by "reaction" of the metal with the "ions" of the electrolyte producing generally a coating with greater volume than the aluminium substrate. There is normally an overall increase in dimension of the pieces after anodizing.

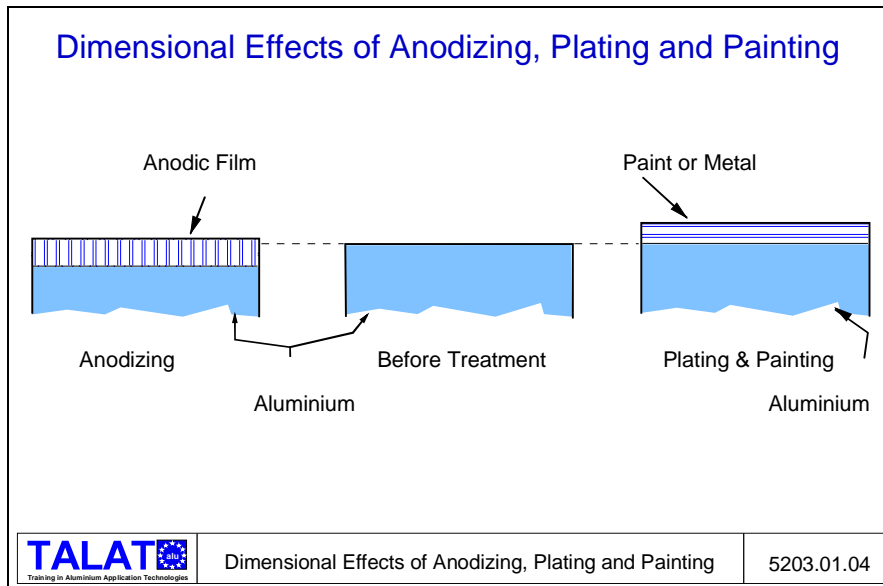
For conventional sulphuric and chromic anodizing this overall increase in dimension is approximately one-third of the coating thickness; for hard anodizing it is approximately one-half the coating thickness.

The basic "dimensional" differences among anodizing, plating and painting is that the former is produced from the substrate while plating or painting are deposited on the substrate (additive process) (see **Figure 5203.01.04**).

There are many practical ways to anodize depending on the type of material to treat, for example small parts such a rivets may be anodized in bulk by means of barrel or basket anodizing. Extrusions normally up to 9-10 meters long are used in the standard batch anodizing. In this technique the aluminium pieces are positioned on jigs and racks and they provide the supports and the electrical contact for the components being anodized.

For aluminium coil, the continuous anodizing process has potential advantages as a cheap process, very uniform in characteristics. The typical applications of this process are: lithographic plates, name plates, decoratives trims, siding and roofing products lighting reflectors etc.

In summary, anodizing can be carried out in many different ways depending on the type of material being anodized and the final application.



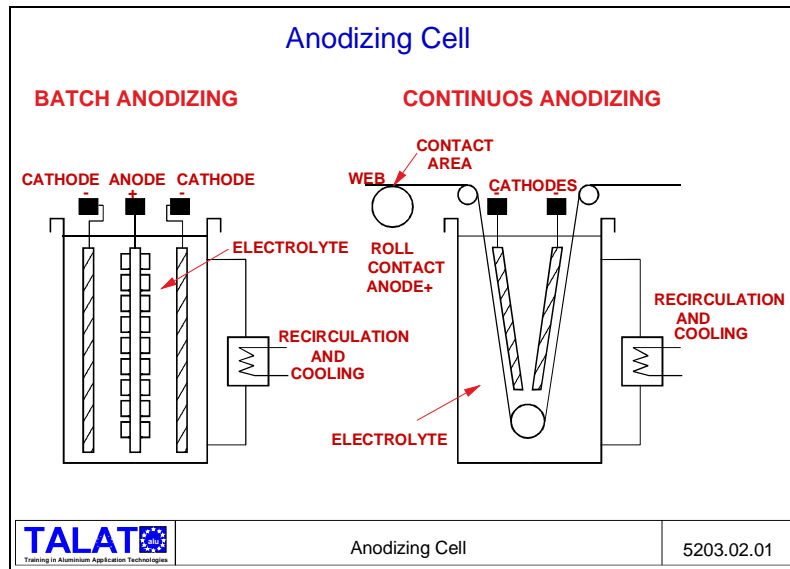
5203.02 The Anodizing Process

- The anodizing cell
- Changes in current and voltage during anodizing
- Anodic coating structure/cell dimensions
- Anodizing solutions
- Change in film thickness during anodizing
- Influence of type of alloy on film weight
- Influence of electrolyte temperature
- Influence of current density
- Influence of acid concentration
- Colouring anodized aluminium
 - Dying
 - Self colouring, integral colouring
 - Electrolytic colouring
- Sealing of anodic films
- Properties of anodic film
- Operational sequences for anodizing

The Anodizing Cell

(Figure 5203.02.01)

As previously mentioned when a current is passed through an electrolyte in which an aluminium piece is used as anode, the negatively charged ions migrates to the anode where one or more electrons are discharged. In an aqueous solution the ion consists in part of oxygen which reacts chemically with the aluminium.

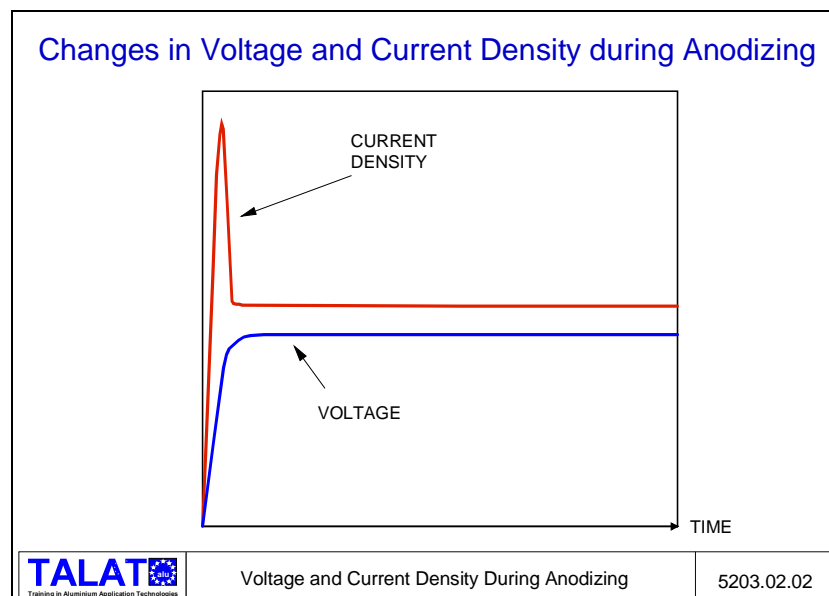


A DC, AC or a combination of both can be used as power supply for anodizing. For standard sulphuric acid anodizing a 24 V rectifier is suitable, however, for chromic acid anodizing or anodizing in organic acid voltages up to 60-70 V are needed. For hard anodizing and for production of barrier-layer films higher voltages are needed.

Recently anodizing using pulsed power supplies is being recommended mainly for applications where high anodizing currents are required, or where difficult alloys are being processed (high copper contents).

Changes in Current and Voltage during Anodizing

As any electrolytic process anodizing is controlled by current density (**Figure 5203.02.02**).



