

# Aluminium and aluminium alloys surface protection by the use of anodization technology

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**Abstract:** This paper presents specialized systems and plants for anodizing of aluminium and aluminium alloys with a description of each specific operation. It describes each of the specific process baths within the process of anodizing aluminium and aluminium alloys. The anodization procedures are given and explained in chronological order. The advantages of the process of anodizing aluminum and aluminum alloy are given as well. Final products commercial usage is also listed. The example of products quality control is shown, with commonly measured parameters of the anode layer by the use of various measuring instruments, in order to determine if the final product meets the specified technical standards.

## 1. Introduction

Anodization procedure is done in an anodizing plant which contains tank (depth to 2.5m), standard and special cranes for manipulating and suspenders for hanging samples.



**Figure 1.** Anodizing plant [1]

Tanks are filled with electrolytes (chemicals and demineralised water), thus form an integral part in anodizing plant for aluminium and aluminium alloys samples. On Figure 1, exhaust ventilation channels are shown, which serve for removal of the gases formed during anodization procedure. Samples are hanged on the suspenders, which are most commonly made from titanium in form of the fish bone. The use of titanium is important, for the reason of its good mechanical properties, described by Kulkami et al. [2], and electricity conduction on aluminium alloys samples. Titanium acts neutral for the most fluids used during anodization procedure, moreover during the repeated use of suspenders.

## 2. Anodization technology process

### 2.1. Cleaning

Cleaning procedure is used for the natural aluminium oxide removal purposes, as well as for the elimination of all imperfections and defects on the surfaces of the aluminium and aluminium alloys. Moreover, defects can be stressed out even more after the anodization procedure. Therefore, the samples must be subdued to

cleaning, either chemical or mechanical, or to electrochemical cleaning, if needed. Electrochemical cleaning is conducted by the use of 75 % concentrated phosphorus acid ( $H_3PO_4$ ), with the procedure lasting from 2 to 10 minutes, at 5 to 10 A/dm<sup>2</sup> voltage and at 50 to 80 °C temperature. Before using anodization procedure for the elimination of imperfections on aluminium and aluminium alloys samples, the degreasing and removal of the natural aluminium oxide must take place, which is repeated after the anodization procedure. Cleaning is often done by the use of NaOH because of the simplicity of the process when dealing with serial production of the samples made from aluminium and aluminium alloys. Drawn profiles are most common for bearing structures and door mounts. Mechanical cleaning, therefore conducted with the use of machines or manually is done less often, due to the complexity of the process. According to the previously defined standard (DIN 17611), different levels of cleaning are present for the samples surfaces, by which each one gets its technical mark regarding treatment quality.

### 2.2. Rinsing in demineralized water

The rinsing procedure in demineralized water is done after each stage of the aluminium and aluminium alloys anodization process. Demineralized water is in fact the quantity of total dissolved solid mass (TDS) between 1 and 10 mg/L, where the water itself has very low electrical conductivity. Additionally purified demineralized water (2. level of purification according to EN ISO 3696:1997), has an electrical conductivity lower than 1 µS/cm. The use of tap water or unpurified industrial water is not recommendable due to the presence of impurities; with the quantity of total dissolved solid mass (TDS) between 50 and 300 mg/L, such as calcium, sodium, magnesium, which leave stains on cleaned samples made from aluminium and aluminium alloys, and affect the final quality of the anodization procedure. Rinsing is used for the removal of residual hydroxide or acid remains, and impurities. Rinsing procedure time duration is between 1 and 3 minutes, in sufficient volume of water.

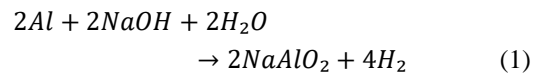
### 2.3. Degreasing

Degreasing process is conducted in detergents or in sodium hydroxide (20 % NaOH) in a bath, with temperature between 65 and 75 °C, and time duration between 5 and 10 minutes. This way, usually all impurities are removed. By conducting a simple test, it can be seen if the degreasing process has performed well by spraying the surface of aluminium and aluminium alloys with water. Degreasing process is successfully done if the water flows freely down the aluminium surfaces without leaving any water clusters behind.

