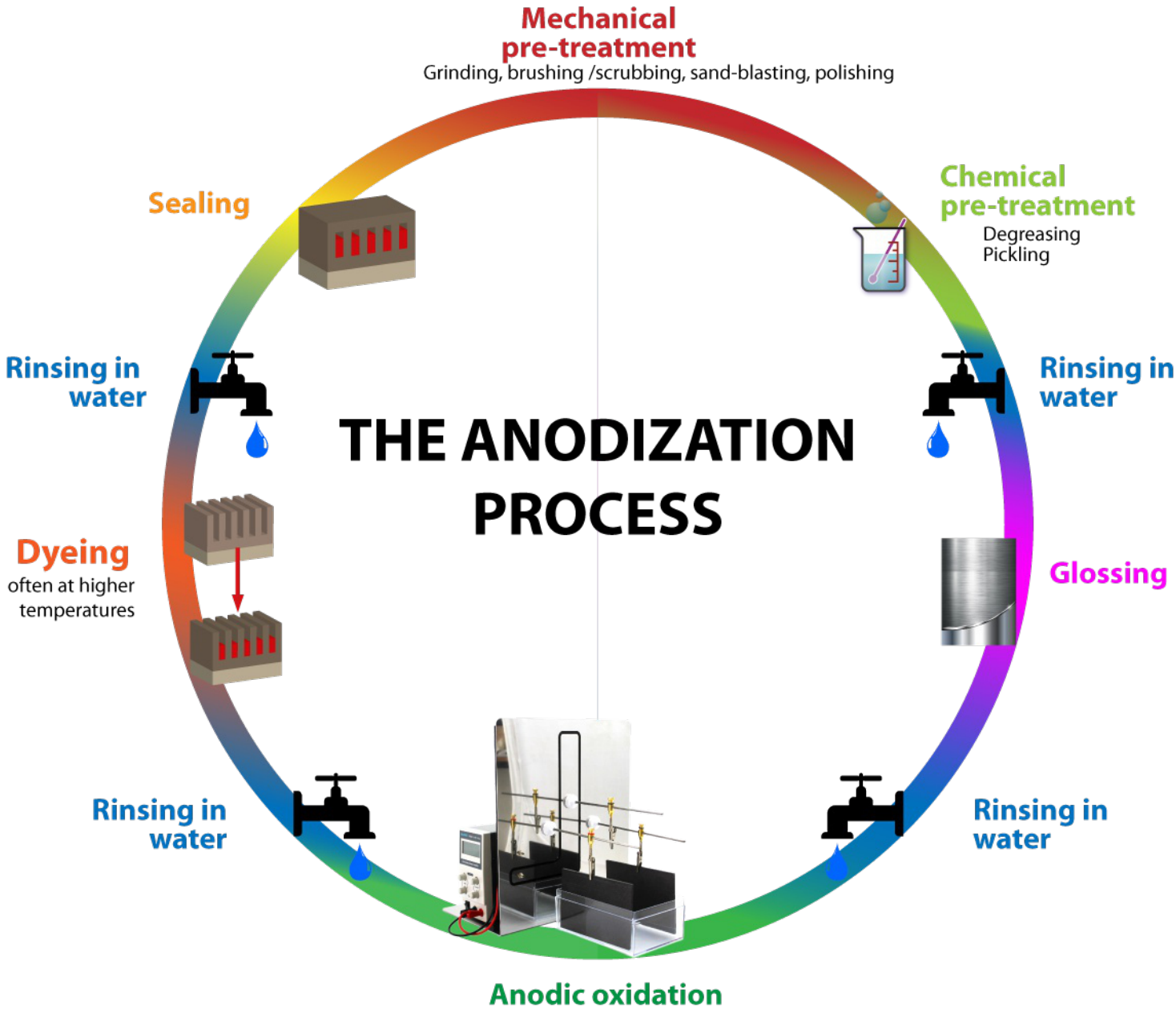

Manual for
ANODIZATION

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TIFOO

1. Basics for anodization

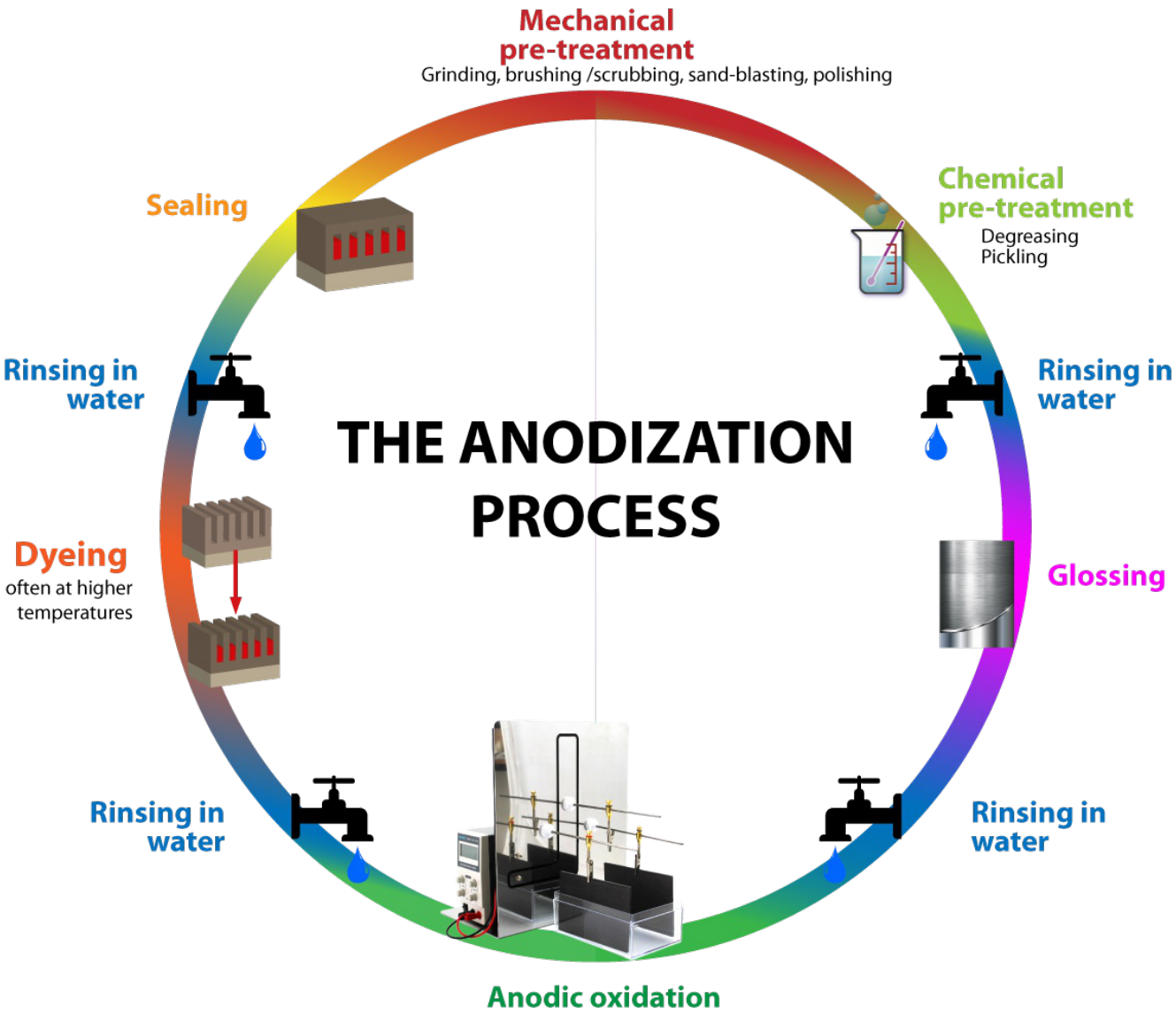
1.1 What is anodization?

The formation of an oxide layer on aluminium or aluminium alloys by electrolyte baths is called anodization. When an oxide layer is formed on aluminium or on aluminium alloys by electrolyte baths, we speak of anodization. Aluminium very rapidly forms a thin oxide layer, about 0.1-0.5 µm, as soon as it is exposed to air. This natural layer protects the metal against further oxidation by oxygen, but cannot resist long against more aggressive conditions. To strengthen the protective effect of the layer and thereby cause the aluminium to become even more resistant to corrosion, anodization is applied.

This means that the oxide layer is increased up to 30 µm (0.3 mm) of thickness and is therefore about 8 times as hard as that of untreated aluminium. By the process of hard anodizing, even thicker layers can be achieved (> 100 µm). These generated anodized coatings are resistant against a large number of chemical compounds. Moreover, it is possible to embed colours into the porous layer, which gives a very pleasing look to the completed work piece. After the so-called sealing, these coloured layers are permanently bound to the oxide layer and cannot flake off easily (as, for example, varnishes often do).