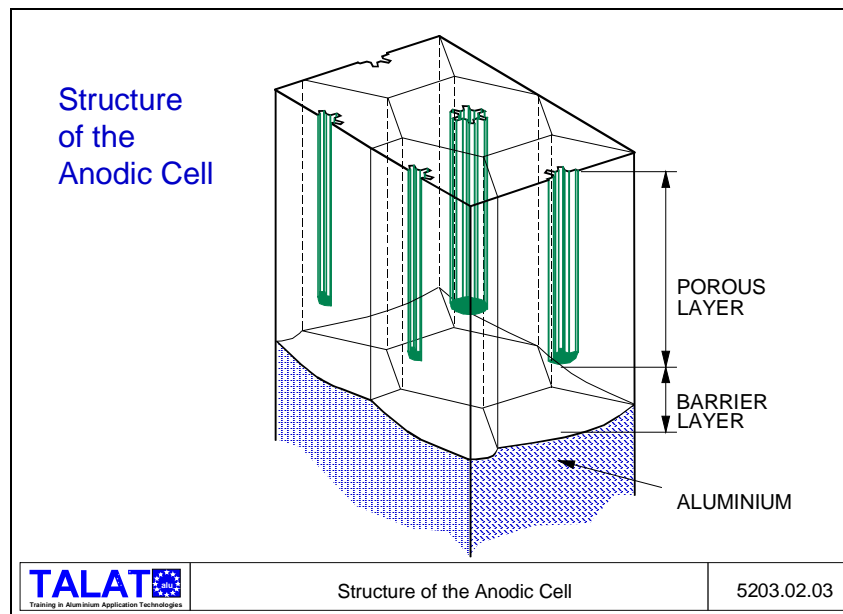
During the initial period of anodizing the aluminium piece is protected by a thin aluminium oxide film that offers little resistance to the current. If anodizing is carried-out at constant voltage a quick rise of current is produced, and later on, a slow drop to a steady

state value. This curve is interpreted as the result of two overlapping processes; one of these is the exponential decrease of barrier film formation and the second represents the pore formation current. At a certain time the current of these processes reach a steady-state value and the film thickness grows proportionally to the charge per surface area in the aluminium piece being anodized.

In the case of barrier layer anodizing when the voltage is maintained constant the current initially increases rapidly and then decreases to very low values ($\mu\text{A}/\text{cm}^2$). The leakage current flowing under constant voltage conditions is electronic but if the voltage is increased then, ionic current begins to flow again with further film formation until a new equilibrium is established. The maximum potential used to produce a barrier layer film is between 500-700 volts due to breakdown and arcing in the barrier layer.

Anodic Coating Structure/Cell Dimensions

As early as in 1932 it was shown that the anodic film consists of two layers, the porous thick layer growing on an inert layer which is thin, dense and dielectrically and normally called barrier layer (**Figure 5203.02.03**).



The thickness of the barrier layer depends on the composition of the electrolyte and the operating conditions.

During anodizing the barrier layer is formed first and its thickness varies directly with the forming voltage.

The barrier layer is non-porous, and conducts current only due to its thickness and faults, the outer layer, is microsporous and built upon a columnar structure.

If no dissolution occurs by the electrolyte; the barrier layer grows at a rate of 14 \AA per volt. This value theoretical is obtained only in solutions in which little or no solvent action occurs. For electrolytes with solvent action values between 10-11.5 A/volts have been reported.

Once the barrier layer has been formed, this begin to transform in a crystalline structure in the outer part of the barrier layer if the electrolyte has enough solvng power.

The mechanism of pore formation is still a matter of discussion but according to some authors the formation of the porous layer is due to a local dissolution of the barrier layer, followed by the passage of the current, which rises. The temperature of the solution at this point further increases and so the rate of dissolution. This fact is responsible for the perpetuation of pores. As the current flows through the simple pore with a roughly hemispherical end and a central cylindrical pore is built up in accordance with the electrical field. As the formation of the film progresses the shape of the cells is altered to give a hexagonal prism shape. The structure of the anodic film is independed of the type of electrolyte and the same structure is obtained in sulphuric, chromic, oxalic or phosphoric electrolytes.

For sulphuric anodizing the rate of growth of porous layer is constant at a constant current density and takes approximately a value of 0.4 $\mu\text{m}/\text{min}$ for a current density of 1.3 A/dm^2 . As the barrier layer thickness remains constant, it should correspond to a similar rate of dissolution at the base of the pores.

The dimensions of the oxide cells are directly influenced by the anodizing conditions (**Figure 5203.02.04**). Depending on the solvng power of the electrolyte the dimension of pores and cells are different being bigger in phosphoric and smaller in sulphuric acid. With increasing voltage, cell size increases and the number of pores decreases accordingly. The relation-ship between cell size and voltage is approximately linear, and the higher the voltage the bigger is the cell size.

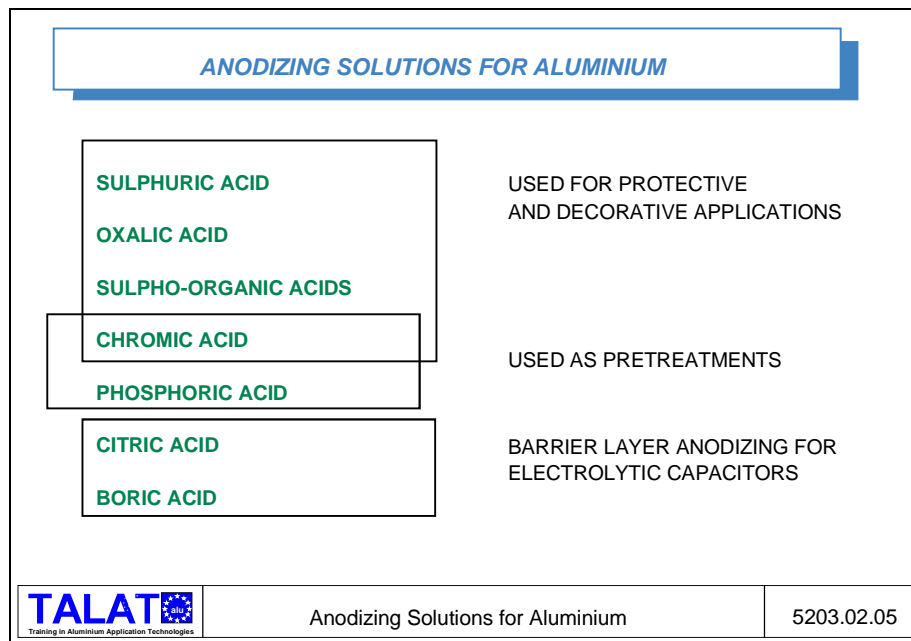
During anodizing there is a chemical attack from the electrolyte to the anodic film producing pores wider in the outer than in the inner part of the film.

PORE DIAMETER	14,5 - 18 nm
PORE POPULATION	40-80 . 10 ⁹ pores/cm ²
CELL DIAMETER	40 - 53 nm
POROSITY	15 %
BARRIER LAYER THICKNESS	14 - 18 nm
POROUS LAYER THICKNESS	5-25 μm (protective purposes)

TALAT <small>Training in Aluminium Application Technologies</small>	Typical Dimensions of the Anodic Cell (Sulphuric Acid Anodizing)	5203.02.04
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Anodizing Solutions

(Figure 5203.02.05)



Among the anodizing electrolytes two kinds can be clearly distinguished:

- Barrier type electrolytes
- Porous type electrolytes

Barrier Type Electrolytes

The main application of these electrolytes is by far the fabrication of electrolytic capacitors, however, it can also be used for protective purposes. The most commonly-used barrier type electrolytes used for protective applications are ammonium tartrate and boric acid solutions. The concentration of this solution is around 3% Ammonium tartrate at a pH $\cong 5.5$.

