

Anodizing of aluminum and its alloys

DISCLAIMER: This is translation from “The Anodizing Handbook” by E. E. Averianov. I haven’t tried any of these techniques, although I suppose they should work fine. I am not liable for any damage of any kind caused by using the information provided.

Sulfuric electrolyte is cheap and most commonly used. It is possible to anodize the vast majority of aluminum alloys in it. However, it should be avoided when the details have some parts welded or riveted. In case of bad washing such parts can corrode.

The most commonly used electrolyte (recommended by ГОСТ 9.305-84) contains sulfuric acid of 180-200 g/l concentration. It is recommended to maintain the current density of 0.5-2 A/dm² and voltage of up to 24 V while anodizing. The process may last from 15 to 60 minutes. Thickness of oxide layer is 5-25 μm depending on the alloy type.

When anodizing aluminum and plated metals one should use the technical conditions mentioned above which are considered to be universal. It is recommended to anodize AMr and AMu type alloys during 30-40 minutes at the temperature of 18-23 °C, current density of 1.0-1.5 A/dm² and voltage of 12-18 V. Д16, Д1 and other alloys with high copper content should be anodized during 40-60 minutes at the temperature of 16-25 °C, current density of 1.5-2.0 A/dm² and voltage of 17-20 V. Alloys with high silicon content are recommended to be anodized with current density raised to 2.0 A/dm² and voltage of up to 28 V. Details with difficult geometry are anodized during 50-80 minutes with current density lowered to 0.5-1.0 A/dm². Thickness of oxide layer is mostly dependent on the alloy (Table 3.3). It is harder to get thick oxide layers on alloys with high copper and silicon content.

Table 3.3. Thickness of oxide layer, deposited on different aluminum alloys while anodizing in 20% H₂SO₄ at the temperature of 20 °C, current density of 1 A/dm², agitated (after A. I. Goloubey).

Alloy type	Voltage, V	Oxide layer thickness (μm), deposited during time, minutes			Oxide layer thicknesses ratio, %
		20	40	60	
АД1	12 – 12.5	6.8	15	25	100
Д16 plated	13 – 14	6.4	14	23.5	94 – 100
В95	12	6.2	13.5	25	94
Д20	12.5	6.6	13.3	21.4	90 – 100
АМr	12	6.3	14.8	22.5	95
АМу	12 – 12.5	5.8	11.7	21	82
В95 not plated	10 – 12	3.8	8.1	12.2	53
Д16 not plated	12, 15	3.4	6.3	8.5	42
АЛ2	10 – 15	5.8	12.8	24.2	89
АЛ8	8 – 10	5.5	10.6	19.5	80
АЛ7	12 – 16	3.2	5.8	7.6	40

It is possible to conduct anodizing using alternating current. During this process the valve (semi conduction?) effect of aluminum oxide is used. It is also possible to conduct anodizing without auxiliary cathode. Anodizing can be conducted using one-phase or three-phase current. Oxide is formed during the anode half-period of wave only. During AC anodizing usually utilizes 15% water solution of sulfuric acid. Other conditions of AC anodizing are the same as of DC anodizing.

On the figure 3.1 there are curves showing the change of oxide layer thickness in time versus current density. On the figure 3.2 there is the change of dimensions of the detail made of Д16 type alloy during anodizing.

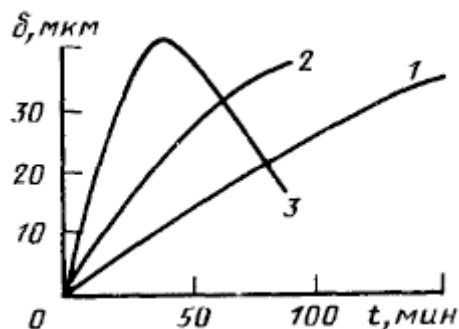


Figure 3.1. Change of thickness of oxide layer, formed on the surface of chemically clean aluminum in 20% water solution of sulfuric acid at 20 °C; current density: 1 – 1 A/dm², 2 – 2 A/dm², 3 – 5 A/dm².