1.2 Procedure/Process flow

To anodize an aluminium component with colours, you need to perform further steps apart from the actual anodizing (meaning the immersion of the work piece into the anodic electrolyte), which are crucial for the end result. An overview of the entire process of the anodization is shown in the illustration below. You will find detailed information and instructions on how to proceed in each step in the following chapters of this manual.

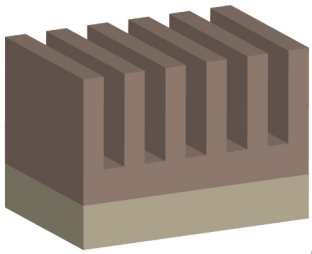


1.3 Build-up of the anodic coating

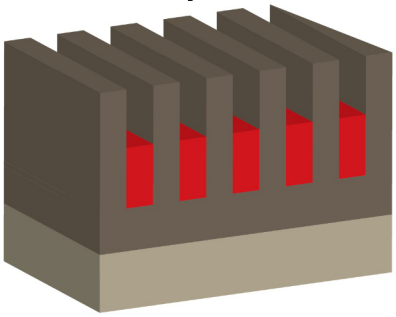
During the actual anodic step, the aluminium work piece is connected to the positive pole and it oxidises because of the applied current flow. During this process the following chemical reactions happen:

cathode: $6H_3O^+ + 6e^- \rightarrow 3H_2 + 6H_2O$
anode: $2Al \rightarrow 2Al^{3+} + 6e^-$
further reaction: $2Al^{3+} + 9H_2O \rightarrow Al_2O_3 + 6H_3O^+$

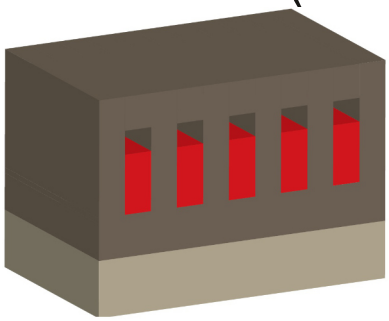
The layer grows in capillary-like pores from the surface into the metal.



This means that the anodic coating is anchored directly in the original aluminium and can no longer be removed mechanically. These pores are able to absorb liquids, e. g. dyes, after the anodization process.



After a dye has been embedded into these pores, you can again close the oxide layer by the so-called sealing. This means that aluminium oxide reacts with water and crystallizes to hydrate alumina ($Al_2O_3 \times H_2O$) which clogs the pores.



The dye is thereby are permanently bound to the aluminium and cannot be scraped off or flake like varnishes for example. It is of course also possible to not embed any dye or to seal the oxide layer directly after anodizing; then, the work piece keeps its silvery grey colour yet is nevertheless protected against corrosion.

1.4 What can be anodised?

In theory, every aluminium piece can be anodized. The result however depends heavily on which kind of alloy was used. In principle, you can say that the purer the aluminium, the better the quality of the anodization. Still, pure aluminium is rarely used as material because of its softness. There are many alloys which can be anodised very well – you can find them in the following tables. These tables are divided into two main classes of aluminium alloys: wrought and casting alloys.

The wrought alloys are mainly used for rolling and extrusion pressing. Generally speaking, wrought alloys are more suitable for decorative anodization than casting alloys. The latter are used for example for sand casting and motor parts and others are produced in this way. For these alloys, the admixtures of alloy metal like, e. g. silicon and zinc, are very high and are therefore comparatively less suitable for anodization (although there are exceptions which work very well!).

Aluminium - wrought alloys

Designation	Euronorm	Anodization	Colouration	Electro-polishing
Al 99.5	EN-AW-1050	very good	very good	very good
Al 99	EN-AW-1200	good	good	
Al 99.5 (A)	EN-AW-1350	very good	good	
AlMg3	EN-AW-5754	very good	very good	sufficient
AlMgSi1	EN-AW-6082	very good	sufficient	insufficient
AlMg4.5Mn	EN-AW-5083	good	sufficient	insufficient
AlCu6BiPb	EN-AW-2011	insufficient	insufficient	
AlCuMg1	EN-AW-2017	good		good
AlMg1SiCu	EN-AW-6061	good		satisfactory
AlZn4.5Mg1.5Mn	EN AW 7005			
AlZn5.5MgCu	EN AW 7075	satisfactory	insufficient	
AlMg1	EN AW 5005	very good	good	good
AlMnCu	EN AW 3003	very good	sufficient	good
AlCuSiMn	EN AW 2014	satisfactory	insufficient	
AlZn4.5Mg1	EN AW 7020	good	satisfactory	
AlCuMgPbMgMn	EN AW 2007	insufficient	insufficient	
AlMgSi0.5	EN AW 6060	very good	very good	very good
AlMg5	EN AW 5019	good	satisfactory	