The usual electrolyte for the fabrication of electrolytic capacitor in a continuous process was the hot electrolyte (95-100 °C) of about 10% boric acid. Actually organic electrolytes are used as solvents based on dimethyl formamide.

Porous type electrolytes

(Figure 5203.02.06)

The sulphuric acid process is by far the most extensively used all over the world and actually many variations of the process are used.

Early solutions contained approximately 25% (w) sulphuric acid, recently the acid concentration has been reduced to 10-20% (w) according to the film properties required, current densities are normally of the order of 1-2 A/dm² with a voltage 12-20 volts and temperatures 18-25 °C for anodizing times of up to about 60 minutes.

MAIN CHARACTERISTICS OF ANODIZING PROCESSES USED FOR PROTECTIVE AND DECORATIVE APPLICATIONS

TYPE OF ELECTROLYTE	CONCENTRATION (%)	CURRENT DENSITY A/dm ²	VOLTAGE (V.DC)	TEMP. (°C)	TIME (min)	COLOUR OF ANODIC FILM
SULPHURIC ACID	15-20	1-2	12-20	18-25	5-60	COLOURLESS
OXALIC ACID (Elosal GX)	3-5	1-2	40-60	18-20	40-60	YELLOW
CHROMIC ACID (Bengough-Stuart)	2,5-3 (CrO ₃)	0,1-0,5	0-50	40	10-60	OPAQUE -GREY

On most aluminium alloys this electrolyte produces colourless, transparent anodic coatings than can be easily coloured.

The chromic acid process consists of a solution containing 30-50 g CrO₃/l. Current is applied so that the voltage is increased in steps up to a voltage of 40-50 volts. The current density is in the range of 0.1-0.5 A/dm² and the temperature around 40 °C.

The oxalic acid process was first developed in Japan and later on introduced in Europe. This process produces hard coatings coloured in gold or light bronze, depending of the alloy used. The oxalic and process is more expensive than the sulphuric one in chemicals and power, another extra disadvantage of this process is that oxalic and poisonous.

The concentration of the electrolyte is approximately 3-5% (w), the current density 1-2 A/dm², the voltage 40-60 volts and the temperature 18-20 °C.

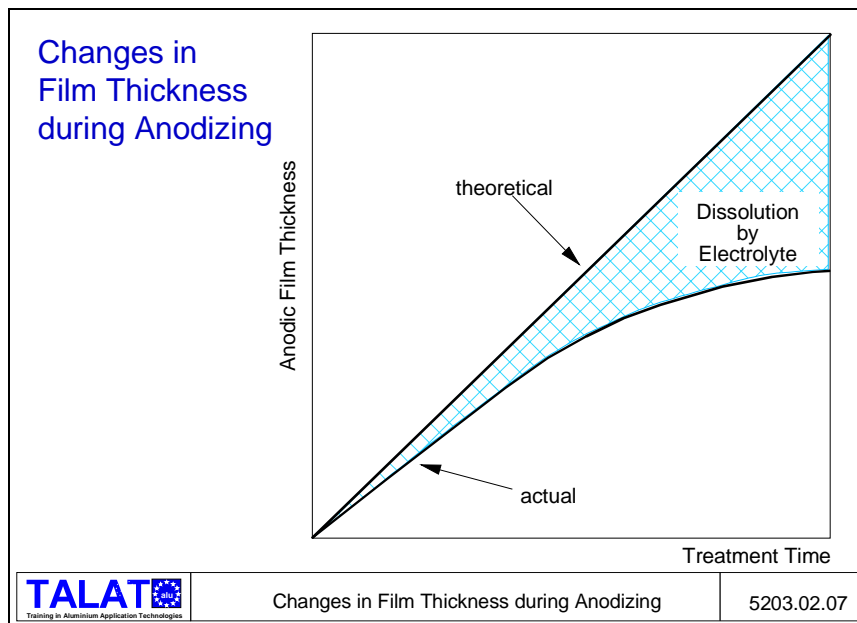
The phosphoric acid anodizing process is rarely used to produce decorative or protective finishes, it is being increasingly used as a pretreatment for application of organic or plated pretreatment. Lately the phosphoric anodizing process have been extensively used as pretreatment for adhesive bonding in the aerospace industry. The process is known as the Boeing Process an uses a concentration 10-12% (w) at 10-15 volts and a temperature of 21-24 °C for 20-25 min.

Other electrolytes such as sulphonic and malonic acids have been used for protective and decorative anodizing, these electrolytes produce generally harder films than standard sulphuric anodizing y colours varying from light bronze to black.

Change in Film Thickness during Anodizing

The thickness of the anodic film increases with treatment time. However, the rate of thickness growing depends of several factors such as: type of electrolyte, current density, treatment time, etc.

Initially there is a rapid and constant increase in the actual thickness, followed, after anodizing for an appreciable period of time, by a small but growing decrease in the rate of thickness growth, heading finally to a stage where the thickness remains approximately constant in spite of continued application of current. During anodizing there are a continuous, thickness growth of the anodic film and a dissolution by chemical attack. The actual thickness is the theoretical thickness minus the thickness of oxide dissolved (**Figure 5302.02.07**).



The theoretical value is proportional to the treatment time when anodizing at constant current density acid it depends upon Faraday's Law, which states that the oxide formed is proportional to the electric charge passed (ampere-seconds) through the anode.

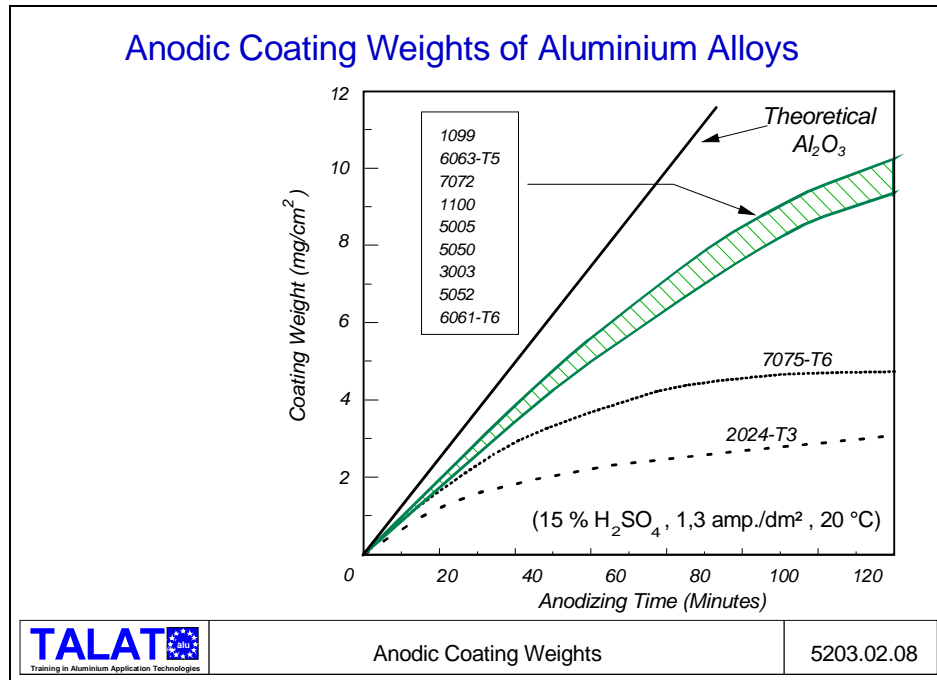
Influence of Type of Alloy on Film Weight (Figure 5203.02.08)

Generally aluminium anodizes better than its alloys and the appearance and performance in service can be related to the alloy and metallurgical history. Size, shape and distribution of intermetallic compound also affect the behaviour and anodizing response.