### 2.4 Etching

Etching procedure is done for the purpose of removal of natural surface aluminium oxide layer ( $Al_2O_3$ ). The procedure is done in saturated sodium hydroxide solution

(NaOH) and demineralised water, at bath temperature between 40 i 60 °C and time duration of 5 minutes. Etching occurs due to the chemical reaction as follows (1):



### 2.5 Rinsing in hydroxide solution

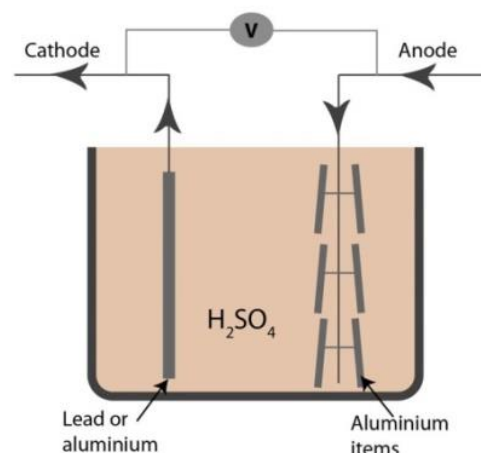
Rinsing in hydroxide solution is done for the purpose of removal of sodium hydroxide (NaOH) remains after the etching process. The procedure is done in the sodium hydroxide (NaOH) and water solution at water temperature 45 °C, no later than one minute after removing the samples made from aluminium and aluminium alloys from etching procedure. This type of rinsing is done to avoid permanent adhesion of hydroxide solution remains left from etching procedure and other impurities on to the aluminium surface. The procedure is to be repeated until the required surface condition quality is reached.

### 2.6 Neutralization

Neutralization procedure is done for the purpose of removal of sodium hydroxide (NaOH) remains from the aluminium and aluminium alloys samples. It is conducted in water and acid solution where the use of the acid depends on the acid type that will be used in anodization process ( $H_2SO_4$ ,  $H_2CrO_4$  and  $H_2C_2O_4$ ), in time duration between 10 and 30 seconds.

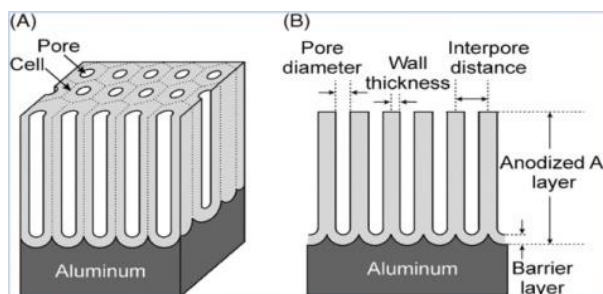
### 2.7 Anodization

The anodization process itself is an electrochemical process, with the use of electrical energy and electrolytes (chemicals and deoxidized water), with cathode and anode (samples made from aluminium and aluminium alloys), which are used for obtaining considerably thicker aluminium oxide layer against the height of the natural aluminium oxide layer that protects the aluminium substrate from corrosion.



**Figure 2.** Basic scheme of anodizing process [3]

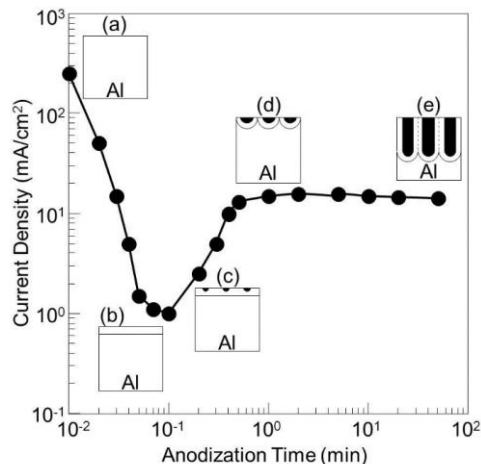
Tank material is most commonly made from polypropylene reinforced with carbon or steel profiles to insure its mechanical strength. Most common dimensions are 8 meters in length, 1 to 1.5 m width and 2 to 2.5 meters in height, with fluid capacity greater than 1000 liters. Anodization process mostly requires direct current (DC) due to the better efficiency of its stray currents. Positive side of direct current is connected to the anode which allows deposition of the aluminium oxide layer on more samples simultaneously. Superficially obtained aluminium oxide layer ( $\text{Al}_2\text{O}_3$ ) due to its hexagonal structure also serves as an electrical isolator, moreover gives good foundation for dyeing procedure. There are several different anodization procedures for aluminium and aluminium alloys and parameters that affect the procedure itself. The properties vary due to the used electrolytes from various acids ( $\text{H}_2\text{SO}_4$ ,  $\text{H}_2\text{CrO}_4$  and  $\text{H}_2\text{C}_2\text{O}_4$ ), dissolved in demineralized water, due to the composition and concentration of the electrolytes and their temperatures, evenly mixed electrolytes, amount of the square area of anode and chemical composition of samples made from aluminium and aluminium alloys. Moreover, properties depend on anodization procedure time duration, electrical voltage [V] and electrical current [A] regulation.