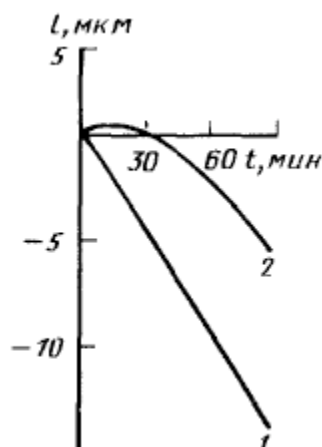


Figure 3.2. Change of dimensions of the detail made of Д16 type alloy, anodized in 20% water solution of sulfuric acid at the current density of 1 A/dm²: 1 – change of metal dimensions; 2 – change of detail dimensions.

Anodic oxides obtained in water solutions of sulfuric acid have good electro-physical qualities. Oxides micro-hardness obtained at the current density of 0.5-2.0 A/dm² equals H300 – 500. As a comparison, micro-hardness of hardened instrumental steel is H1100, micro-hardness of AK4M4 alloy – around H90, micro-hardness of technically clean aluminum – around H30. Micro-hardness of anodic film on the technical aluminum is higher and can achieve H600, on the chemically clean aluminum micro-hardness of up to H1500. Thickness of oxides micro-hardness is uneven; layers close to the metal have micro-hardness 50 – 100% higher than outer layers. Micro-hardness grows when electrolyte temperature lowers.

Porosity of oxide surface area changes from 15% to 40% depending on the alloy type and anodizing conditions. When electrolyte temperature rises, porosity grows. The density of anodic oxide is 2.9-3.8 g/cm³ depending on anodizing conditions. Corrosion resistance measured with wetting method changes from several minutes to dozens minutes. Anodic oxides are a good isolator:

their medium specific electrical resistance is $4 \cdot 10^{15}$ Ohm·cm. At the thickness of 75 – 100 µm oxide can withstand 2000 V.

In the table 3.4 there are the most common defects occurring during AC and DC anodizing of aluminum alloys in sulfuric electrolyte.

Table 3.4. The most common defects occurring during AC and DC anodizing of aluminum alloys in sulfuric electrolyte.

Defect description	Reason	Treatment
No oxide or insufficient oxide thickness	1. Bad contact of detail and support 2. Insufficient amount of electricity passed 3. Bad electrolyte	Improve contact Increase anodizing time Change or correct electrolyte
Loose oxide or doesn't stick to the metal	1. Electrolyte temperature too high 2. Too much aluminum in electrolyte	Cool electrolyte Change electrolyte or remove aluminum
Burns	1. Bad contact of detail and support 2. Short circuit between the detail and cathode or between details	Improve contact Remove short circuit
Dissolution of oxide layer	1. Electrolyte temperature too high 2. Process duration too long 3. Insufficient cleaning after anodizing	Cool electrolyte Decrease anodizing time Improve cleaning
Dissolution, black dots	Excessive amount of chlorides in electrolyte	Change electrolyte
Dissolution of oxide layer near contacts	Detail and support are made of different metals	Make the support from the same metal as the detail
Gray loose film on the anodized surface	Bad treatment of the detail before anodizing	Improve the detail cleaning before anodizing
Dark stripes or patches on the oxide	Accumulation of copper in the electrolyte more than 0.2-0.4 g/l when anodizing aluminum alloys with copper content	Add chromium anhydride to electrolyte (2-3 g/l) or nitric acid (6-8 g/l) or change electrolyte
Greenish color or oxide dissolution (AC anodizing)	Accumulation of copper in the electrolyte	Treat electrolyte with DC, thus precipitate the copper at cathode or change electrolyte
Dark stripes or patches on the oxide when anodizing in fresh electrolyte (AC anodizing)	Accumulation of metals (except copper and aluminum)	Treat electrolyte with DC or change electrolyte

When anodizing details with welded or riveted parts or of difficult configuration it is recommended to use **chromic electrolyte**. Oxides formed in chromic electrolytes have high corrosion resistance (can be used without sealing), comparably high elasticity and density. However, these oxides are less wear resistant and have reduced and micro-hardness. Due to their low porosity, they are not dyed. In the table 3.5 there are technological conditions of anodizing aluminum and its alloys in chromic electrolyte.