Aluminium - wrought alloys

Designation	Euronorm	Anodization	Colouration	Electro-polishing
AlMg2.5	EN AW 5052	very good	good	
AlMg0.7Si	EN AW 6063	very good	very good	very good
AlMg1Mn1	EN AW 3104			
AlCu4Mg1	EN AW 2024	good	sufficient	
AlMgSiCu	EN AW 6111			
AlMg4.5Mn0.4	EN AW 5182			
AlMg3Mn	EN AW 5454	good	sufficient	
AlMg2Mn0.8	EN AW 5049	good	sufficient	
AlCuBiPb	EN AW 2011	insufficient	insufficient	
AlMg2Mn0.3	EN AW 5241	good	sufficient	
AlMgSi0.7	EN AW 6005	very good	good	
AlMgSiPb	EN AW 6012	satisfactory	insufficient	
AlMn1	EN AW 3103	good	sufficient	good
AlMn1Mg0.5	EN AW 3005	very good	sufficient	
AlMn1Mg1	EN AW 3004	very good	satisfactory	
AlZnMgCu0.5	EN AW 7022	good	insufficient	

Table 1: General view of the wrought alloys of aluminium

Aluminium - casting alloys

Designation	Euronorm	Anodization	Colouration	Electro-polishing
AlSi12	EN AC 44300	poor	insufficient	
AlSi9Cu3	EN AC 46000	insufficient	insufficient	
AlSi12CuNiMg	EN AC 48000	insufficient	insufficient	
AlMg3	EN AC 51100	very good	very good	
AlMg5	EN AC 51300	very good	very good	

Aluminium - casting alloys				
Designation	**Euronorm**	**Anodization**	**Colouration**	**Electro-polishing**
AlZn5Mg	EN AC 71000	good		
AlMg9	EN AC 51200	good		good
AlMg5Si	EN AC 51400	good	good	
AlSi11	EN AC 44000	poor	insufficient	
AlSi6Cu4	EN AC 45000	insufficient	insufficient	
AlSi7Mg	EN AC 42100	sufficient	insufficient	
AlSi9Mg	EN AC 44200	sufficient	insufficient	
AlCu4TiMg	EN AC 21000	poor	insufficient	

Table 2: General view over the characteristics of the anodization of various commun casting alloys of aluminium.

It is important that the aluminium is not yet anodised. Otherwise, the work piece is no longer conductive and no further reaction can happen. For this purpose, the Tifoo De-Anodizer can be used (see chapter 4. Pre-treatment). Concerning accurately fitting aluminium parts, it must be noted that after the anodization process, work piece will have increased in size.

We recommend using some aluminium test sheets for first anodization experiments to get a feel for the right approach.

2. SAFETY

While handling chemicals, several safety measures must be implemented so that yourself and others are not endangered. Make always sure to wear protection goggles and gloves. Furthermore, closed shoes and long clothes are important, old clothes are recommended, perhaps even an overall, if available.
If you do come into contact with chemicals, you should immediately rinse the affected skin areas with clear water for several minutes. When clothing gets contaminated, change it as soon as possible.

The baths used, especially the anodising bath and the anodising remover, corrosive vapours can arise.
These can be prevented by fume extraction or good ventilation. Do not inhale toxic fumes and use a mask if able.
The workplace should be in a well-ventilated place and no fire should be lit in the immediate vicinity.

3. Tifoo Anodizing set (starter or deluxe)

The starter set includes everything needed to achieve good first anodizing results without the need to buy further chemicals. It is suitable for beginners as well as more advanced users and covers the required basics.

Anodising Starter Set without power supply

Anodising Starter set with 10 A power supply

Anodising Deluxe Set with 10 A power supply

Anodising accessories deluxe set

Further needed:

distilled water (e. g. available at petrol stations)
Additional options to include in your order:

further colours
many more options --> You will find in our online shop

4. Pre-treatment – mechanical and chemical

4.1 Mechanical pre-treatment

The first step in the anodization process is the mechanical pre-treatment. This is one of the most important steps for the anodization of aluminium because despite of the anodic coating formation every scratch and every imperfection remains visible. Every impurity (grease residue, finger prints etc.) may cause a worse end result. Additionally, the mechanical pre-treatment enables mirror-like aluminium surfaces. It is also important to rinse the work pieces thoroughly in between the individual work steps.