**Figure 3.** Parameters of aluminium oxide layer [4]

Considering the fact that the oxide layer is an excellent electrical isolator, it provides bigger resistance to electrical energy conduction in relation to its height increase, which automatically decreases the growth of the oxide layer, its mechanical and structural properties therefore its corrosion resistance. Due to this features, it is recommended to use a constant value of electrical current [A] in aluminium and aluminium alloys anodization procedure, moreover to regulate the electrical voltage [V], which provides uniformed mechanical and structural properties of the obtained aluminium oxide layer which, at the same time, requires a lower electrical current [A]. The usual values of the needed electrical current vary from 1-1.5A/dm<sup>2</sup> anode surface area.

At the beginning of the anodization procedure, electrical current is at its peak in order to generate oxygen on anode surface (a). Afterwards, electrical current steeply

decreases due to forming of high electrical resistance because of barium-aluminium oxide layer generating (b). During the formation of porous aluminium oxide layer, electrical current increases (c, d). Electrical current than stabilizes due to the constant rate of porous al-oxide forming (e), explained by Ohgai [5].

**Figure 4.** Electrical current by anode square area regulation due to duration of aluminium and aluminium alloys anodization process in tank [5]

During the anodization process, good electrical conductivity of generated aluminium oxide layer must be insured, therefore anode efficiency of electrical current ( $\eta_a$ ), which enables the oxide layer to form evenly. To insure finer oxide layer with balanced texture on the aluminium and aluminium samples surfaces, constant temperature from 18 to 21 °C needs to be maintained, as well as electrical current by samples square surface area. The samples are then immersed in electrolytic bath, thus presenting the anode connected on positive side of direct current (DC), which conduction makes the electrolyte to dissolve, and anode surface area to oxidise with oxygen from the electrolyte. Minimum distance between anode and cathode must be 25 mm, to minimize the electrical bridges to the lowest point. Cathode is mostly made from aluminium, lead, stainless steel and titanium. Aluminium cathodes lifetime is 4 years at best, while stainless steel cathodes last to 10 years. Lead cathodes last between 10 and 15 years, but at the same there are not environmentally friendly due to the fact that their ions could be found in anodization procedure waste waters. Aluminium cathodes are generally made from 1100 or 1350 sheets, or extruded 6063 T5 and 6101 T5 or T6 alloys. Advantages of using these cathodes reflect in lower electrical voltage requirements for the anodization procedure, lower energetic requests and expanses. Anodization procedure parameters regulation is less complicated; less wasted heat during the procedure, cathode lifetime is longer, smaller frontal dimensions could be obtained. Larger cathode surface area can be generated as well, because the extrusion process provides the fish bone profile, which consequently generates

smaller cathode dimensions in relation to its overall surface.

Cathodes may be coated with polymer inserts in order to reduce their effective working area. In order to gain evenly distributed oxide anions on anode and balanced height of the aluminium oxide layer, sufficient amount of electrolyte mixing is necessary, which is commonly done by aeration (compressed air blowing with "oil free" compressors or specialized magnetic mixers). Moreover, heat exchangers are used for eventual heating of the anodization procedure in case of its overcooling. The temperature should not go below its default one.

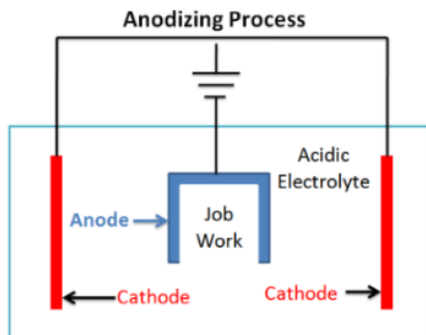


Figure 5. Anode and cathode position scheme [6]

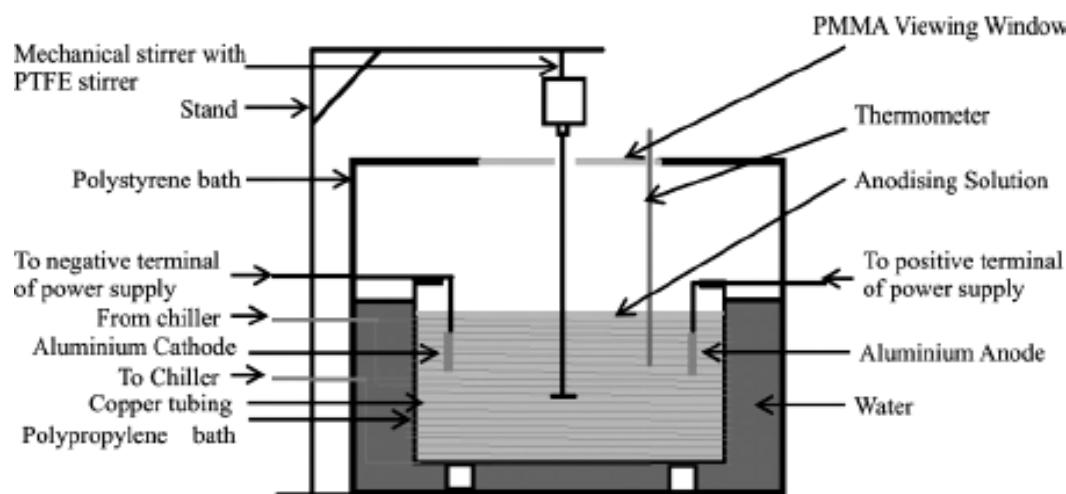


Figure 6. Cross-section of the anodization tank with its constituent parts [7]