Electrolyte 1 is recommended by ГОСТ 9.305-84 for anodizing aluminum and its alloys including casting alloys. The voltage is raised to from zero working value during 5 – 15 minutes. Electrolyte 2 is used for anodizing AJ12, AM14 and AM17 type alloys in case when the details have polished surface and close tolerances. Electrolyte 3 is used for anodizing the same types of alloys but for details with looser tolerances. The Voltage is raised step by step (during first 25 minutes up to 40 V, during next 5 minutes up to 50 V). Electrolyte 4 is recommended for details made from casting alloys AJ12 and AJ19. Current density is held constant while voltage is raised up to 30 – 40 V. Later the current density drops by itself. Electrolyte 5 is recommended for fast anodizing. During the first 5 minutes, the voltage is raised up to 40 V and after that is held constant. One should not process casting alloys with silicon and alloys with high copper content in one tank, as well as details from plated and not plated aluminum.

Table 3.5. Solutions and anodizing conditions of aluminum and its alloys in chromic electrolyte.

Solution	CrO ₃ concentration, g/l	Current density, A/dm ²	Voltage, V	Temperature, °C	Duration, minutes
1	30 – 55	Up to 3	Up to 40	20 – 40	30 – 60
2	30 – 35	0.2 – 0.3	40 – 50	40 ± 2	70 – 80
3	50 – 55	0.2 – 2.5	Up to 50	40 ± 2	70 – 80
4	70 – 100	4	30 – 40	35 ± 5	60
5	85 – 100	1.0 – 2.5	Up to 40	36 – 38	30 – 35

Anodizing in chromic electrolyte has its own peculiarities with regarding to sulfuric electrolyte anodizing. Electric conductivity of water-based chromic acid solutions and their dissolution ability are lower then that of the sulfuric acid. This forces one to use higher voltages and electrolyte temperatures. Current output (efficiency?) is 20 – 60% depending on the alloy type anodizing conditions and duration. Change of dimensions of the detail is shown on the figure 3.3. Anodic film thickness for this type of anodizing is 2 – 5 µm, detail dimensions barely change. The shine of polished aluminum surface is preserved because oxides are colorless and glass-like. When 5 µm thick the break-through voltage of oxide film is 200 V. Sulfate-ions are contaminants in electrolyte (allowed not more than 0.5 g/l) and are removed by injection of carbonic barium.

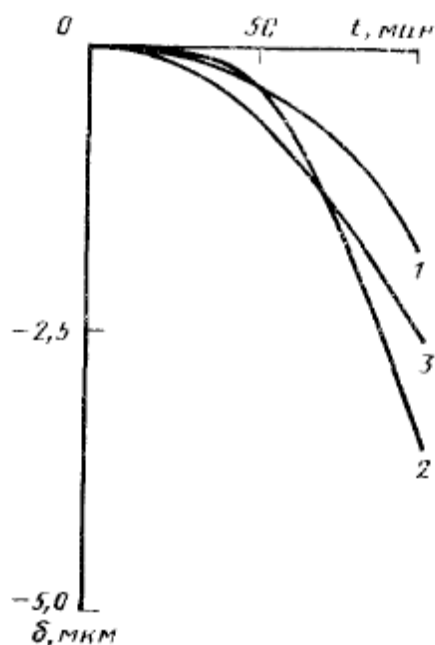


Figure 3.3. Anodizing in 5% water-based solution of chromic acid at the temperature of 40 °C and current density of 0.3 A/dm², no electrolyte agitation. Dimensions change of the detail made of aluminum (1), Al19 type alloy (2) and Al16 type alloy (3).

During anodizing the amount of free chromic acid is reduced (because of accumulation of 3-valent chrome in electrolyte). 3-valent ions of chrome can be transformed into 6-valent ions by treating the solution with lead anode and steel cathode. Anode current density should be 0.2 – 0.3 A/dm². Electrolyte should be corrected depending on its pH value. With 30 g/l concentration of CrO₃ pH should be 0.7 – 0.9; with 100 g/l concentration of CrO₃ pH should be 0.1 – 0.3. For this type of anodizing cathodes are made of corrosion-resistant steel 12X18H9T or technically clean aluminum A0. In the table 3.6 one can find the most common defects occurred during anodizing in chromic electrolyte and methods of treatment.