Depending on the condition and state of each surface, different pre-treatment methods are recommended:

steel wool grinding sponge brushes
rotary tools with different attachments sand blaster
polishing paste

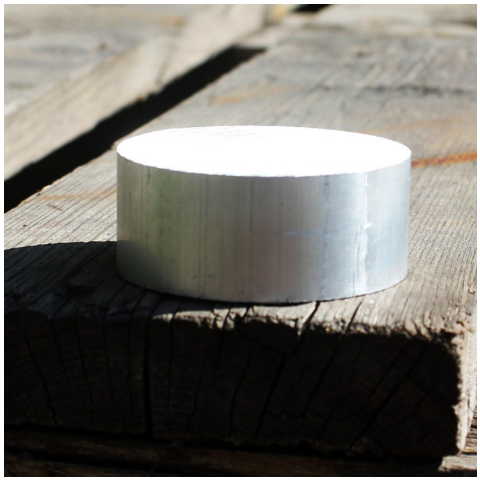
There is no universal strategy for the mechanical pre-treatment: depending on your goal (matt or glossy?), aluminium alloy (hard or soft?) and initial condition (scuffed or already polished), the procedure will vary. But as a general rule, anodization does **not** (!) compensate for scratches or other imperfections. The quality of the surface before the anodization decides the quality of the end result.

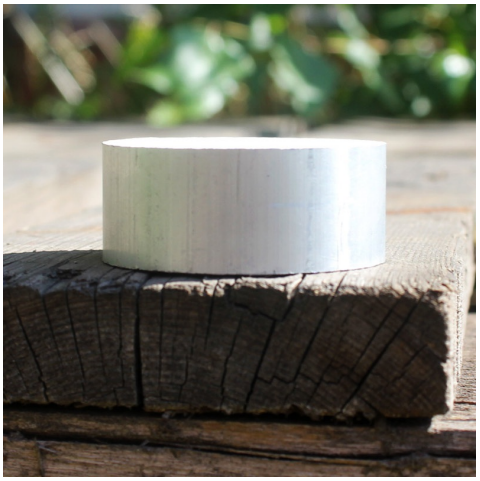
The following table provides an overview concerning the methods for the mechanical pre-treatment, the respectively needed equipment/utensils and subsequently, there are illustrations of some tools which are also useful/helpful for the mechanical pre-treatment of aluminium; they may be purchased partially in our online shop, in construction markets or other specialist shops.

Process	Tools	Indication
Rough grinding	- grinding sponge (grain size of 40-100) - coarse steel wool - drill with coarse-grained aluminium grinding wheel	evenly rough surface
Smooth grinding	- grinding sponge (grain size of 150-2000) - fine steel wool - fine polishing paste in connection with grinding wheels	even surface, slightly rough
Polishing	- buffing wheel attachment for drill or multifunction rotary tool - polishing pastes	smooth surface
Polishing to a mirror-like gloss	- molleton wheels	nearly like a mirror-like gloss
Barrel polishing	- rotating barrel filled first with steel balls in a polishing liquid, then with leather pieces (for a mirror-like sheen)	very smooth surfaces possible
Brushing / Glazing	- steel wire brushes	even surface, slightly roughened in one favoured direction
Sand-blasting	- sand-blasting equipment	

4.2 Mechanically polishing aluminium to a mirror-like gloss

Below we will describe how aluminium pieces with a mirror-like gloss will also keep this sheen after anodization. All necessary equipment can be purchased in our shop. As an example serves a 50 mm x 20 mm aluminium alloy (EN-AW-5754, also called AlMg3) round blank, which looked like this before anodization:





The surface, dull but otherwise in a good condition, was polished to a high sheen with a molleton wheel, which is an attachment available for conventional drills, by using a polishing paste.

You proceed in the following way: fasten the molleton wheel to the corresponding drill and rub some polishing paste onto the wheel (while this wheel is turning) and rub a bit of the paste also over the object. Then, you polish the object as shown on the following picture:

You see the increasing mirror-like gloss come to light. After the polishing, the surface has darkened areas which are easily removed by a cloth and some water.