The oxide layer inserts into the aluminium and aluminium surface with one part of its height, which creates a very good adhesion between them. Due to the very good connection of aluminium and its oxide which literally merges with aluminium substrate, samples made from aluminium and aluminium alloys are resistant to external abrasive influences and peeling.

not have any physical connection and adhesion to substrate material, thus are subjected to peeling. Obtained oxide layer consists of barrier layer on the surface of aluminium substrate and hexagonal layer with open porosities. The oxide layer has ceramic characteristics. Porosities are needed to be closed in sealing procedure. Quality of anode layer depends on quality of aluminium and aluminium alloys samples which are anodized, made mostly from Al 99.5, than AlMgSi0.5, AlMg1 and AlMg3. Obtained oxide layer provides effective protection from corrosion with considerable mechanical resistance and insulation properties; it is good electrical and heat isolator considering the obtained hardness and height. By reaching the requested height of the oxide layer, anodization procedure is instantly stopped by the use of digital operating system and anodization procedure regulation. Most commonly used electrolyte in anodization procedure is the one from sulphuric acid (H<sub>2</sub>SO<sub>4</sub>). Few other used electrolytes are from chromatic

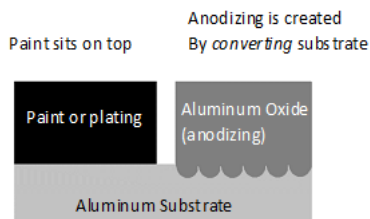


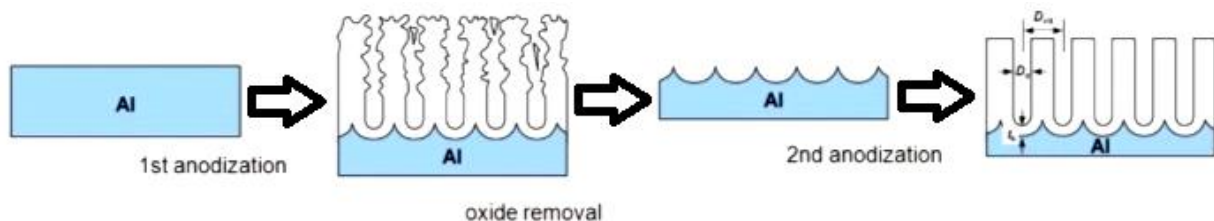
Figure 7. Coating and aluminium oxide layer adhesion on pure aluminium [8]

On Figure 7, the adhesion of coating and aluminium oxide layer on aluminium substrate is shown. Applied coatings overlap the aluminium substrate surface and do



acid ( $H_2CrO_4$ ) and oxalic acid ( $H_2C_2O_4$ ). Quality of obtained oxide layer can be improved by the use of two-stage anodization, where uniformed and highly arranged porous hexagonal aluminium oxide layer structure is obtained. Considering the fact that primarily obtained

aluminium oxide layer is removed, surface of aluminium substrate retains its characteristic web-like structure with concave spots for porosity forming that give better characteristics of oxide layer during the conduction of the second stage of anodization procedure.

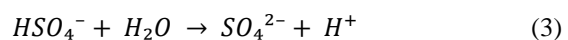
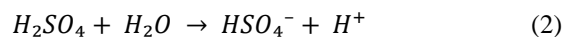


**Figure 8.** Two-stage anodization of aluminium oxide layer scheme [9]

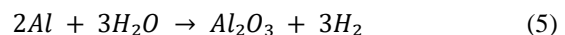
### 2.7.1 Chemical reactions in anodization tanks