Table 3.6. The most common defects occurred during aluminum anodizing in chromic electrolyte.

Defect description	Reason	Treatment
Lowered speed of oxide growth	1. Excessive amount of sulfate-ions in electrolyte (more then 0.5 g/l) 2. Electrolyte temperature too high	Precipitate the excess of sulfate-ions with barium hydroxide. 1 g/l of Ba(OH) ₂ precipitates 0.2 g/l of sulfate Cool electrolyte
Dissolution of the surface, yellow patches	CrO ₃ is too low in electrolyte	Raise the amount of chromium anhydride up to the norm
Opaque film	SO ₄ ²⁻ amount in electrolyte is too low (H ₂ SO ₄ is less then 0.01%)	Raise concentration of H ₂ SO ₄ up to 0.03% or higher
Semi-opaque film	SO ₄ ²⁻ amount in electrolyte is too low (H ₂ SO ₄ is less then 0.01% – 0.03%)	The same

Easy removable gray film on the surface	Global or local electrolyte overheat	Cool electrolyte, increase agitation
Roughness of the surface	Excessive amount of chlorides in electrolyte (more then 0.1 g/l)	Adjust electrolyte

Anodizing in **oxalic acid** is mostly used for obtaining electro-insulating surfaces and casting alloys anodizing. This type of anodizing can be conducted without deep cooling of electrolyte. Oxalic acid anodizing is suitable for alloys with high copper and silicon content. However, with regarding to consumed power and chemicals cost anodizing in oxalic acid is more expensive then in sulfuric acid. Oxide micro-hardness is lower as well. In the table 3.7 one can find solutions and technological conditions for anodizing in oxalic acid.

Table 3.7. Electrolyte solutions (ГОСТ 9.305-84) and technological conditions for anodizing in oxalic acid.

Solution number	$(\text{COOH})_2 \cdot 2\text{H}_2\text{O}$ concentration, g/l	Current density, A/dm^2	Voltage, V	Temperature, $^{\circ}\text{C}$	Duration, minutes
1	40 – 60	2.5 – 3.5	Up to 120	15 – 25	90 – 210
2	40 – 60	3	Up to 90	1 – 25	180
3	50 – 100	1.0 – 2.5	50 – 65	30	10 – 30

Electrolyte 1 is the standard for anodizing aluminum and its deform alloys (types AMr, AMu). Electrolyte 2 is used for obtaining wear-resistant surfaces and surfaces that are to be stuffed later. Oxide thickness during this process is 42 – 52 μm . Break-through voltage is 425 – 500 V. It is necessary to agitate electrolyte. Current density drops by itself during anodizing. Electrolyte 3 is used for protective and decorative anodizing of AЛ1, AMu, AMr, B95, Л16 type alloys; oxide thickness is around 15 μm , films are yellow colored.

Oxalic electrolyte is not cooled because the dissolution of $(\text{COOH})_2$ falls rapidly, electric resistance of electrolyte increases and thus higher forming voltages are needed, when using these voltages the electrolyte is broken through. For 25 – 40 $^{\circ}\text{C}$ temperature range optimum pH value is 0.5 – 1.0, which equals to 3 – 8% concentration of $(\text{COOH})_2$. Solution is adjusted by adding 0.13 – 0.14 g/l $(\text{COOH})_2$ for every ampere-hour of electricity passed. Chlorine and aluminum are considered contaminants. After accumulation of 30 g/l of aluminum electrolyte should be changed. Maximum concentration of chlorine is 0.04 g/l. Current output (efficiency?) during anodizing in 3% water-based solution of oxalic acid at the temperature of 20 $^{\circ}\text{C}$ and current density of 1 A/dm^2 swings from 65% (for technically clean aluminum and AMr type alloys) to 25 – 30% for Л16 type alloys. On the figure 3.4 one can find the change of details made from technical aluminum and Л16 alloy versus anodizing time.