After this treatment, the round blake looked like this:

But what happens with surfaces which are in a worse condition than the round blank, when they are scratched and worn out? This would also be a case where the molleton wheel with polishing paste is put to use; however, the object has first to be treated with a grinding sponge or drill attachments like flap wheels, for example. These can be bought with different corn sizes in construction markets or in online specialist jobs. According to the damages of the surface you have to start out with coarser or finer work. An example for a rather
battered surface which we could bring back to a higher gloss after a mechanical treatment is the aluminium kickstand (of an unknown aluminium casting alloy) below, which was afterwards anodized green as well.

Casting alloy aluminium piece
before polishing

Casting alloy aluminium piece
after polishing

The subsequent anodization and dyeing with Tifoo Eloxal-Green achieved the result shown below:

We are happy to answer any questions to the correct mechanical pre-treatment of aluminium alloys and give recommendations on which tools to choose. We recommend you to send us an email to tifoo@marawe.de. It is always very helpful if you can include a picture of the object you wish to anodize so that its condition is easier to evaluate.

4.3 Chemical pre-treatment

After the mechanical pre-treatment it is important that the work piece is also treated chemically before the anodization. First rinse the work piece thoroughly with water so that all residue of the mechanical treatment is removed and afterwards immerge it into the **Tifoo Anodization activator** – because: a completely grease- and dust-free surface is essential for a good anodization result.

The duration of the pre-treatment lasts about 5-20 minutes, depending on the degree of soiling. If you wish to check the evenness of the surface during the bath, use tongs to pick the work piece from the bath. If you have achieved the desired result, you should now rinse it thoroughly with distilled water.

The criterion for a well pickled surface: the object stays wet everywhere and the water does not drip off off the surface!

It is important not to touch the aluminium from now on, you should only work with tongs or clean wet gloves to avoid grease spots.

Some alloys (containing Si, Mn or Zn) can cause a dark discolouration of the aluminium.

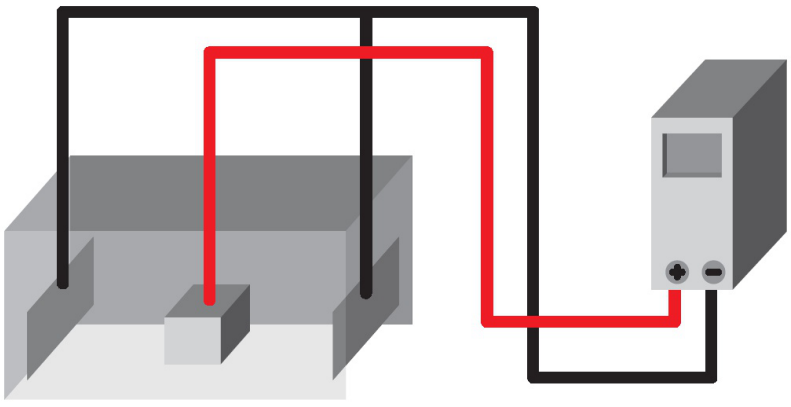
During the chemical pre-treatment, you should soon observe the formation of gas. If not, this could be a hint to the fact that your aluminium piece is already anodized. You can check by carefully realizing a "scratching test" on a bearly visible part. It's very easy to leave scratch marks on untreated aluminium; if it's anodized, that's more difficult.

If your workpiece is already anodized and you want to remove the oxidation layer, you can use the Tifoo De-Anodizer (available in our online shop).

You can of course also use the De-Anodizer when you yourself have anodized an object but without being satisfied with the result. In this case, you can simply remove the layer and start all over again.

5. Anodic oxidation

The anodic oxidation is the step during which the anodic coating is built up and it is therefore the most important part of the overall process. The schematic assembly of the anodization is seen below:



Attach the 2 stainless steel anodes (cathodes) supplied along the 2 long sides of the tub or in a suitable vessel. The arrangement with 2 cathodes around the workpiece has the advantage of of a better current density distribution. The aluminium workpiece is connected as an anode i.e. it is connected to the positive pole!

It is also possible to work with round stainless steel vessels which can function directly as cathodes. But in this case, please always ensure that this kind of stainless steel is indeed resistant to chemicals. For many applications, an amount of 1 to 5 litres of anodization electrolyte should be sufficient.
Now the already prepared work piece is fixed in the middle between the electrodes (or respectively in the middle of the stainless steel container). It is important, that all surfaces to be anodized are actually immersed in the liquid.