The composition of the alloy is quite important in some applications such as bright anodizing where the level of insoluble particles must be a low as possible.

The anodic coating on 99.99% aluminium will be clear and transparent, with a level of iron of 0.08% it is slightly less clear and becomes increasingly cloudy as the film thickness is increased. With the level of insolubles of the AA-1050 alloy the coating becomes quite

cloudy in comparison with the more pure metal.



Generally among the aluminium alloys, the series 5xxx y 6xxx produce the best decorative and protective coatings, some 7xxx series alloys also produce clear coatings with good performance. Usually the 2xxx series produce coating colours of inferior quality.

The behaviour of intermetallic compounds during anodizing is different depending on the type intermetallic and anodizing solution.

Some of the intermetallics are oxidized or dissolved much more rapidly than aluminium (β Al-Mg) producing porous coatings. Others as silicon particles are practically insoluble during anodizing, producing inclusions in the anodic film. Intermediate between the two extremes are constituents (FeAl₃, α Al-Fe-Si etc) of which part is dissolved and part remains in the coating, and which affects the colour transparency and continuity of the film to varying degrees.

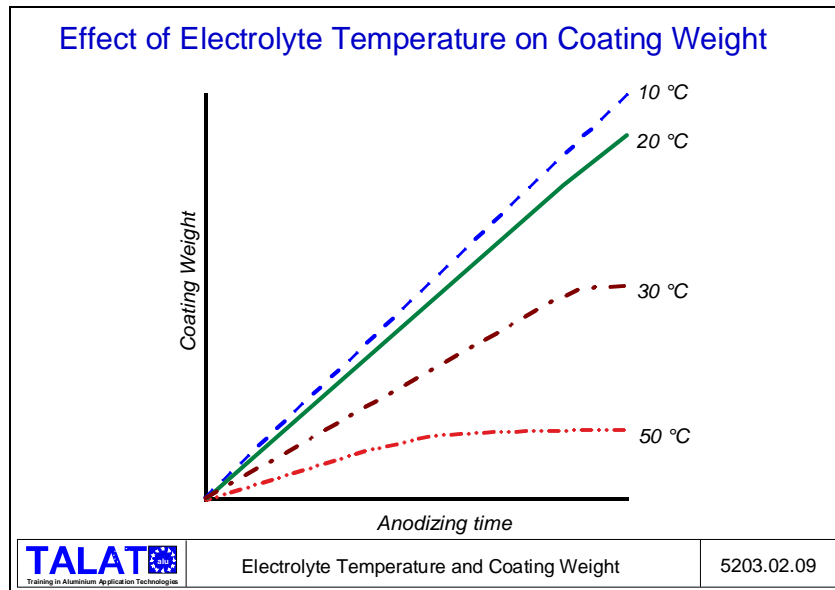
Influence of Electrolyte Temperature

The effect of an increase of electrolyte temperature is a proportional increase in the rate of dissolution of the anodic film resulting in thinner, more porous and softer films (**Figure 5203.02.09**).

Low temperatures are used to produce hard coatings normally in combination with high current densities and vigorous agitation.

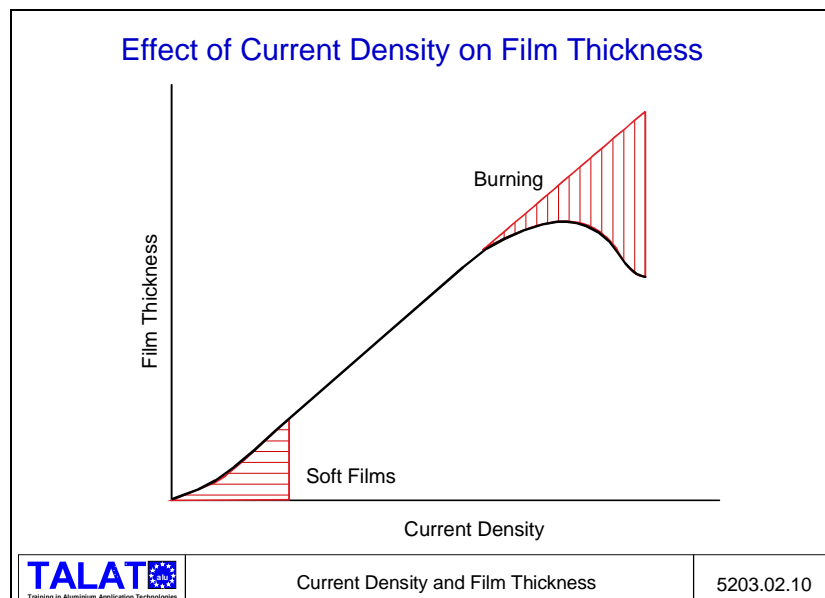
In decorative and protective anodizing temperatures in the range of 15-25 °C are normally used.

If temperature is increased further the maximum thickness is reduced to lower values due to the higher dissolving power of the electrolyte.



Influence of Current Density

The range of current density used in standard anodizing varies from 1-2 A/dm², for certain application up to 3 A/dm². Current densities below this range produce soft, porous and thin films. As the current density is increased, the film forms more quickly with relatively less dissolution by the electrolyte, consequently the film is harder and less porous. At very high current densities, there is a tendency for "burning"; this is the development of excessively high current flow at local areas with overheating at such areas (**Figure 5203.02.10**).

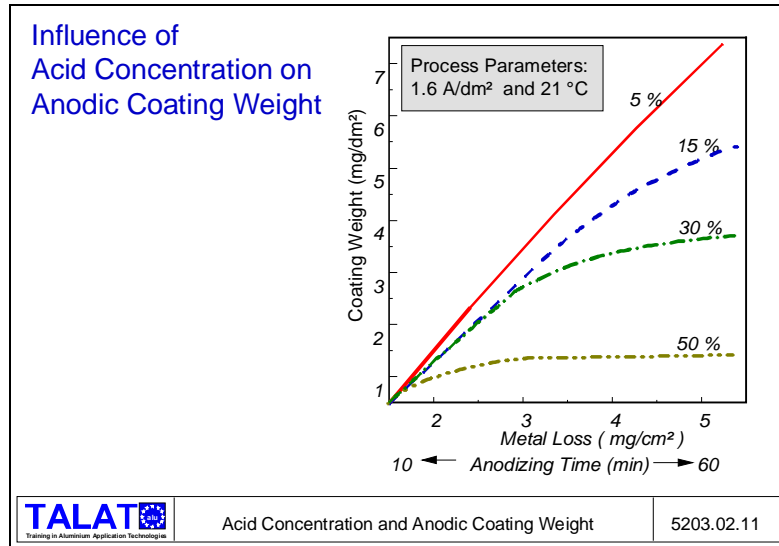


When reflectivity and image clarity are of importance, normally special conditions are used and low current densities in the range of 1 A/dm² tend to improve image clarity.