Sulphuric acid is used in majority of cases. The anodization procedure is based on classic electrolysis process, where electrochemical reaction consists of oxidation process; anode oxygen reaction where negatively charged anions release excess electrons to anode which receives oxygen in process of cathode reduction of hydrogen, where positively charged cations receive the same amount of electrons and release hydrogen. These reactions are necessary for starting and conducting of the anodization procedure where the electricity is transported within mentioned reactions. During electrolysis process, explained by Redkin et al. [10], different chemical agents are released on anode and cathode, galvanic cell is formed, so the electrolysis can proceed only if the electrical voltage of outer electrical energy source is opposite and greater of the electrical voltage (negative anode reaction) of the formed cell. The chemical reaction itself occurs between aluminium substrate and aluminium oxide layer, and between electrolyte and aluminium oxide layer. Electrolyte contains free hydrogen  $H^+$  ions (hydrogen ion formed by proton binding), therefore contains  $H_3O^+$  (hydronium cation formed by binding of proton to water molecules) and  $SO_2$  (sulphur-dioxide in the form of gas). During the electrical energy flow between anode and cathode, dissolution of sulphuric acid occurs, with negatively charged sulphur oxide anions ( $SO_2$ ) forming on the cathode and traveling to anode, sending oxygen and creating reaction on the aluminium anode's surface where oxygen binds with aluminium forming aluminium oxide ( $Al_2O_3$ ). Moreover, unstable sulphur dioxide ( $SO_4$ ) forms, which binds with water atoms ( $H_2O$ ). Sulphuric acid ( $H_2SO_4$ ) forms again, while remaining oxygen molecules bind with aluminium and also form aluminium oxide. Aside of exchanging negative and positive ions, electrical energy is spent also on growth of the aluminium oxide extraction of oxygen and ionization of aluminium in cations  $Al^{3+}$  between al-substrate and aluminium oxide layer according to Lin et al. [11].

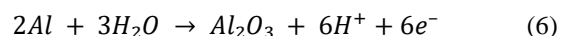
Electrolytic dissociation of water enables it to split on hydrogen  $H^+$  and hydroxide  $OH^-$  ions, which then enables gases oxygen and hydrogen to be released on anode and cathode. Electrochemical reactions of sulphuric acid in water can be shown as follows (2, 3, 4);



Products formed after the electrochemical anode reaction can be shown as follows (5);



Electrochemical anode reaction can be shown as follows (6);



Electrochemical cathode reaction can be shown as follows (7);



Electrochemical reaction of water dissociation can be shown as follows (8);



### 2.7.2 Anodization in chromic acid

The anodization procedure in chromic acid ( $H_2CrO_4$ ) (Type I), provides an aluminium oxide layer height from 5 to 10  $\mu m$ . Obtained oxide layer has very good corrosion resistance due to noncorrosive properties of chromic acid. At this particular anodization procedure, the concentration of the acid used is in range of 10 %, electrolyte temperature is at 40  $^{\circ}C$ , electrical current by anode square area is 0.5  $A/dm^2$ , electrical voltage

gradually increases during procedure to 40 V, and time duration is calculated in minutes or read from the diagram. These parameters are defined by experience. Obtained aluminium layer has a ceramic characteristic which means it is a good isolator. Due to the low height of aluminium oxide layer, it does not affect the sample dimensions where narrow tolerances are in use.

### 2.7.3 Anodization in sulphuric acid

Anodization in sulphuric acid ( $H_2SO_4$ ) (Type II), gives an aluminium oxide layer height from 10 to 25  $\mu m$ . Obtained width of aluminium oxide layer is further separated on "class 1" with minimal layer width of 18  $\mu m$ , which is used for outdoor purposes, and "class 2" that has minimal layer width of 10  $\mu m$ , which is used for internal purposes [12]. Obtained aluminium oxide layer has very good corrosion resistance, mechanical resistance and hardness just next to diamond's. At this anodization procedure in sulphuric acid, the concentration of the acid used is commonly in range of 10 to 20 %, electrolyte temperature is between 18 and 21  $^{\circ}C$ , electrical current by anode square area is from 1.0 to 1.5  $A/dm^2$ , electrical voltage varies from 10 to 30 V and time duration is calculated in minutes or read from the diagram. These parameters are defined by experience. At the start of anodization procedure, thin barrier oxide layer forms as well as hexagonal porous layer. Obtained aluminium oxide layer has ceramic characteristics; it is a good electrical isolator.

Aluminium oxide layer inserts in the aluminium and aluminium alloys samples surface with 2/3 of its height, which forms a very good bond and adhesion between them. Therefore, it is important to take dimensions of finished aluminium and aluminium samples into

consideration, having in mind that their dimensions increase by 1/3 of the aluminium oxide layer height