5.1 Connecting the work pieces to electricity

Titan clamps and wires, which are included in the set, may be used to attach the work pieces. It is important to attach the work pieces in such a way that the contact points do not shift and are firmly attached to each other: if during anodization the titan clamp shifts onto an already anodized, no longer conductive part, the electric current collapses immediately.

The advantages of titan are the resistance against chemical corrosion and which also means that it can be used time and time again. Furthermore, crocodile clips made of stainless steel or nickel-plated steel are also part of the set. These should not come into contact with the anodization electrolytes and are suitable to connect parts to the current, which are not supposed to be anodized completely or to hold the titan clamps in position or else for other connecting assemblies.

You can also make suitable holding or connecting devices out of aluminium. For this, please observe the following instructions: the aluminium rack will logically also be anodized, so this means it has to be pickled. In addition to that, the fixtures should be of the same aluminium alloy as the one that gets anodized. Keep the surface as small as possible, because otherwise high current losses will occur. Generally speaking, position and switch your work pieces always with wet gloves to avoid prints and blemishes.

5.2 Calculating the current's intensity and the needed time for anodization

The thickness of the anodized layer depends especially on the time of the anodization process and on the current's intensity. A guideline for the intensity to be used is the following rule: 1.5 A per square decimetre ($1dm^2$ = 100 cm^2)
for an anodization period of 60 minutes at room temperature.
The currrent intensity measured in amperes for the corresponding workpiece results from the multiplication of the surface of the measured piece in dm^2 with 1.5 A.

Surface in dm^2 x 1.5 A = (surface in cm^2)/1000 x 1.5

5.3 Exemplary calculations

An example will make that clearer: An aluminium cylinder / a round rod with a diameter of 2 cm and a height of 10 cm is to be anodized. The cylinder's total surface equals 2 x the base area + shell surface. The shell surface of this cylinder equals to the circumference x the height and therefore equals 63 cm^2. The cylinder's base area is calculated according to the following formula: $(radius)^2$ x pi = 3.1 cm^2.
The result therefore is a surface of (2 x 3.1) + 63 = 69.2 ~ 70 cm^2 (corresponding to 0.7 dm^2) for the exemplary cylinder. According to the rule above, our power supply unit should provide a current of

0.7 dm^2 x 1.5 A = 1.05 A.

As our small power supply unit is capable of providing 2 A, you will be able to anodize at 1.05 A within an hour without any problems. You will also be able to anodize a cylinder with twice the surface with the little power supply unit within an hour. For even bigger objects, you should increase the anodizing time or work with our stronger power supply unit of 10 A (available in our online shop by searching "10 ampere power supply").

Example:
In order to treat an aluminium object with a surface of 200 cm^3 = 2 dm^2, one would need a current strength of 3 A (2 dm^2 x 1.5 A). Therefore, one needs either a stronger power supply unit or to anodize for 1.5 hours at 2A.

Attention: The other way round, i.e. using a higher current strength in order to anodise for a shorter amount of time and therefore save some time is not recommended because a current density that is too high will destroy the layer.

Please consider the mentioned values to be only guidelines, as the conditions depend on the used alloy, the conductor cross section and on the bath's state. We recommend to work with a current regulation when using our power supply units because the layer's progressing growth increases the electric resistance and the current decreases more and more. When you adjust the corresponding current's intensity on the power supply unit, the latter will regulate the needed tension automatically and you normally shouldn't have to adjust it manually. To do so, first position everything (workpiece, cathodes and the bath) and then, when turned off, you adjust the power supply unit's regulators for the current strength and the voltage completely to zero. Then turn the voltage to the maximum and turn on the device. Now turn the current regulator until the calculated amperage is achieved.

During the anodization, there will be a formation of hydrogen bubbles on the cathode(s). This gas formation is a hint to the fact that the electrochemical reaction works properly.

Please keep in mind that hydrogen and oxygen together form "oxyhydrogen", an explosive and easily available mixture. Even if the quantities are relatively small, you have to guarantee a sufficient ventilation of the anodisation bath and to avoid any fire or ignition source near the corresponding basin.