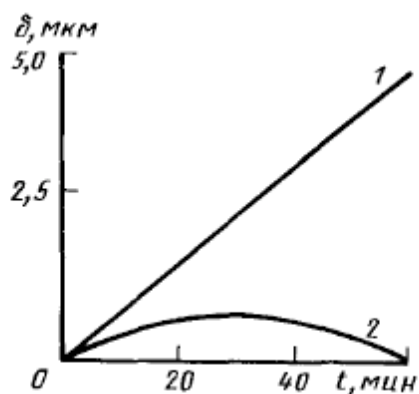


Figure 3.4. Dimensions change of the detail during anodizing in 3% water-based solution of $\text{H}_2\text{C}_2\text{O}_4$ at temperature of 20 °C and current density of 1 A/dm²: 1 – technically clean aluminum, 2 – Д16 alloy.

It is possible to conduct AC anodizing with the oxalic electrolyte. Anodizing conditions are the same as for solution 1, however, the forming voltage should be reduced to 60 V and duration should be shortened to 40 – 60 minutes.

The color of anodic oxides depends on many factors. On technical aluminum it changes from silver-white to brown depending on oxide thickness. White-colored films can be dyed. Cathodes for oxalic acid anodizing are made of lead, graphite or corrosion-resistant steel 12X18H9T.

Some other **single-component electrolyte solutions** and anodizing conditions are shown in the table 3.8

Table 3.8. Some others single-component electrolyte solutions and anodizing conditions.

Solution, concentration, g/l	Current density, A/dm ²	Voltage, V	Temperature, °C	Duration, minutes
1. Sodium carbonate, 50	0.5	110 – 115	30	25 – 30
2. Sulphamine acid	1.0	8 – 45	30 – 45	30 – 45
3. Sulfosalicylic acid	1.0	–	20 – 40	20 – 40
4. Phosphoric acid	2.0	40 – 50	20 – 25	Up to 10

Electrolyte 1 (carbonate anodizing) is used for obtaining milk-white (on technically clean aluminum, AMr type alloys) or transparent (AK4, AK6 alloys) films with 1 – 5 μm thickness. These oxides have comparably low corrosion resistance and conduct electric current, which allows to deposit them on details made of AMr and AMu alloys before spot welding. This method of anodizing demands comparably high voltages (110 – 115 V); electrolyte pH equals 10; cathode material is corrosion resistant steel 12X18H10T.

Anodizing in sulphamine acid can give oxides with high corrosion resistance. Films are denser and less porous than those formed in sulfuric acid. Resulting oxides can be dyed. It is possible to use higher current density than that shown in the table 3.8. Anodizing is conducted at the current density of 2.7 A/dm² with gradual voltage raise from 5 to 45 V during 3 – 5 minutes. The whole anodizing process takes 20 – 45 minutes. However, films, obtained with this method, are more porous and should be filled or sealed. Anodic oxides formed in the sulphamine acid are colorless and wear resistant. The disadvantage of this method is that sulphamine acid is very hard to get. Cathodes for this type of anodizing are made of lead or corrosion-resistant steel 12X18H10T.

Anodizing in sulfosalicylic acid (electrolyte 3) is used for obtaining dense and thin films. Aluminum oxide dissolution rate in this electrolyte is low. Formed oxide films have colors from dark-grey to brown depending on alloy type. These films are often used as protective and decorative finish or for electric insulation. Sulfosalicylic acid is used as a part of many multi-component electrolyte solutions. When anodizing in sulfosalicylic acid cathode is made of corrosion-resistant steel.

Electrolyte 4 is used for obtaining films that are used as an underlying layer in galvanic plating. Oxide thickness is insignificant (0.3 – 3 μm). Lead cathode is recommended for this method.

It is possible to broaden the possibilities of obtaining oxides with desired qualities employing multi-component electrolytes. The most common electrolyte solutions and technological conditions are listed in the table 3.9.