Influence of Acid Concentration

The effect of increased concentration on the coating characteristics is similar to temperature increase, although the effect of temperature is more important than that of concentration.

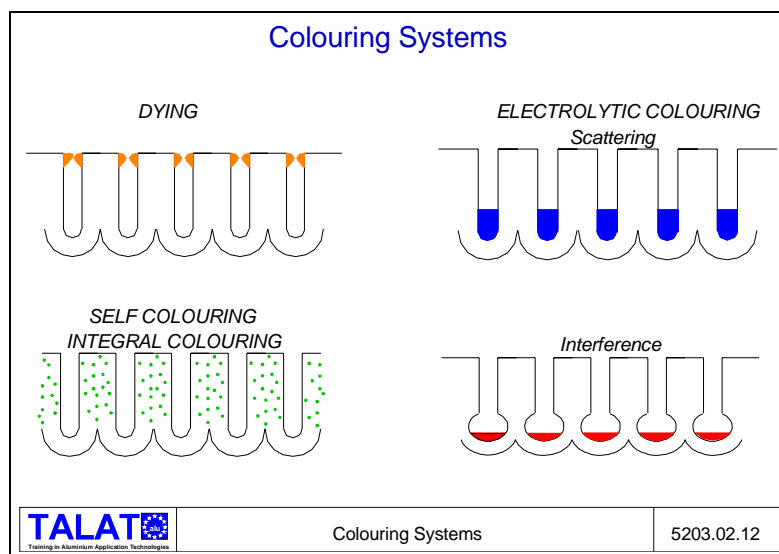
The increase in concentration limitates the maximum film thickness due to the higher dissolving power of the concentrate solutions (**Figure 5203.02.11**).



Colouring Anodized Aluminium

The development of colour anodized aluminium is almost simultaneous to the development of anodizing, and several methods have been developed using different techniques to obtain different colours and shades. The most important are:

- Dying
- Self colouring, integral colouring
- Electrolytic colouring (**Figure 5203.02.12**)



Dying

Hundreds of commercial dyestuffs are available for colouring anodic films produced by most anodizing conditions yielding a wide range of attractive colours. The colour intensity depends on the amount of dye taken up by the film.

The absorption mechanism of chelate complex is produced in the upper part of the anodic film (in the 3-4 external μm).

The most widely process to produce gold colour by immersion with inorganic dyes are ammonium oxalate solutions. The solution has normally a concentration of 5-50 g/l and a temperature 30-60 °C at a pH around 4.5. In this case the colour obtained by precipitation of iron salts, is basically iron oxide.

Self Colouring, Integral Colouring

In both processes the colour is produced during anodizing in the first case due to the constituents of the alloy in the second case due to the inclusions during anodizing produced by using special electrolytes.

The most common alloy for obtaining grey shades when anodize in sulphuric and is an Al-5% Si alloy. The colour and uniformity of the finishes are depending on composition and metallurgical history. The mechanism of colour formation in that case is the occlusion of silicon crystals in the anodic film.

Probably the first integral colour anodizing is the oxalic process which under controlled conditions can give coatings coloured from pale yellow to deep bronze. The colour on these type of finishes is dependent on film thickness and the thicker the film the darker the colour.

Many electrolytes have been used to produce integral colours or "hardcolour", the main constituent are: sulphosalicylic, sulphosphthalic and sulphuric acid; maleic and, etc.

The range of colour using integral colouring are: different tones of gold and bronze to deep black.

Electrolytic Colouring

The electrolytic colouring or "Two Step anodizing" has been developed industrially in the sixties.

The process consists of immersing the anodize work in an and solution containing metallic salts and to apply and AC or DC voltage. Under these conditions metallic deposit are formed at the bottom of the pores in the interphase between barrier a crystalline layer. The colour depends on the nature of the electrolyte; most metals give a bronze to black colour (Sn, Ni, Co, etc) some as copper gives reds etc.

The colour is independent to a certain extent of the thickness of the anodic coating and is only dependent of the amount of metal deposited (200 mg/m^2 Sn produces a light bronze and 2000 mg/m^2 Sn producer a deep black).

The properties of electrolytic finishes are similar to the normal sulphuric and films. The light fastness of the finishes produced with most electrolytes are very good.

In the late seventies electrolytic colouring took a step forward with the development of interference colouring.

This procedure allows to produce a wide range of colours using an electrolyte due to a mechanism of optical interference. Normally a pore enlargement treatment is necessary between anodizing and electrolytic colouring in order to increase the intensity of the colour.

The amount of metal deposited in conventional bronze electrolytic finish is higher than and standard interference colours however, in this case is "packed" uniformly at the bottom of the pores.

The main advantage of interference colour it is de wide variety of colours that it is possible to produce.

Sealing of Anodic Films

Sealing is the last step in the anodizing process and is essential for retention during service of the initial appearance of the anodized material. Water sealing seems to produce little change in the bulk oxide film (increases water content up 4 to 10 percent) but causes major pore blockage, closure of the intercrystalline regions and formation of various forms of hydrated alumina, the most important of which is probably boehemite.

The mechanism of water sealing (**Figure 5203.02.13**) consists of three overlapping stages:

- Precipitation of gel out of the pore walls and near the outer film surface
- Condensation of gel to form pseudo böhemite, continuing reaction rate controlled by diffusion of water into film and anions into the liquid
- Recrystallisation to form boehemite starting at the surface, intermediate layer formed by diffusion

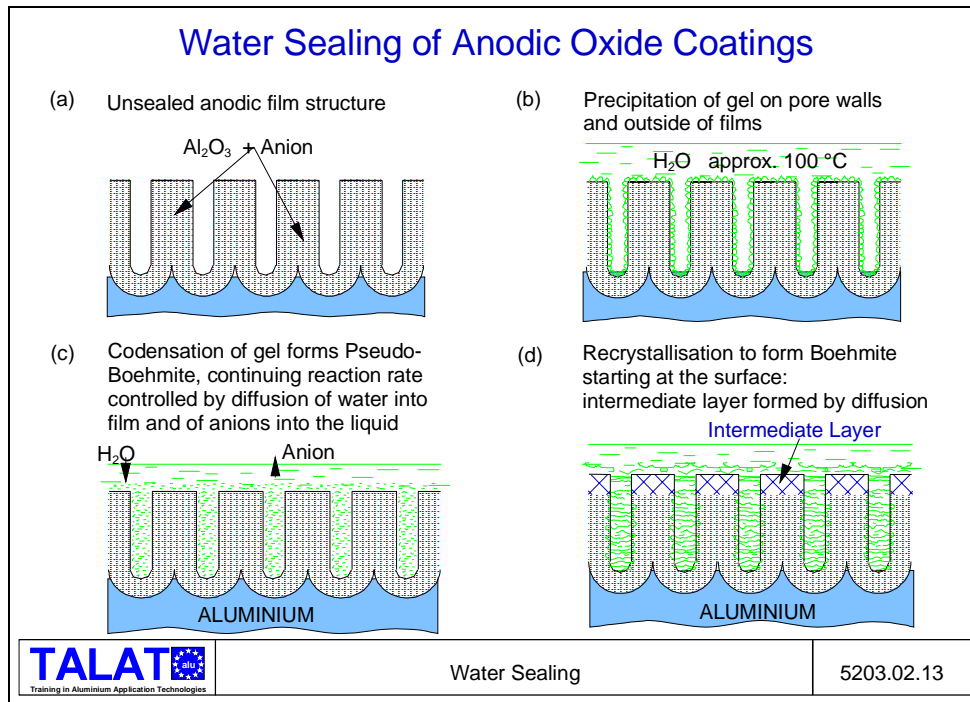
After a correct sealing the crystalline material is largely böhemite and is the cause of the visible "smut" seen on most sealed anodic film surfaces.