Calculation of the layer thickness H:

H measured in µm = (0.26 x time in minutes x current strength in A) / (surface in dm^2)

Example: time = 50 min
current strength = 0.3 A
surface = 20 cm^2 = 0.2 dm^2 H = 19.5 µm

After the desired anodisation time, the power supply unit has to be turned off, the workpiece has to be taken out of the bath and rinsed thoroughly for a long time period first with normal water and afterwards with some distilled water. Better too much than too few of this step! Rinsing too shortly is one of the most frequent reasons for ugly or stained colourations.
Please also guarantee to touch the object only by its suspension and to not touch the anodised surfaces. If the object has to be touched despite of that, please only do it with wet rubber gloves.

6. Dyeing

From this point on, dyes can be stored in the pores created by the anodisation. The included dyes are of solid matter. Here are some values to dissolve them in distilled water:

0.1 to 1 g per litre --> light colourations 2
to 5 g per litre --> strong colourations > 5
g per litre --> dark colourations

You can reuse the dyeing baths several times, but you have to keep the following factors in mind: the pH-value should be between 5.5 and 7.5. If it is too low, please add some NaOH; if it is too high, some acetic acid. It is furthermore important to rinse the workpiece for a sufficient time before dyeing it, as the residues of the anodization electrolyte remaining in the pores can render the dyeing baths ineffective. When a lot of time has passed after the anodization process, it is recommended to dip the aluminium piece again in the anodization electrolyte to "reactivate" the layer.
The dye solutions are filled into a heat-resistant receptacle and heated up to 50 to 60 °C. The aluminium piece that just got anodized is rinsed thoroughly and put into the warm dye solution for some minutes. The typical needed time for dyeing with the Tifoo Anodizing colours are from 5 to 20 minutes of effect. If possible, it is advisable to stir during that time so that the bath's circulation is better, which makes the colourations more even. The workpiece is then carefully taken out with a pair of galvanic pliers and rinsed thoroughly.

Important factors to achieve the highest colour authenticity:

- thick oxide layer (< 20 µm)
- well absorbant oxide layers (i.e. anodization at room temperature)
- flawless rinsing after the anodization
- correct concentration of the dye
- long dyeing time guarantees deep colourations (more than 30 minutes however don't have any extra advantage
- perfect sealing (see following chapter)

7. Sealing

Directly after dyeing, the dyed aluminium is put into the already boiling sealing solution. This solution consists of distilled water (especially sulphate- and phosphate-free). The sealing causes a hydration of the oxide layer; this means that the pores are closed which seals the surface completely or "locks" the colourants into the layer. Please keep the following mind: the water's or sealing solution's temperature should be of at least 97 °C and the pH-value between 5.5 and 6 (can be tested with paper pH indicator). There is no use sealing for a longer time at a lower temperature - the temperature over 96 °C is decisive! If the pH-value has to be adjusted, please do so with acetic or formic acid - **not** with sulphuric acid. The time used for the sealing process should be at least 30 minutes.
The ideal time varies according to the layers' thicknesss. It should be sealed for three minutes per µm, i.e. about 60 minutes for a thickness of 20 µm. Then the colour is firmly bound to the aluminium and the anodization is finished.

8. Disposal information

Stick to the instructions of your local waste disposal services or ask them for information about the appropriate disposal.

Short guide

1. Mechanical pre-treatment (grinding, polishing)

2. Rinse

3. Dip in the Tifoo Anodization Activator (5 to 20 minutes, depending on the pollution degree)

4. Rinse

5. Calculate the surface of the aluminium piece to be anodized

6. Position the stainless steel anodes inside the basin, dip in the piece you want to anodize for about 45 - 60 min at 1.5 A/dm2, the workpiece is connected to the positive pole and the two stainless steel sheets to the negative pole.

7. Rinse

8. Dye --> The rinsed workpiece is now dipped in the dyeing bath heated up to 50 °C. Move it around a bit to accelerate the absorption of the dye. The dyeing bath's concentration depends on the dye itself and on the desired saturation. According to the colour's intensity and the bath's concentration, the immersion time is from 2 to 20 minutes. More time in the dyeing bath means a more intense colouration of the workpieces. Thanks to that, you will be able to create light colourations as well as very saturated dyeings very easily - including the different shades between the two.
9. Rinse

10. Seal --> The workpiece is dipped in boiling water for about 60 minutes at at least 96 °C. This closes the pores of the surface and the compound is transformed into its final form responsible for the extreme hardness of the layer.
    We recommend distilled water!

Tifoo

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MARAWE GmbH & Co. KG

Donaustaufer Strasse 378

Gebäude 64

93055 Regensburg

Germany

Tel:(0049)941/46521716

Email: tifoo@marawe.eu

Web: www.tifoo-plating.com