Electrolyte 1 is recommended by ГОСТ 9.305-84 for aluminum and its alloys. Anodizing is conducted with intensive electrolyte agitation. Films are colored from dark-grey to brown depending on the alloy. Details with non-hermetic and non-continuous joints that are not operated under static and cyclic loads can be anodized in this electrolyte and boiled in the distilled water afterwards. For Д16, B95, АЛ2 alloys recommended anodizing temperature is 5 – 15 °C; for aluminum and АМ_г, АМ_ц, АБ alloys – 17 – 23 °C. For Д16 and B95 alloys recommended current density is 1.5 A/dm²; aluminum and АМ_г (*note: possibly typo, maybe АМ_ц*) type alloys are anodized with 3 A/dm² current density. For АМ_г (*note: possibly typo, maybe АМ_ц*) and АБ alloys recommended current density is 2 A/dm². Details larger than 300×200 mm are anodized with current density lowered by 1.5 – 2 times, increasing process time accordingly. Electrolytes with sulfosalicylic acid are advantageous because anodic oxides dissolution speed is about 10 times lower than that in sulfuric acid. This allows conducting anodizing at normal temperatures or in tanks cooled with tap water.

Electrolyte 2 is also recommended by ГОСТ 9.305-85 for anodizing of aluminum and its deform alloys. Electrolyte is agitated mechanically, with compressed air or with pumping. This electrolyte is not recommended for alloys with copper content higher than 4.5%. When extra fine surface finish is required it is possible to lower sulfuric acid concentration down to 90 g/l and raise oxalic acid concentration up to 50 g/l.

Electrolyte 3 is conventionally recognized as universal. It is advantageous both over sulfuric electrolyte (because it doesn't require deep cooling) and over oxalic electrolyte (because it uses lower forming voltage). Oxides obtained with this methods can be used as corrosion protection without additional impregnation. Admixtures in this electrolyte should not exceed the following limits: copper – 0.5; aluminum – 25; chlorine-ions – 0.002; iron – 0.2 g/l. It is recommended to raise the forming voltage smoothly during first 15 minutes and hold constant. Lead cathodes are recommended. Oxide film thickness on aluminum alloys is 30 – 65 μm .

Table 3.9. Multi-component electrolyte solutions and technological conditions of anodizing of aluminum and its alloys.

Solution	Concentration, g/l	Current density, A/dm ²	Voltage, V	Temperature, °C	Duration, minutes
1. Sulfuric acid Oxalic acid Sulfosalicylic acid	2 – 4 27 – 33 90 – 110	1.5 – 3	Up to 100	10 – 28	20 – 120
2. Sulfuric acid Oxalic acid	180 – 200 10 – 20	2 – 5	Up to 90	10 – 25	30 – 60
3. Sulfuric acid Oxalic acid Ethyl alcohol	180 – 210 17 – 20 40 – 100	4 – 6	40 – 60	10 – 30	50 – 60

4. Oxalic acid Citric acid Boric acid	40 – 60 10 – 30 3 – 10	2.5	50 – 90	10 – 40	180 – 240
5. Phosphoric acid Oxalic acid Citric acid Isopropyl alcohol Aluminum sulfate	20 – 80 10 – 40 10 – 50 20 – 500 0.5 – 2	1.5 – 2.5	160 – 170	10	8 – 14
6. Sulfuric acid Fluorinated carbon Synthanol DS-10 or OS-20 preparation	180 – 200 50 – 200 5 – 20	1.5 – 2.5	20 – 30	–7 ÷ –8	
7. Sulfuric acid Metallic titan powder	200 – 300 50 – 100	1 – 3	–	0 – 10	40 – 100
8. Sulfuric acid Oxalic acid Chromic acid Hexanoic acid	150 – 200 15 – 30 1 – 10 1 – 5	–	15 – 20	15 – 30	15 – 20

Electrolyte 4 is recommended for obtaining electrical insulating surfaces. Recommended alloys are Д16, АМц, АМр. Oxide film thickness is substantial and achieves 80 µm; lead cathode is recommended.