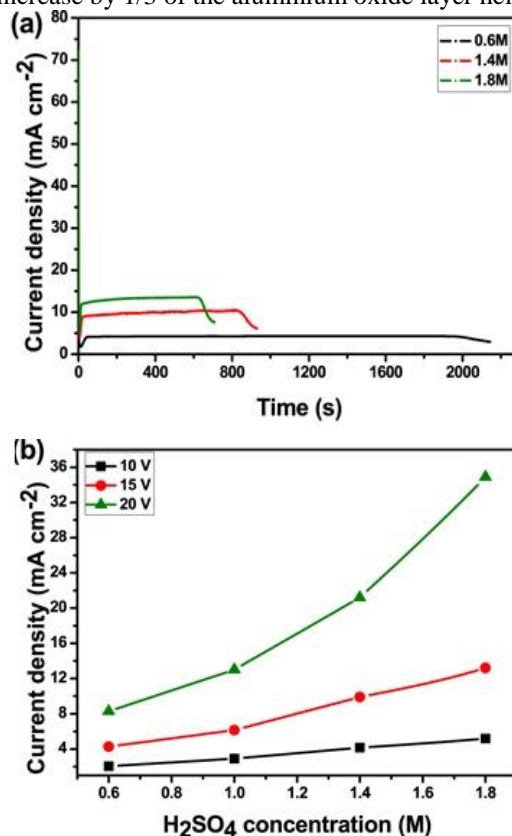


Figure 9. Aluminium and aluminium alloys anodization time duration, sulphuric acid concentration and electrical current by anode square area display due to the needed electrical voltage [12]

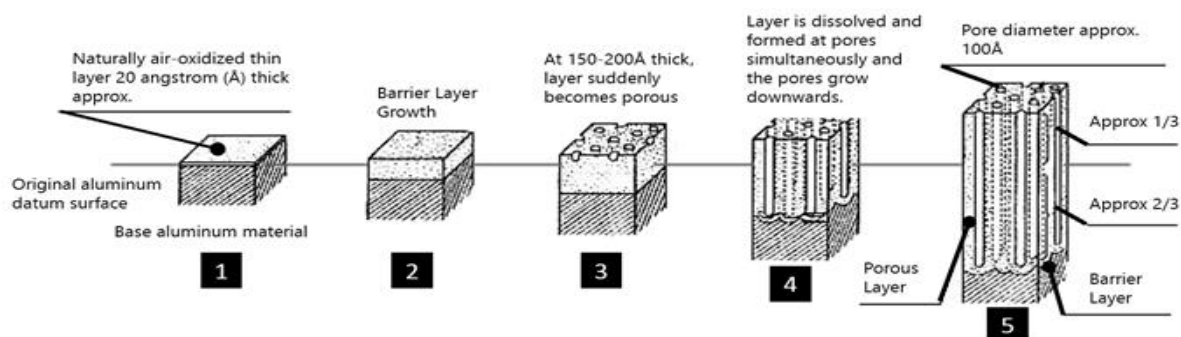


Figure 10. Aluminium oxide layer forming chronology [13]

Porosities are to be closed in sealing procedure or by introducing dyeing procedure instead. The obtained aluminium oxide layer is very pliable for dyeing due to the very highly developed porosities.

### 2.7.4 Anodization in sulphuric acid – hard anodization

Hard anodization procedure in sulphuric acid ( $H_2SO_4$ ) (Type III) provides aluminium oxide layer of height

between 50 to 100  $\mu m$ . Obtained oxide layer has very good corrosion and mechanical resistance with hardness from 50 to 70 HR<sub>C</sub>. This procedure is suitable for dynamically loaded mechanical parts like sliding rails, gears, revolving joints and pistons, due to their exposure to significant mechanical wear. Obtained aluminium oxide layer has ceramic characteristics; it is a good electrical isolator. For this type of anodization procedure, acid concentration vary from 10 to 20%, electrolyte

temperature goes from 0 to 10°C, direct electrical current by anode square area varies from 2.5 to 3.5 A/dm<sup>2</sup>, electrical voltage is above 100 V and time duration is calculated in minutes or read from the diagram. These parameters are also defined by experience. Aluminium alloys suitable for this type of anodization are from 5000 and 6000 series. Aluminium oxide layer inserts in the aluminium and aluminium alloys samples surface with 1/2 of its height, which forms a very good bond and adhesion between them. Therefore, it is important to take dimensions of finished aluminium and aluminium samples into consideration, having in mind that their dimensions increase by 1/2 of the aluminium oxide layer height. In most cases, porosities are not sealed, due to the excellent corrosion resistance of the obtained aluminium oxide layer height.

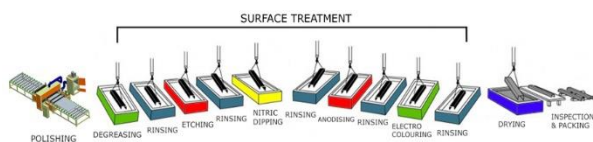
### 2.7.5 Anodization in oxalic acid

The anodization procedure in organic oxalic acid (H<sub>2</sub>C<sub>2</sub>O<sub>4</sub>) (Type IC), gives an aluminium oxide layer height up to 50 µm. Obtained oxide layer has very good mechanical resistance with excellent hardness but, unfortunately, weaker corrosion resistance. Obtained aluminium oxide layer has ceramic characteristics; it is a good electrical isolator. For this type of anodization procedure, acid concentration is at 20% range, electrolyte temperature goes from 15 to 35°C, direct electrical current by anode square area varies from 1 to 3 A/dm<sup>2</sup>, electrical voltage is from 30 to 50 V and time duration is calculated in minutes or read from the diagram. It is important to take dimensions of finished aluminium and aluminium samples into consideration, having in mind that their dimensions increase by 1/2 of the aluminium oxide layer height.