The change in properties produced by sealing are basically:

- Increase of the corrosion resistance
- Reduction of the retention of dyes
- Reduction of "bloom" formation under outdoor exposure
- Increase in impedance of the anodic film
- Reduction in hardness and abrasion resistance
- Reduction of thermal crazing temperature
- Reduction of paint or adhesive adhesion

Sealing is commonly done by immersion in good quality water heated to 95-100 °C at a pH of 6.0 ± 0.5 for a period of 2-3 min/ μm . Some impurities such as: phosphates, silicates or fluorides can inhibit the sealing process.

Some metal salts are frequently used as sealing additives. The salts are absorbed into the coating where they are hydrolysed and precipitated as hydroxides. Nickel and cobalt are the more common and are very suitable to reduce losses of colour after dyeing.



The Dichromat sealing has been used in some application where enhanced corrosion resistance is necessary.

A practical cold seal system has recently been developed (used at around 30 °C). The seal solution normally contain fluoride or silica compounds in the presence of nickel salts often in a water-alcohol mixture.

Properties of Anodic Film

(Figure 5203.02.14)

These properties are:

1. Generate clear crystalline coatings

Anodic films on aluminium are used for lighting reflector due to the good reflective properties of aluminium in combination with the clear and protective anodic coating.

The clear crystalline coating formed during anodizing of pure aluminium maintain the metallic aspect and most optical properties of bright aluminium.

2. Increase of surface hardness and abrasion resistance

The anodic oxide film is very hard and will protect aluminium from surface scratches but is generally too thin to protect the metal from deep scratches or strong pressure.

The hardness and abrasion resistance is inversely proportional to the porosity; thus the surface layer is softer than the inner layer.

Sealing decreases abrasion resistance in hard and architectural anodizing.

3. Increase corrosion resistance

The corrosion resistance of anodic films is influenced by several factors as: type of alloy, anodizing condition, anodic film, thickness, quality of sealing and maintenance procedures.

The major factor controlling pitting performance is according to several exposure programs film thickness.

Generally marine atmospheres are less aggressive than industrial ones and the rate of film thickness removal is half in marine atmospheres than in industrial ones.

4. Able to keep good brightness and image clarity

Pure aluminium is able to maintain a high value of total and specular reflectance. This values are around 90 and 85% respectively and are only slightly affected by film thickness. When the content of alloy elements or impurities increases (1050 alloy) it is possible to obtain a good image clarity after brightening but it is lost when a 2 µm film of anodic film is applied.

5. Easy to colour

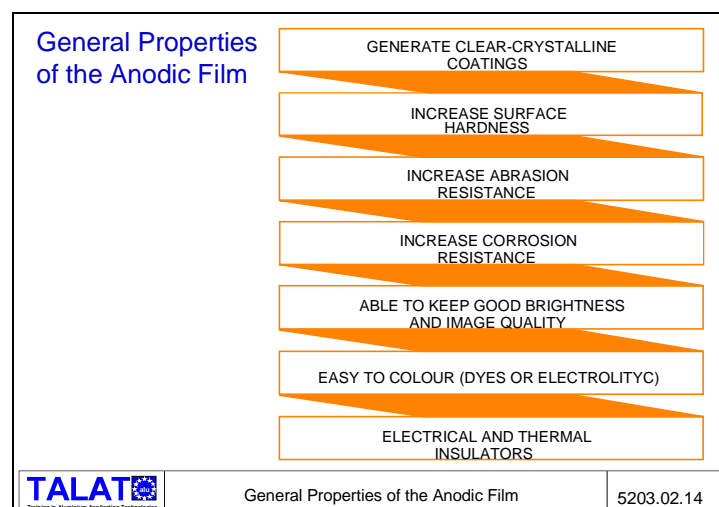
Anodized aluminium is able to adsorb dyes easily or to be coloured electrolytically in many different colours or tones. The behaviour of the different colours depends on the type of colouring method and material deposited to obtain the colour.

Generally electrolytic colours are of resistant to fading and there are experiences for more than twenty years on buildings and outdoor exposure programmes which confirm the good behaviour of these finishes.

6. Electrical and thermal insulators.

One of the main application of anodizing is the fabrication of electrolytic capacitors, the dielectric constant is around 8.5 for barrier layer films.

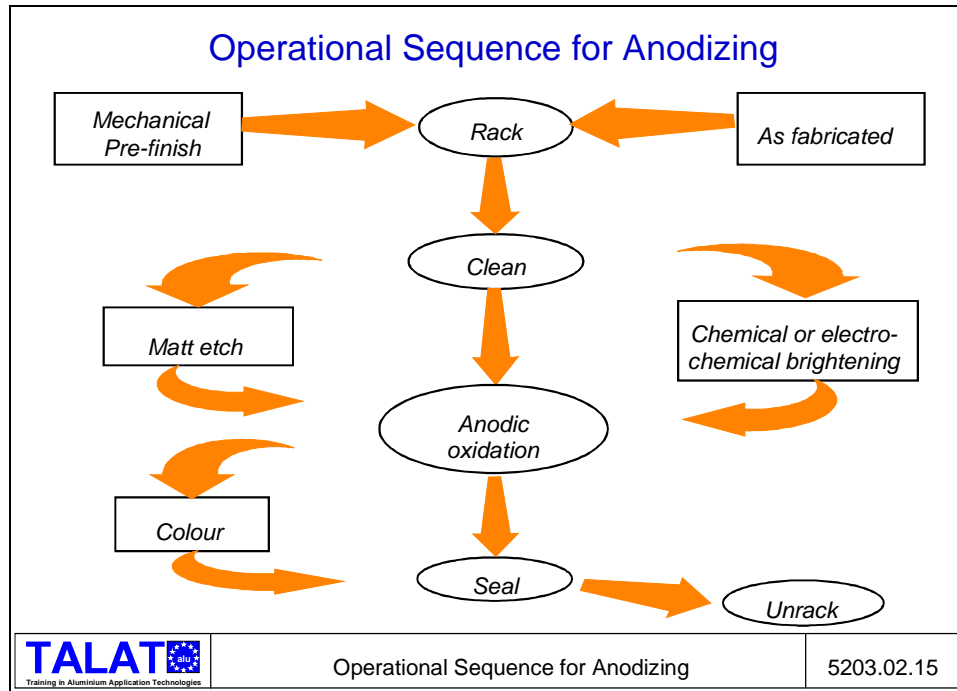
Anodic coatings are good insulators, though they tend to craze at high temperatures, the breakdown voltage is not seriously affected by this as cracks are filled with air. The specific resistance is around $4 \cdot 10^{15} \Omega \cdot \text{cm}$ and the breakdown voltage depends on the anodizing procedures and will vary between 8-50 V/µm.



Operational Sequences for Anodizing

In **Figure 5203.02.15** we try to explain briefly the different steps of an industrial anodizing process.

The material to be anodized can be as fabricated (extrusion, mill finish for sheets, or castings) or has been mechanically prefinished (buffing, polishing, grinding, etc).