Electrolyte 5 is recommended for obtaining dielectric temperature-resistant films, for example, for manufacturing underlying layers and micro-pcbs for hybrid ICs. This electrolyte provides extended thermo-resistance of oxide layers. Temperature-resistance of such oxides can achieve 500 – 530 °C. Quickly formed anodic oxides (8 – 14 minutes) have good electro-physical parameters: thickness up to 22 µm; specific electrical resistance up to $0.4 \cdot 10^{14}$ Ohm·cm; break-through voltage up to 1650 V; micro-hardness up to H420. Electrolyte was tested for anodizing АД1, АМр3, Д16, АМц, АЛ2 alloys. Anodizing is conducted in galvanostatic conditions with current density of 0.5 – 3.0 A/dm² and electrolyte temperature of 5 – 15 °C (in the table 3.9 one can find current density and temperature values for which specific oxide electro-physical parameters exist). Corrosion-resistance steel cathode is recommended for this method. Electrolyte is prepared by dissolving required amount of phosphoric, oxalic and citric acids and isopropyl alcohol in deionized water and agitating during 20 minutes. Right before anodizing the required amount of aluminum sulfate is added, agitated during 10 minutes. For vacuum melted aluminum, technically clean aluminum and АМр alloys the amount of oxalic acid should be around 10 – 15 g/l. When anodizing АМц, Д16, АЛ2 alloys oxalic acid concentration is 20 – 50 g/l.

Electrolyte 6 is used for obtaining self-lubricating anodic films on aluminum alloys and can be used employed for friction units without lubricants in instruments manufacturing, vacuum and cosmic devices. Fluorinated carbon is added into electrolyte as a fine powder stabilized by surface-active substance (Synthanol DS-10, OS-20 preparation). In this particular electrolyte fluorinated carbon penetrates the full depth of anodic film. Antifriction tests were conducted in vacuum under pressure of $7 \cdot 10^{-9}$ Pa employing plane – sphere scheme paired with spherical indenter made of BK8 steel, with sliding speed of 5 cm/sec, loading of 16.5 N, friction path of 0.5 km; as well as on the МИ-10 plant employing ring – plate scheme, imitating shaft – bush, with specific loading of 1.7 MPa. Tests showed that films have friction coefficient of than 0.20 and have extended wear-resistance. Film thickness is 25 – 50 µm, micro-hardness – 381 – 489. Lead cathode is recommended for anodizing.

Electrolyte 7 is used for obtaining oxides with extended corrosion-resistance. Corrosion resistance measured in express tests in 5% NaCl solution + 0.3 g/l CuCl₂ achieves 0.008 g/(m²·h). Metallic titan

powder reacts with sulfuric acid forming 3-valent titan ions and titan spinel $\text{Ti}_2\text{O}_6\text{Al}_2$. This compound is very stable with regarding to corrosion destruction. Recommended titan powder granules size is 40 – 50 μm .

Electrolyte 8 is used for quick growing of corrosion-resistive oxides. The structure of films provides very good impregnation by dyes or sealants. Film formation speed achieves 1.2 $\mu\text{m}/\text{min}$. Corrosion resistance of 13.9 μm thick film is 95 minutes (measured using wetting method). When dyed these oxides have low loss of color intensity.

Notes

As you may noticed there're a bunch of Russian alloys mentioned in this article. I'll give a short description of them so you can have a clue with which of European/American alloys you can substitute them. Here we go!

12X18H9T, 12X18H10T – this is a corrosion-resistant steel. Can't tell you more right now because I know nothing about steel.

AMr – this is the group of aluminum and magnesium alloys. We have different types of them (AMr1, AMr2, AMr3, AMr4, AMr5, AMr6) with different qualities. Some of them have close analogues in America and Europe.

AMц - this is the aluminum and manganese alloy. It is softer than aluminum and magnesium alloys.

АД1 – it's almost pure aluminum. The closest group is 6000 alloys in American system.

Д16 – this is duralumin alloy with high copper content.

ГОСТ – is a set of government-regulated standards.

AK2, AK3 etc – casting aluminum alloys.

This information can be made publicly available. However, you cannot modify the text in any way.

Have fun and don't hurt yourself ☺

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