### 2.8 Dyeing

The most common color shades in use are the ones from "EURAS Colour Code" color palette standard. Few other commercial color standards in use are from SANDALOR and SCHÜCO. For aluminium and aluminium alloys samples to be properly colored, oxide layer must be at least 10 µm high. The color deposits at the bottom of the porous layer of the aluminium oxide, after the pores are closed by sealing process and eventually protected from environmental influences. Dyeing procedure is used with coloring bath temperature range between 65 and 75 °C and time duration between 10 and 30 minutes. Metal oxide based colors are in use which are deposited at the bottom of the porous aluminium oxide walls, by the use of electrolytic process in proper baths.

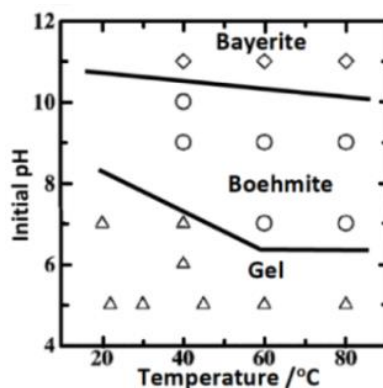
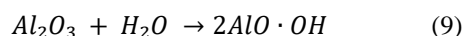
#### ELECTRO COLOURING PROCESS OF BRIGHT ALUMINIUM, CHENNAI



**Figure 11.** Anodization process chronology with dyeing procedure [14]

### 2.9 Sealing

Sealing process is used for the purpose of closing of the porous aluminium oxide layer thus increasing corrosion resistance. It is done in two ways; by "warm" or "cold" sealing procedure. "Warm" sealing procedure (hydration sealing) is conducted in demineralized water at boiling temperature, with time duration between 30 and 60 minutes, depending on the height of obtained aluminium oxide layer. This procedure forms "boehmite" (Al<sub>2</sub>O<sub>3</sub>·H<sub>2</sub>O) at the surface of oxide layer, due to the reaction of aluminium oxide layer (Al<sub>2</sub>O<sub>3</sub>) and water (H<sub>2</sub>O), with ratio of oxide layer 83 % and water 17% and pH values of sealing bath between 5.5 and 6.5. Boehmite layer forms by chemical reaction as follows (9);



**Figure 12.** Boehmite formation diagram [15]



**Figure 13.** Boehmite structure image [16]

Boehmite layer is hard, vitreous layer that has greater volume than aluminium oxide layer; it physically seals (fills) the pores, thus increases the resistance of the layer to corrosion and wear. The "cold" procedure (cold sealing) is conducted in demineralized water, with the addition of 5 to 6 g/l of nical-fluoride at room temperature, with time duration between 20 and 30 minutes. pH values of the bath vary from 5.5 and 6.5. The

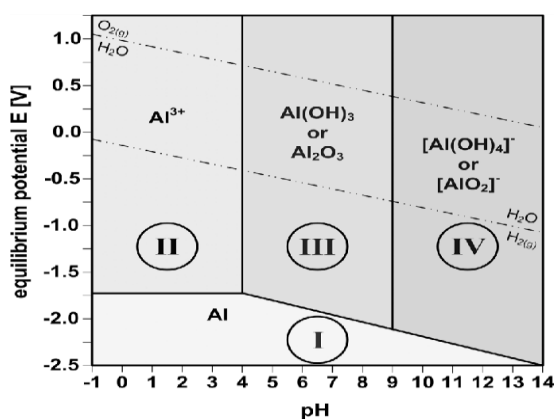
procedure is economically acceptable due to the lower bath temperatures, thus more suitable for sealing the samples which are colored. During the conduction of sealing procedure, it is preferable to use inhibitors (acetates, chromates, molybdates), which improve corrosion resistance.

### 2.10 Drying

Drying procedure is conducted for the purpose of maturation of sealing procedure. It is conducted in natural air, at room temperature with time duration of 48 hours. During drying procedure, samples should not be wrapped up or covered. Ideally, samples should not be removed from suspenders used during anodization procedure, therefore set to drying for 48 hours at anodizing plant.