The first step in the anodizing operation is racking. Racking is the operation that provides support and electrical contact for the components being anodized. After racking the material is cleaned in a solution in order to remove: oils, solid particles and even the oxides on surface. Once the material is clean there are three possibilities of treatment: direct anodizing, matt etching or chemical or electrochemical brightening.

Direct anodizing is carried out when a mechanical pre-finish is sufficient, or for very low quality finishes. Matt etching is normally carried-out in a alkaline type of bath base on caustic soda, this operation removes the material on surface and produces a matt, light diffusion finish.

If a bright or mirror like finish must be obtained the aluminium pieces should be treated normally in a solution with current (electrobrightening) or without current (chemical brightening). These procedure remove aluminium generating a very even surface normally with high gloss and image clarity. After chemical or electrochemical pretreatment the aluminium is anodized under prefixed conditions.

After anodizing the load could be coloured, or directly sealed if the finish is natural anodizing. The load could be coloured according to the different procedures (dying, integral, electrolytic colouring etc).

After anodizing or colouring the load is normally sealed in order to "close" the pores. This operation is essential for retention during service of the initial appearance of the anodized material.

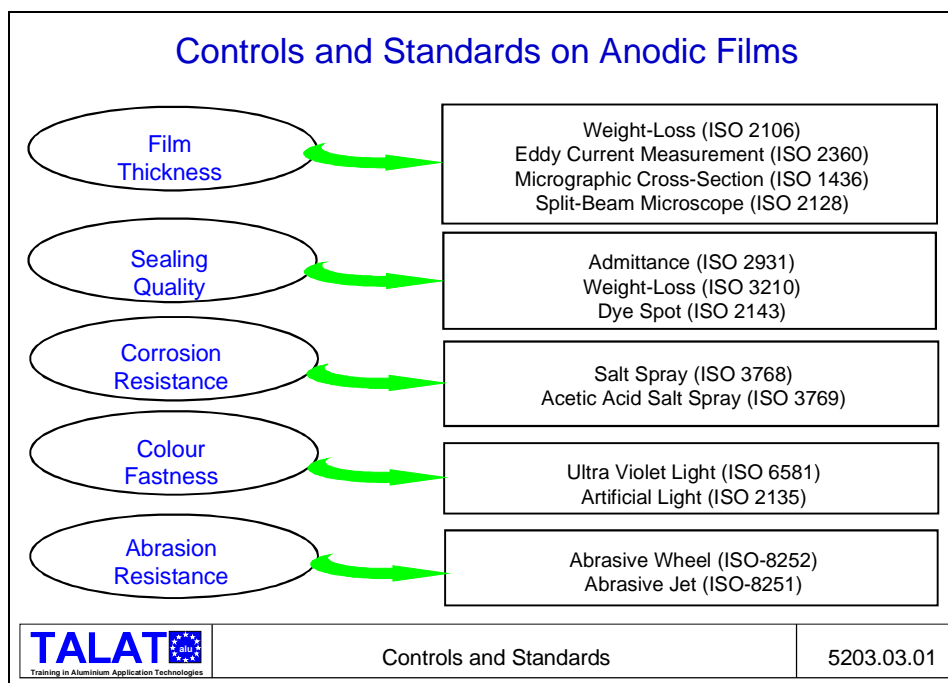
After sealing the pieces are taken out of the racks to end the anodizing operation.

5203.03 Quality Control and Standards

- Quality control
- Standards

Quality Control

Normally for routine control and acceptance testing checks on film thickness and sealing quality are sufficient to ensure quality, but however, other test are necessary in order to know the overall quality (**Figure 5203.03.01**).



Film thickness in practice is one of the most important control parameters and numerous methods have been suggested. Some film thickness meters are now accurate and dependable (Eddy current measurement), but the referee methods in cases of dispute inevitably involve destruction of the coating (Micrographic cross-section).

Sealing quality is another routine control for acceptance in an anodizing plant. Many tests have been developed along time, as in the case of film thickness the reference methods involve attack of the coating.

The dye spot test or dye absorption and impedance test are used because they are quick and non destructive.


The weight-loss test is the reference method but involves to treat a sample in a phosphoric-chromic acid solution and to determine the weight loss.


As corrosion resistance tests for anodic coatings standard methods used for other applications are also carried-out such as: neutral salt spray (NSS), acetic and salt spray (AAS), Copper acetic and salt spray (CASS), etc.

The use of colour anodized finishes for outdoor architectural applications has lead to develop some test on colour fastness and attempts to correlate such tests with outdoor behaviour. The test normally used are de U.V. light (UVIARC) or artificial light (XENOTEST).

Another important property is the abrasion resistance and two different method have been developed for this application. The first is based on the abrasive wheel and the second on abrasive jet. This property allows to distinguish between soft and hard films.

Standards (Figures 5203.03.02 and 5203.03.03)

<p>EWAA - EURAS Quality Label "QUALANOD"</p> <p>The European Anodizers Assoc. (EURAS) has fixed minimum quality standards for anodized aluminium which guarantee the quality level in plants having this label</p> <p>Thickness</p> <p>Standards ISO-2360 (Eddy-Current Measurements) ISO 2128 (Split-Beam-Microscope) ISO 1436 (Micrographic Cross Section) ISO 2106 (Weight-Loss)</p> <p>Reference Standard ISO 2106 (Weight-Loss)</p> <p>Thickness Classes Indoor Exposure.....5 and 10 µm Outdoor Exposure.....15, 20 and 25 µm</p>		
	EWAA - EURAS Quality Label "QUALANOD" (I)	5203.03.02

<p>Sealing Quality</p> <p>Standards ISO-2143 (Dye Spot) ISO 3210 (Weight Loss) ISO 2931 (Admittance)</p> <p>Reference Standard ISO 3210 (Weight Loss)</p> <p>Level of Quality ISO-2143 (Dye Spot) Values 0 - 2 are accepted Values 3 - 5 are not accepted ISO-3210 (Weight Loss) Maximum Weight Loss - 30 mg/dm² ISO-2931 (Admittance) Maximum recommended admittance for a 20 μm clear anodized film is 20 μS</p> <p>Colour</p> <p>The difference in colour of all products must be between the reference samples for each colour (maximum and minimum), and must be an agreement between two parts.</p> <p>Light Fastness (Coloured Products)</p> <p>Products for outdoor exposure must have a light fastness higher than 8 in the international "Blue Scale" according to ISO-2135.</p>		
	EWAA - EURAS Quality Label "QUALANOD" (II)	5203.03.03

EWAA - EURAS Quality Label/ QUALANOD

The European Anodizers Association (EURAS) has selected a series of standards and fixed a minimum quality for anodized aluminium in order to guarantee a quality level in the plants having this label. The standards and minimum Quality levels established by QUALANOD are the following:

Thickness

Standards

- ISO - 2360 Eddy-Current Measurement
- ISO - 2128 Split-Beam-Microscope
- ISO - 1436 Micrographic Cross Section
- ISO - 2106 Weight Loss

Reference Standard

- ISO - 2106 Weight Loss

Thickness Classes

- Indoor exposure 5 and 10 μm
- Outdoor exposure 15, 20 and 25 μm

Sealing Quality

Standards

ISO - 2143	Dye Spot
ISO - 3210	Weight Loss
ISO - 2931	Admittance

Reference Standard

ISO - 3210	Weight Loss
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Level of Quality

ISO - 2143	Dye Spot
Values 0 - 2 are accepted	
Values 3 - 5 are not accepted	
ISO - 3210	Weight Loss
Maximum weight loss - 30 mg/dm ²	
ISO - 2931	Admittance

Maximum recommended admittance for a 20 µm clear anodized film is 20 µS.