## 3. Discussion

Important properties of obtained aluminium oxide layer are corrosion and mechanical resistance, thus resistance to wear due to the hardness of porous oxide layer, where porosity itself enables coloring or good adhesion for gluing. Another important property is dielectricity where the aluminium oxide behaves as an isolator and does not conduct electrical energy. Very important property of the obtained aluminium oxide is its passivity and the fact that it is environmentally friendly. Pourbaix diagram (generally known as the diagram of potential towards pH values), gives an insight in area of acidic and alkalic corrosion therefore passivity of certain metal at room temperature, where the corrosion of metal in electrolytic liquids is surveyed [17]. Aluminium and aluminium alloys are passive in pH range from 4 to 9, at potential from -2 to 1, in humid atmosphere, in tap and saltwater and in majority of aerated electrolytes like rain, snow and ice.



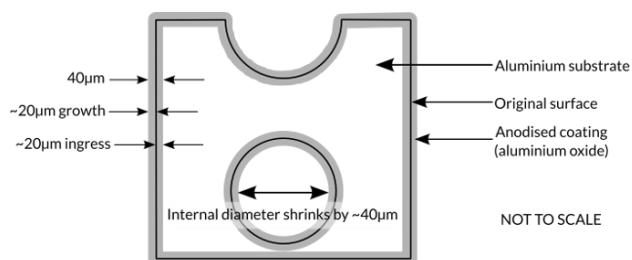
**Figure 14.** Pourbaix diagram for pure aluminium at 25 °C [18]

Characteristic areas shown on Figure 14, are:

- i. area of general immunity
- ii. area of acidic corrosion
- iii. passive area

- iv. area of alkalic corrosion
- ..... water stability border (H<sub>2</sub>O)

Considering the fact that Pourbaix diagram shows an empiric area of corrosion for pure aluminium, corrosion values must be measured for each aluminium alloy combination, in order to obtain the area of immunity at requested polarities and pH values tested by Sukiman et al. [19]. Porous aluminium oxide layer is suitable for coloring procedures, where (considering the applied color), different color tones and shades can be obtained on sample surfaces made from aluminium and aluminium alloys. Obtained colors are resistant to bleaching, outer atmosphere influences and ultra-violet radiation. The height of the obtained aluminium oxide layer can be controlled, so the needed tolerance fields can be acquired.



**Figure 15.** Sample dimensions enlargement due to the use of anodization process [20]

Aluminium oxide layer has good resistance to acids, but not to alkalic atmosphere. While using it in civil engineering, it should be protected from lime influences, because it causes permanent damage to the oxide layer which is hardly corrected. It is possible to gain excellent adhesion properties which enable better glue and coating adhesion as well as welding. Due to the good bond between aluminium substrate and aluminium oxide layer, samples made from aluminium and aluminium alloys are resistant to outer abrasion influences. Their commercial use today is literally limitless:

- various supporting structures in mechanical and civil engineering,
- profiles and walls manufacturing for civil engineering fittings and decorative panels,
- parts for engines with internal combustion, car chassis and rims, bicycle frames,
- outer and internal panels for aeronautical and space industry,
- in naval architecture for vessels hull and superstructure manufacturing,
- household appliances, commercial and industrial mirror manufacturing, scientific telescope mirrors production,
- electrical and electronical parts and components,
- various furniture accessories,



- equipment for food industry; food storage and consuming manufacturing, food and industrial foil production,
- jewellery manufacturing and medicament additives.

#### 4. Conclusion

The main advantage of anodization procedure reflects in obtained aluminium oxide layer that carries very low maintenance demands. It is passive; it does not have any impact to health and environment and does not generate any notable corrosion. The anodization procedure does not produce CO<sub>2</sub> emissions or any solvents. Obtained aluminium oxide layer is permanently bonded with aluminium substrate, on which it evenly forms whether on straight or curved areas or sharp edges, and has uniformed final surface texture. It has great mechanical resistance and does not change its properties through time, like surface coatings do. Aluminium oxide is impermeable, therefore resistant to the majority of chemical influences; moreover gains very good corrosion resistance in humid, sea, industrial and urban atmospheres which are saturated with chlorides and sulphur. It is an isolator, so it does not conduct electrical energy. While being welded, the colors are resistant to all outer influences. 100% recycling is enabled by remelting or pressing. It enables quality control by on-the-spot check, which is done without damaging the oxide layer. For example, quality control can be conducted in chemical laboratory at anodizing plant FEAL Siroki Brijeg (Bosnia and Herzegovina), with the use of specific technologies in order to guarantee the required properties of the final product and treated surfaces. Besides measuring all required parameters of the aluminium profiles anodization procedure, the laboratory also conducts testing of colored aluminium profiles. For the anode layer height measuring, an instrument with eddy current technology is introduced, Fischer DualScope MPOR, that enables measuring height/width of the layers up to 200 µm.



**Figure 16.** Eddy current height/width measuring gauge [21]

For conductivity measurements, a WTW Cond 315i instrument is introduced, which enables measuring bath conductivities in micro Siemens by centimeters (µS/cm). For pH measurements, a WTW pH3110 instrument is used, which enables measurements of baths pH values.

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