Colour

The difference in colour for all products must be between the reference samples for each colour (maximum and minimum), and must be an agreement between two parts.

Light Fastness (Coloured Products)

Products for outdoor exposure must have a light fastness higher than 8 inches in the international „Blue Scale“ according to ISO - 2135.

5203.04 Behaviour of Anodized Aluminium

Chemical resistance of anodic coatings is greatest in approximately neutral solutions (pH 4 - 8,5). In general, acidic or alkaline solutions attack anodic coatings.

Anodic coatings are resistant to most weathering conditions.

The corrosion resistance and atmospheric weathering of anodic coating depend on several factors. The most important are:

- Type of base metal
- Pretreatment before anodizing
- Thickness of anodic coating
- Anodic coating Quality
- Quality of sealing
- Maintenance procedures

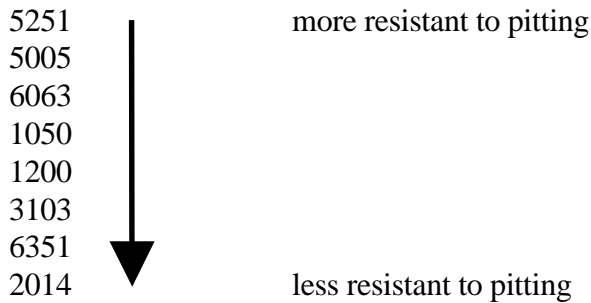
Weathering involves a relatively uniform erosion of the anodic film.

Type of Alloy

The nature of the alloy has a marked influence on the corrosion and weathering resistance

of anodized aluminium.

The approximate order of resistance to pitting of alloys which are commonly anodized is as follows:



Pretreatment before anodizing

The pretreatment used before anodizing affects only the pitting resistance of an anodic film and not its tendency to bloom formation. In general, the smoother the surface produced during pretreatment the greater the resistance to pitting.

Material that has been mechanically or electrochemically brightened before anodizing has a higher pitting resistance than material that is etched.

Anodic Quality

Temperature and concentration of anodizing electrolyte affect film quality and therefore resistance to weathering.

Quality of Sealing

The sealing quality has a relatively minor effect in determining the resistance to pitting, however, it is a major effect in the determination of resistance to bloom formation.

Anodized aluminium sealed in a chromate solution increase the resistance to pitting.

Maintenance Procedures

Maintenance procedures are important in obtaining the maximum life from anodized aluminium.

In industrial areas due to accumulation of dirt and contamination is an increase in the rate of pitting with reference to rural areas and frequent maintenance is necessary to reduce it. To remove dirt from an anodized aluminium surface a mild abrasive or a neutral detergent should be sufficient.

Care should be taken not to use harsh abrasives such as emery, sandpaper, steel-wool, etc. during cleaning. Chemical cleaners that are strongly acidic or alkaline must not be used with anodized aluminium.

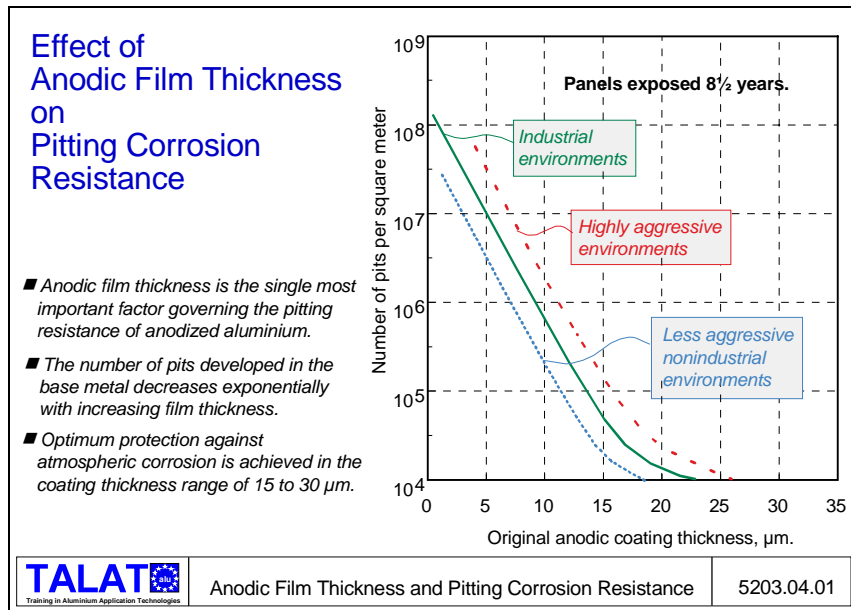
Influence of Film Thickness

Anodic film thickness is the most important single factor governing the pitting resistance of anodized aluminium (**Figure 5203.04.01**).

The number of pits developed in the base metal decrease exponentially with increasing

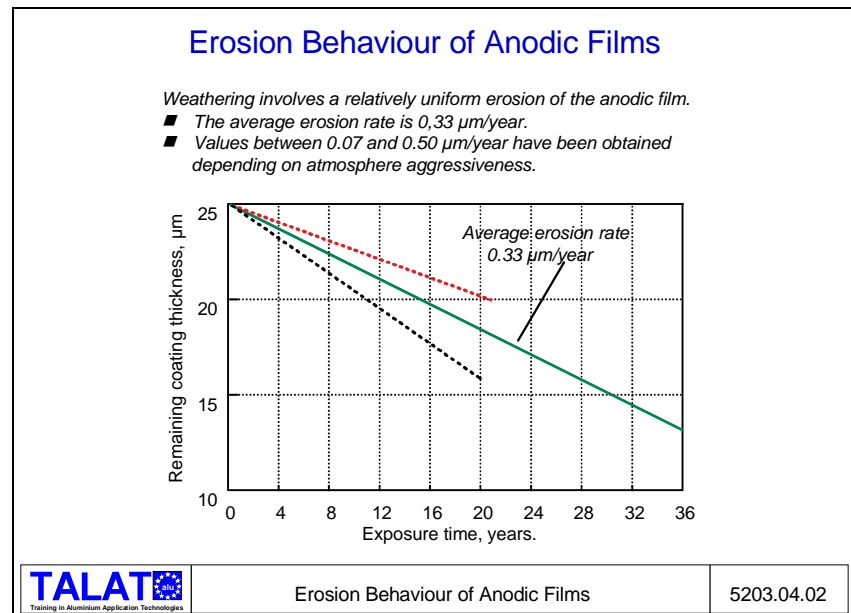
film thickness.

Optimum protection against atmospheric corrosion is achieved in the coating thickness range of 15 - 30 μm .



Anodic Film Erosion

Weathering involves a relatively uniform erosion of the anodic film (Figure 5203.04.02).



The average erosion rate is 0.33 $\mu\text{m}/\text{year}$. Values between 0.07 and 0.50 $\mu\text{m}/\text{year}$ have been obtained depending on atmosphere aggressivity.

5203.05 Literature

Hübner, W. and Speiser, C. Th.: Die Praxis der anodischen Oxidation des Aluminiums, 3. Auflage, Aluminium-Verlag, Düsseldorf, 1977

Wernick, Pinner and Sheasby: The Surface Treatment and Finishing of Aluminium and its Alloys, Fifth Edition, Volume 1, ASM International Finishing Publications Ltd, England (1987)

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